

"A MILLING AND BAKING COMPARISON
OF HARD WHITE WHEAT VERSUS HARD RED
WHEAT WITH FLOUR COLOR AND EXTRACTION
LEVEL AS PRIMARY QUALITY FACTORS"

by

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INTRODUCTION

In the last five years, there seems to have been a shift in the marketing trends of world wheat exports. The world wheat market is still a buyers market, but the identity of the buyers seems to be changing. Formerly the rich countries of Eastern and Western Europe were the principal importers of wheat. Lower per capita consumption, combined with increased domestic wheat production has either lowered or stabilized their imports. The developing nations in Africa, Central America, South America and Asia along with some of the financially rich countries such as Japan, and Saudi Arabia now account for over 50% of all world wheat imports (Foreign Agricultural Science Report 1975, International Wheat Council Report 1977 and 1978, U.S. Wheat Associates Export Summary 1980). This trend can only increase because many of the developing nations have alarming birth rates which can only increase the burden on their currently inadequate food production. In addition, many of the financially rich countries are just now beginning to develop cereal eating habits.

Cereal eating habits in the developing nations are somewhat encumbered or controlled by the financial plight of the existing governments. Government officials are keenly aware of the cost involved in importing cereal grains and, therefore, seek long extraction wheats to keep their imports to a minimum. Long extraction wheat products are the norm in most developing nations. Extraction rates hover around 78%, with many countries using 80% or even higher as their standard (International Wheat Council Report 1978).

High extraction rates have developed either new flour quality factors or enhanced existing quality factors. In the past, quality de-

mands by buyers were somewhat limited. Eastern and Western European buyers were seeking strong, high protein wheats to blend with their locally grown lower protein wheats. Now, they too are mindful of import costs and are actively seeking high extraction wheats to keep their import costs to a minimum. Obtaining high extraction wheat would not be a problem if consumer demands did not have to be considered. Wheat product consumers of all countries have traditionally preferred white or lighter colored products as compared to darker color products (Dunlap, 1945). If this fact did not exist, the flour milling business would have never developed as it did.

Many countries must face the dilemma of minimizing wheat imports while satisfying the lighter color preferences of their consumers. Some countries have already recognized the emergence of flour color as a prime quality factor. The United Kingdom buys and sells flour by its color (Kent-Jones, 1955). The producer must recognize the demands of the new markets and the changes in requirements of the old markets. Hard Red Winter Wheat presently represents 60% of total wheat grown in the U.S. Because of Red Wheat's inherent color, it cannot meet or satisfy the quality demands of some of the wheat markets. White Wheat presently represents only 10% of the total U.S. production and almost all of this is Soft White Wheat. Yet, Hard White Wheat has the capability of satisfying the new grain markets as well as the old. It is the purpose of this paper to investigate the possibility of an economic advantage in growing Hard White Wheat as compared to Hard Red Wheat. A milling and baking comparison will be presented with flour color and extraction rate being the basic quality factors considered.

LITERATURE REVIEW

Throughout the history of flour milling, flour color has always been one of the major flour quality factors. Man, by choice, has turned to white flour in preference to the darker flours for his nourishment (Dunlap, 1945). Because of this preference, millers have searched for methods of flour color evaluation. Flour color evaluation is a complexed process if useful and sufficiently exact measurements are to be obtained. According to Gillis (1963), there are four primary factors controlling flour color. The first is "flour grade" which is dependent on the degree of bran contamination in the flour. The second is "degree of yellowness" which is dependent upon the amount of natural carotene or natural yellow coloring matter present in the wheat endosperm. The third factor is granularity or particle size distribution within the flour. The final color controlling factor is attributed to the presence of extraneous matter in the wheat itself. All of these factors have played some role in the millers' search for color evaluation.

Several methods have been developed to evaluate the amount of carotenoid pigmentation present in wheat flour (Binnington et al, 1939; Coleman et al, 1926; Winton, 1944). Winton (1944) developed what was known as the gasoline-value method as a measure of yellowness. In the method, gasoline is used as a solvent, to extract the yellow pigments. The extract was then filtered and its color matched with an arbitrary color standard of potassium chromate. This method was proven to have some shortcomings when Farrari and Bailey (1929) established that additional yellow pigments could be extracted with a naptha-alcohol mixture. This information led several cereal chemists to investigate the use of

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many different solvents. Binnington and Sibbitt (1939) tested 60 different solvents for extraction of yellow pigment and found that water saturated n-butanol was an effective extractant. Binnington and Geddes (1939) would later improve the speed and accuracy of the method. The present AACC method (1972) is based on water saturated n-butanol extraction and spectrophotometric measurements with pure beta carotene as a standard.

The amount of carotenoid pigmentation in wheat flour was significant to the millers because it gave them some ideas as to the amount of bleach application needed. Carotenoid pigmentation does not represent a problem in reference to flour color because its discoloring effects can be eliminated by a bleaching process. Unfortunately, the bleaching process has no effect on the discoloring power of bran particles that contaminate almost all flours.

Bran contamination of flour is the essence of flour milling. The whole kernel is broken down by a grinding and sieving process that attempts to remove the endosperm from the bran and germ. It is the small bran particles that find their way into the flour that accounts for the major portion of the discoloring of the flour. The Pekar test was probably the first subjective color test that considered the discoloring power of bran contamination. Pekar obtained a British patent for his Pekar "Slick" test in 1876 (Speight, 1973). This test is still used by most practical millers as a quality control device. The test involves placing the flours that are to be compared on a metal, wood, or glass strip. A smooth uniform surface is then formed on the metal strip by pressing down and smoothing off the flour with a flour slick. The flour is then immersed in water. Upon immersion, the enzyme tyrosinase reacts with the bran protein to discolor the existing white flour to grays and browns. The amount of discoloration is proportional to the amount of bran contamination present in

the flours. This test is basically subjective in nature and very dependent upon the individual performing the test. Kent-Jones and Amos (1957) identified this problem by increasing the pressure applied to the flour sample when smoothing it out. Increasing the pressure in making the flour slab had an improving effect on the flour appearance. The color seemed to improve as additional pressure was applied. This fact is understandable if one remembers that flour color is partially determined by flour particle size. Additional pressure on the flour sample would cause the flour particles to compact and present a smoother, more uniform surface which would reflect more light than a rougher surface.

The flour milling industry was still in need of an objective, non-biased test for flour color. The answer was to be found in an instrumental measurement that was in accord with what was being perceived as color. Color, as it is perceived in flour, is merely a function of light that is reflected from the surface of the flour. Using the principle of incident light reflectance, two reflectance meters were introduced to the flour milling industry that received wide acceptance. The Kent-Jones and Martin Color Grader was well received in Great Britain, Canada, and Europe and the Agtron Reflectance meter was later accepted in the United States. Both meter values have been established as color grade quality factors by millers and bakers alike (Jackel, 1979; Kent-Jones, 1955).

Kent-Jones and Martin (1950) were the first to apply the principle of reflected light to an instrumental type measurement of flour color. They found that the color grade or brightness of flour was related to the extent to which a smooth surface of flour reflects light. Their color grade meter consisted of a standard light source that was directed by a lens system to two standard white surfaces of magnesium

oxide. The reflected light from the oxide surfaces was received by two photo-electric cells that were equipped with filters having their main transmission in the 530 nm band. To operate the color grader, the optical system is balanced using the two standard surfaces of magnesium oxide and one is then replaced by a similar surface of flour paste. The optical system is then rebalanced and a color grade value is obtained. The amount of light reflected is not measured in absolute units but is recorded as a portion of the amount of light of the same wavelength which is reflected from the standard magnesium oxide surfaces. The Kent-Jones and Martin color meter is capable of measuring fine differences in the proportion of incident light reflected by a flour surface. Kent-Jones and Martin (1950) made their measurements independent of variations in the granularity of flour and in the degree of bleach by employing a flour paste and light of a prescribed wavelength. The Kent-Jones and Martin color grader was an advance in flour color measurement because it produced objective, numerical evaluations for flour color that were quick, and reproducible.

The Agtron reflectance meter is very similar in principle to the Kent-Jones and Martin color grader in that they both measure the color of flour as a proportion of the light reflected from a standard surface. The reflectance is measured by a photo-electric cell which gives a readout indicating the reflectance in the 0-100% range. Unlike the Kent-Jones and Martin color grader, the Agtron uses a number of calibration discs to standardize the meter. The calibration discs range from black, through various shades of gray to white. The numerous calibration discs allow the operator to select the sensitivity range desired. It is essential that the calibration discs used in any color measurements be identified because the corresponding flour color measurements obtained will be meaningless unless the standard surfaces they are compared to are identified. The official

AACC method (1972) for Agtron Flour Color evaluation employs discs 63 and 85 to standardize the meter to 0 and 100% reflectance. The Agtron is also equipped with filters that allow the operator to measure monochromatic reflectance at one of four spectral lines (blue, yellow, green and red).

Several researchers have employed the use of the Agtron for flour color evaluation. Gillis (1963) was one of the first to work on the early model Agtron. His initial work dealt with the Blue Agtron wavelength (436 nm). He found that the Blue wavelength was incapable of distinguishing between bran contamination and variations in bleach. He shifted to the Green mode wavelength (546 nm) and found it to be insensitive to bleach treatment. This was in agreement with the monochromatic setting (530 nm) that Kent-Jones and Martin had established as being insensitive to bleach. Gillis also found that if his flour sample was made into a slurry, by adding 25 ml of water, better replicability was possible. By adding water to his flour sample, Gillis had removed the effects of particle size on flour color. He was also convinced that there was a good correlation between ash and Agtron reflectance values. It was his desire to use the Agtron as a quality control device to predict ash values after a reference sample had been run by the quick ash method.

Patton and Dishaw (1968) investigated the Green Agtron to determine its potential use as a quality control tool for commercial bakery flours. They established the sample preparation procedure and the standardization discs which are now employed as the official AACC method for Agtron Flour Color determination. They also found that when clear flour or bran flour was added to an existing patent flour, Agtron Color readings were lowered in a predictable manner. The most significant result from their work was the establishment of a definite relationship between Green Agtron readings

and flour grade. They found that shorter patent flours gave higher Agtron readings. They did not find a quantitative correlation between ash and Agtron values which does not agree with Gillis' work.

Several other researchers went on to investigate flour color using various types of reflectance meters and spectrophotometers. Some of the principal findings are given below:

- a) Murthy and Diets (1974), found that when different blends of flour were analyzed in the Agtron, linear relationships between the percent of one ingredient and the Agtron color reading existed. This investigation lended support to the concept that color readings were additive like ash values.
- b) Fujh and Ukita (1956) studied the relationship between flour color and different flour constituents. They used a Beckman Spectrophotometer with a reflectance attachment. They found a high correlation between ash and flour color and bran content and flour color.
- c) Croes (1961) developed an equation for flour whiteness using the Kent-Jones paste techniques for sample preparation and a Hunter photoelectric tristimulus meter. He reported high correlation with the visual Pekar test. His equation was never universally adopted because of the inherent disadvantage of requiring three different readings for one sample.
- d) Yasunaga and Uemura (1962) used the Hitachi EPU II photoelectric spectrophotometer to evaluate color characteristic of flours used for Japanese noodle

production. Flour color is the most important quality factor in the production of Japanese noodles because consumers demand white noodles. Their findings showed that flour color was affected not only by grade or extraction rate but also by endosperm and wheat skin or bran color characteristics. They felt that the carotenoid pigments of wheat endosperm did have an effect on flour color even after bleaching. In their study, they not only recognized that bran was the major factor causing deterioration in flour color but that its effect varied among the different types or varieties of wheat. This agreed with Jones' reports (1954) that showed Australian white bran had a less severe effect on flour color deterioration than several red wheat brans.

Flour color had finally been categorized. It was not only affected by extraction, but by color characteristics of the endosperm and the skin of the wheat kernel itself. Each variety of wheat will have its own specific "discoloring power." If White Wheat bran has a lower "discoloring power" than Red Wheat bran, higher extractions with comparable color should be obtainable using Hard White Wheat as opposed to Hard Red Wheat.

MATERIALS

A milling and baking comparison of one wheat with another is essentially asking questions about the quality of the wheats. The two major factors influencing wheat quality are environment and genetic characteristics (Gillis et al, 1974). To compare one genetic wheat variety with another, the environmental source of quality variation should be eliminated. This elimination is easily accomplished by growing the wheats under investigation at the same location and during the same crop year. Such is the case with the wheats used in this research. Three different wheats were selected to be grown in the 1976 crop year at ten different Kansas Experimental Research Stations (See Figure 1). The three wheats in question are Eagle, Clark's Cream and KSU 73256.

Eagle is a Hard Red Winter Wheat and represents about 21.1% of the total Hard Winter Wheat grown in Kansas (Hard Winter Wheat Quality Council 1978). Eagle was used as a control in all of the experiments in this research. Clark's Cream is a Hard White Winter Wheat that was developed in Kansas by independent wheat breeder Earl Clark. It is one of the few Hard White Winter Wheats already developed for Kansas wheat production. Clark's Cream represents less than 1% of the total Hard Winter Wheat production in Kansas. KSU 73256 is one of many experimental Hard White Wheats that are being investigated for possible full scale production capabilities.

The apparent color of all three varieties under investigation varied depending upon not only genetic variety but also the degree of weathering and vitreousness. Vitreousness was a key factor in determining if a White Wheat would appear to be white or amber in color. White Wheat, as defined by the official US Grain Grading Standards, is a wheat which has

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KANSAS AGRICULTURAL EXPERIMENT STATIONS

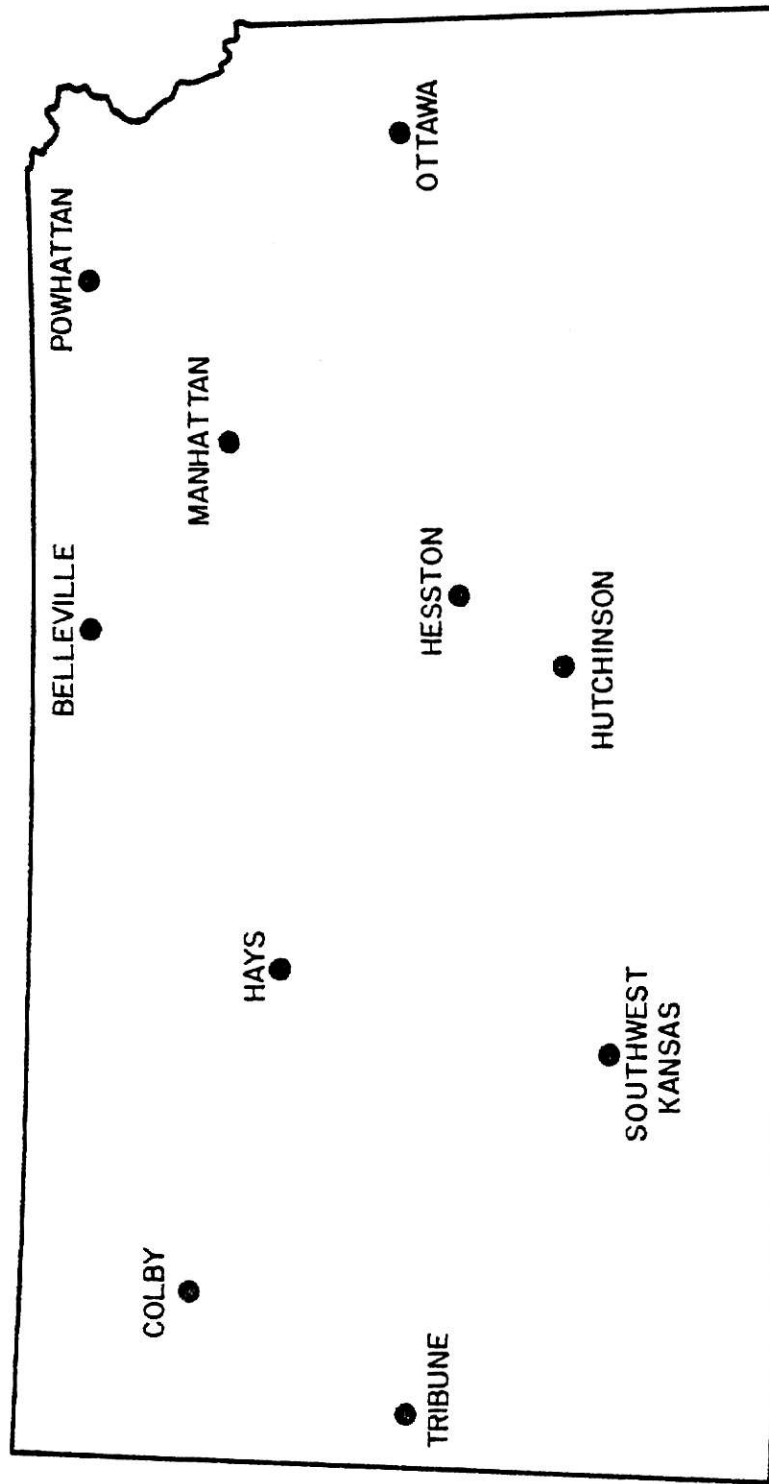


FIGURE 1

no pigment in the testa layer. Nowhere in the standards is a differentiation made between vitreous and non-vitreous kernels. A White Wheat that is vitreous appears to be amber in color while a non-vitreous kernel appears to be white.

METHODS

General Quality Factors

If a genetic wheat variety is to be considered for full scale production, it must meet the requirements of the producer, the processor and the consumer (Gillis et al, 1974). It was the purpose of this paper to investigate the quality characteristics of Hard White Wheat versus Hard Red Wheat as they pertain to the processor and consumer. Millers and bakers, as processors, are concerned with wheat quality characteristics that will enable them to produce acceptable products in terms of quality and ultimately profitability.

The primary wheat quality characteristic, as it pertains to millers, is the ability of the wheat to give a high yield of flour without sacrificing other flour quality factors such as color, ash, and baking quality. The bread baker requires a flour with high water absorption, medium mixing time, good mixing tolerance, satisfactory dough handling properties and, above all, the ability to produce high volume bread of good grain and texture (Gillis et al, 1974). Neither the miller nor the baker would be overly concerned with flour color as a quality factor if it were not for the timeless demand of the consumer for white bread (Dunlap, 1945). Flour color has been linked to bread crumb color (Pomeranz, 1960) and because of this, plays an important role in flour quality characteristics for millers and bakers.

Quality Testing Principles

It is quite difficult to determine the milling and baking quality of a specific wheat variety. The final decision is always made on the basis of actual experimental milling and baking tests. Prior to the actual milling and baking tests, many different individual tests are performed on the wheat and flour. These individual tests are considered to be quality criteria and are broken down into physical and chemical tests. These physical and chemical tests measure different parameters of wheat and flour, and can be used either to predict overall wheat quality or assist in the decision making processes involved in the actual milling and baking tests.

The physical and chemical test results obtained in this research can be found in Results and Conclusions (Graphs 1-10). All of these tests were determined to give indications of quality and to aid in the milling and baking experiments that are to follow. All methods utilized for the physical and chemical tests were official AACC methods unless stated otherwise.

Experimental Milling Tests

Experimental laboratory milling tests are performed to get some indication of the commercial milling behavior of a wheat variety. Three different types of experimental milling systems were used in this study. The milling systems, methods of utilization and tempering process for all three systems are described below.

Prior to milling, all the wheats from each location were cleaned, then tempered to 16% moisture. The original moisture of the wheat was determined by the official AACC air oven method, and all other secondary moisture measurements were made with the MOTOMCO moisture meter. Since the original wheats were so low in moisture, a two stage tempering system

was employed to bring the wheats to 12% moisture on the first stage and 16% on the final stage. In each case the requisite amount of water was applied to the wheat in a fine mist as the wheat was being mixed in a Laboratory Tempering unit. Each sample was allowed to equilibrate or rest for 48 hours after each tempering stage.

The Buhler Experimental Mill was the first milling system used to evaluate milling characteristics. The Buhler Mill is a completely pneumatic, three break, three reduction mill. The flow of the mill is shown in Figure 2. The rolls have a differential of 2:1 with the fast roll operating at 540 RPM. The break rolls have the following corrugations:

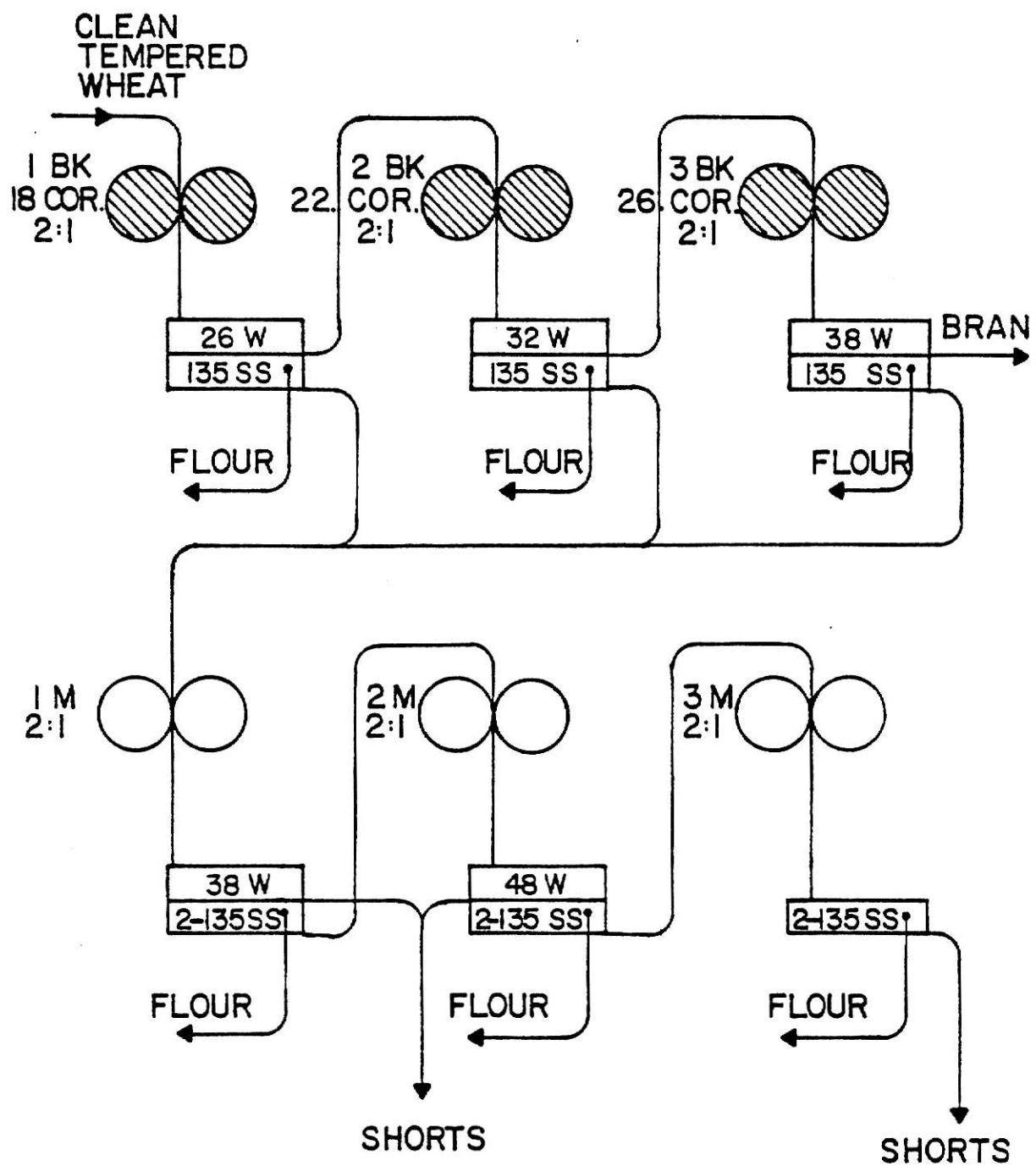
First Break 18/inch
Second Break 22/inch
Third Break 26/inch

The mill produces three break flours, three reduction flours, bran and shorts. The break and reduction flours were blended together to form a straight grade flour. The Buhler Experimental tests were evaluated by comparing the Agtron and Kent-Jones straight grade color values versus the percent extraction.

The Buhler Mill roll settings were calibrated by setting both break and reduction rolls .10 mm apart. The pointers were then set at 10 on all four adjustment knobs and tightened. The roll gaps were then changed to the following settings:

BREAK ROLLS		REDUCTION ROLLS	
Left	Right	Left	Right
12	11	6	5

These basic settings were used for all preliminary milling tests. Each milling test was preceded by a 1000 gram sample that was used to allow the rolls to attain normal grinding temperature. Once normal grinding temperature was attained, 1000 gram samples were used to set the mill to produce



FLOW SHEET FOR BUHLER EXPERIMENTAL MILL

FIGURE 2

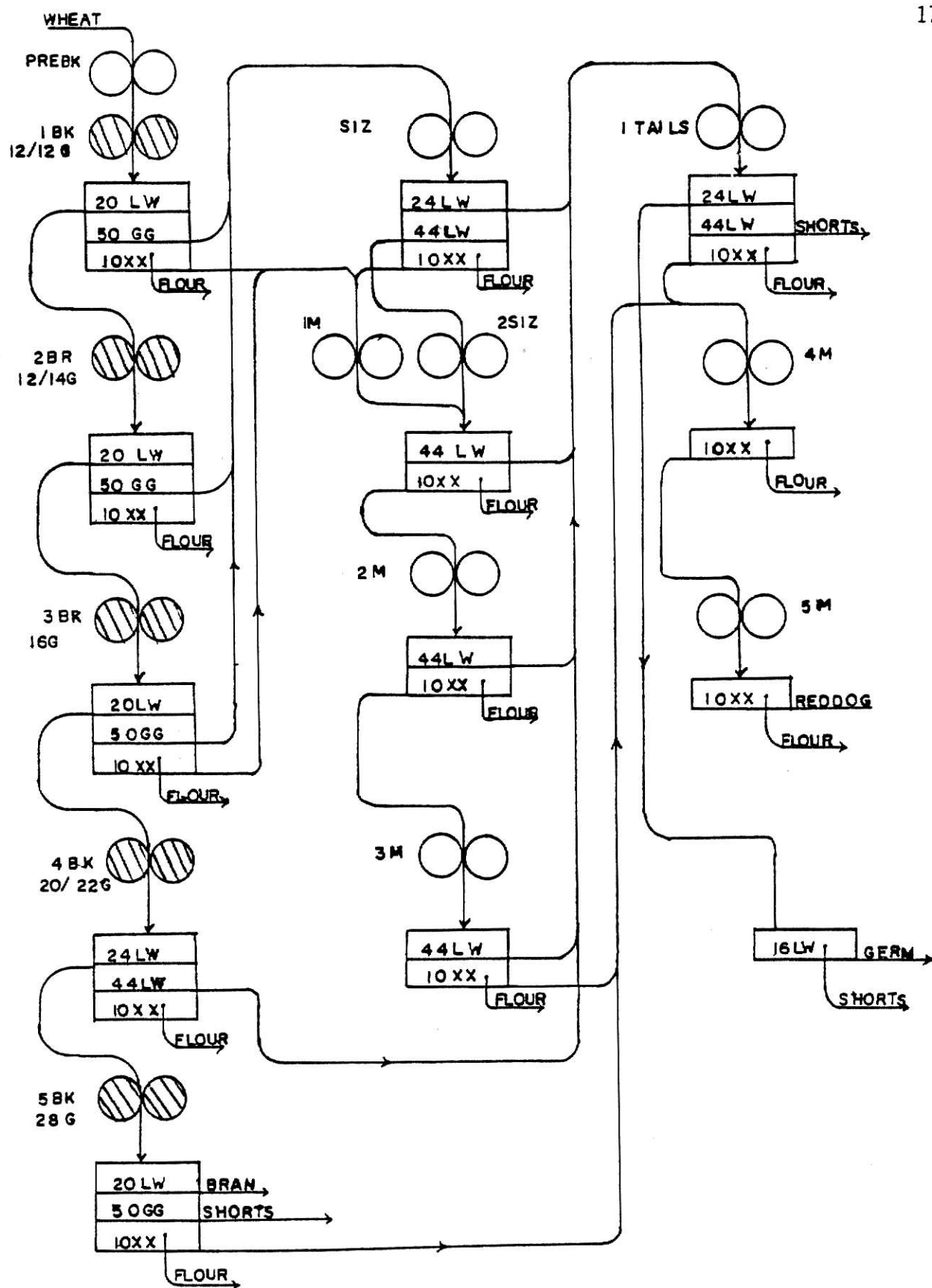
70% extraction flour. Trial and error was used until 70% flour, 20% bran and 10% shorts was produced.

The Ross Experimental Mill flow was also employed. The Ross flow as depicted in Figure 3 consists of a pre-break, five break rolls and eight reduction rolls. A Great Western Experimental Sifter was used for bolting. The break rolls have a $2\frac{1}{2}$ to 1 differential and the prebreak and reduction rolls have a $1\frac{1}{2}$ to 1 differential. The break rolls had the following corrugations, break releases and initial gap settings.

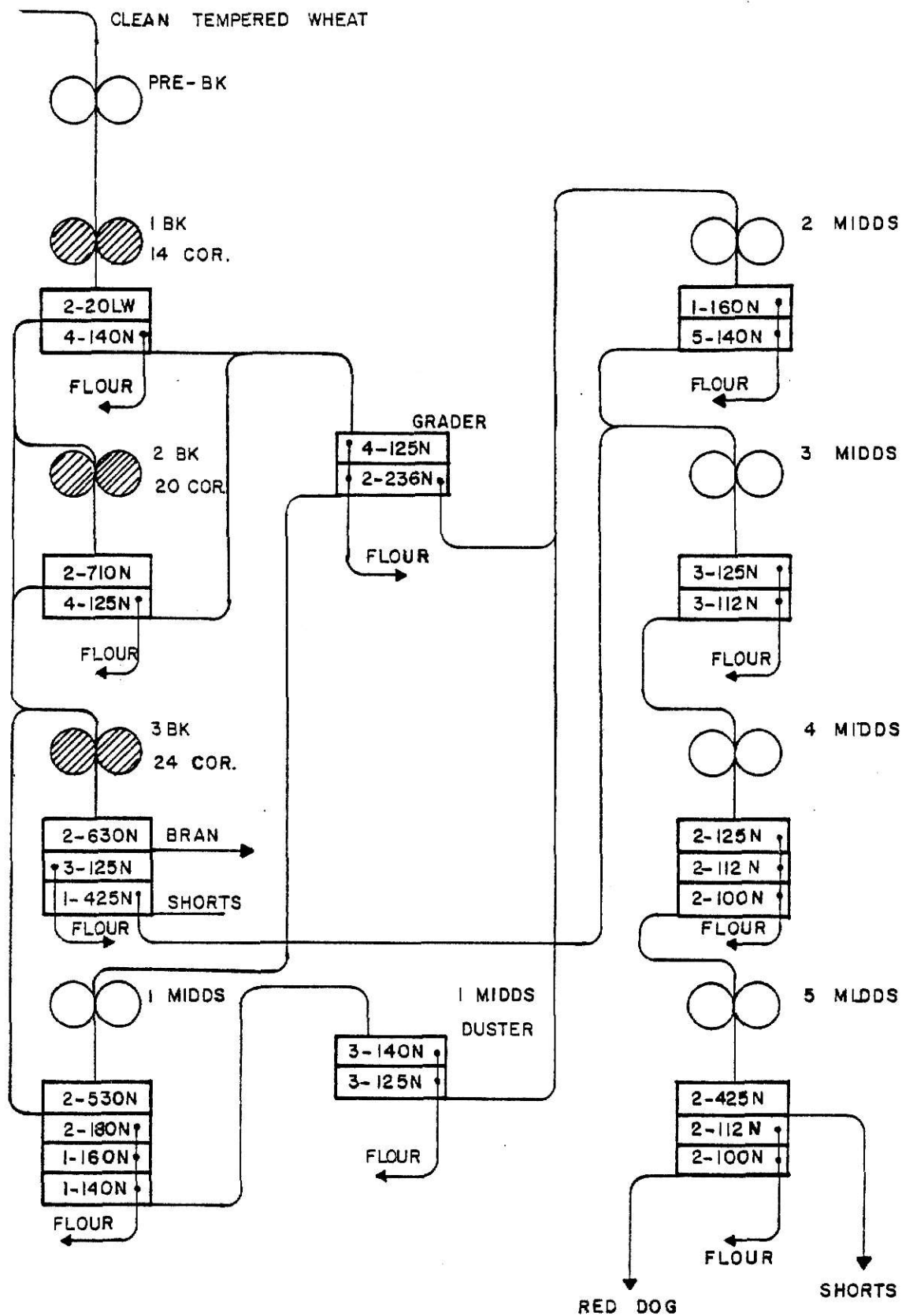
ROLL STAND	CORRUGATIONS/IN (Fast Roll/Slow Roll)	BREAK RELEASE	INITIAL GAP SETTINGS (IN)
Prebreak	Smooth	-	.076
1st break	12/12	30%	.024
2nd break	12/14	40%	.012
3rd break	16/16	40%	.010
4th break	20/22	25%	.009
5th break	22/28	cleanup	.006

Each individual roll stand was calibrated by setting the gap indicators on the left side of the roll stands to the seventh indentation starting from the rear of the roll stand. The gap of the rolls was then set to the initial settings as stated above and each roll was adjusted to achieve the prescribed break release. A 1500 gram sample was used to set the rolls for the proper break release. Once the proper settings were established, two 1500 gram samples were run in succession and taken as the official runs. The Ross Flow produces five break flours, eight reduction flours, red dog, shorts, bran, and germ. Each individual flour stream was tested for Agtron color value and a cumulative color curve was produced by adding the flour streams together in decreasing order of color. The Ross Flow was used in these experiments because it closely simulates a commercial milling flow.

The Miag Multomat was the final experimental milling system to be used. The Multomat is a completely pneumatic, three break, five reduction mill (See Figure 4). The Multomat used for these experiments was equipped



FLOW SHEET FOR ROSS EXPERIMENTAL MILL
FIGURE 3



FLOW SHEET MIAG MULTOMAT EXPERIMENTAL MILL

FIGURE 4

with a pre-break roll. The break rolls have a $2\frac{1}{2}$ to 1 differential and the reduction rolls and prebreak rolls have a $1\frac{1}{2}$ to 1 differential. The break rolls had the following corrugations and break releases:

	CORRUGATIONS	BREAK RELEASES
FIRST BREAK	12* MD/Inch	45%
SECOND BREAK	16 MD/Inch	45%
THIRD BREAK	24 MD/Inch	Cleanup

*Modified Dawson

The mill produces four break flours, six reduction flours, red dog, break and reduction shorts and bran. A composite sample consisting of 3000 grams from each of the ten locations was blended together to be milled on the Multomat Mill. The break releases were set with the mill under load and an official test was made by closing the flour spouts, emptying the flour bins and reopening the spouts. The mill was then allowed to empty out and individual flour streams were tested for protein, moisture, ash, and color (Agtron and Kent-Jones). Cumulative ash, protein, and color curves were produced.

Baking Tests

The straight grade flours produced from the Buhler Experimental Mill were used for baking analysis. Because of low flour protein content, only four locations (Ottawa, Hays, Hesston, SWK) were chosen for baking tests. Amylographs and mixographs were performed on these flours to optimize mixing time, and water absorption and standardize malt content at the 500 line of the amylograph. Several test baking experiments were used to optimize potassium bromate and confirm mixing time and water absorption. A straight dough method was employed for the baking experiments and the formula was as follows:

STRAIGHT DOUGH METHOD

flour	100 grams
sugar	6 grams
salt	1.5 grams
non fat dry milk (NFDM)	4 grams
shortening (Crisco)	3 grams
yeast	2 grams
malt	optimum (500 line)
ascorbic acid	100 ppm
potassium bromate, KBrO_3	optimum
water	optimum

The procedure for the baking tests was as follows:

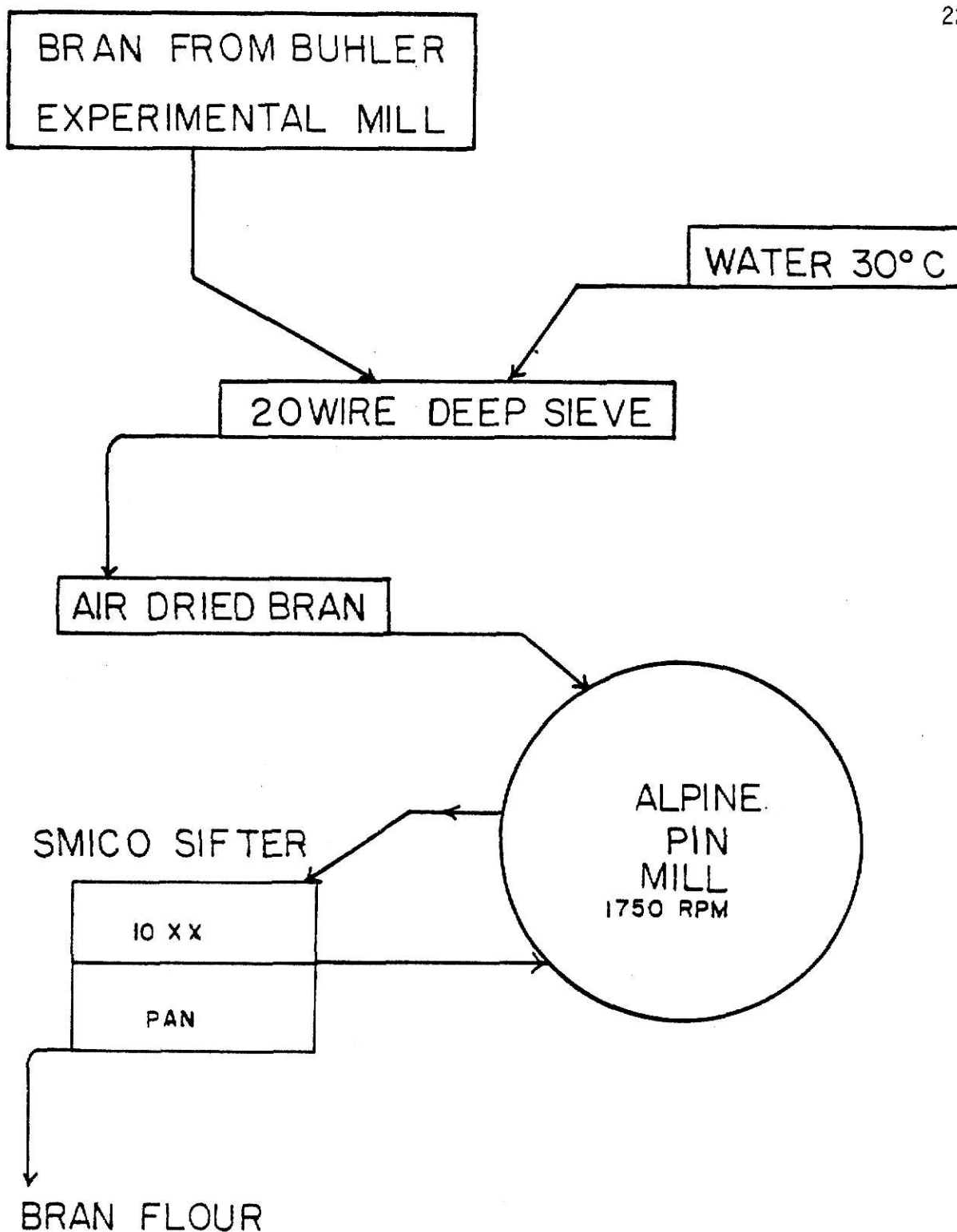
1. Each dough was mixed to optimum development in a National pin mixer (National Mfg. Co., Lincoln, Neb.).
2. A 180 minute fermentation was used with punching at 105, and 155 minutes by means of a double roll sheeter set at 3/16" opening. Fermentation was carried out in a proof cabinet maintained at 30°C and 95% RH.
3. At the end of fermentation the dough was sheeted through the rolls set at 5/16" opening and molder by means of a drum molder.
4. The molded dough was panned and proofed for an additional 55 minutes.
5. The panned loaves were baked for 24 minutes at 218°C (425°F). The weight and volume of each loaf was measured immediately after baking. Volume was determined by rape-seed displacement. The bread was finally evaluated by determining the volume/percent flour protein ratio.

Bran Flour Discoloring Power

In an effort to study the effects of different brans on flour discoloration, it was necessary to produce pure bran flour. Several investigators have studied the effects of bran flour discoloration on flour by

either adding pin milled bran or shorts as bran flour (Shuey et al, 1977; Watson et al, 1977). Their results could be misleading because a significant amount of endosperm remains on bran and shorts. These investigators could not be sure if they were adding bran flour or simply the endosperm that remained attached to the bran. The amount of endosperm remaining on bran and shorts would also vary to some degree according to variety of wheat.

The production of what was considered 100% bran flour was accomplished by taking the bran from the Buhler Experimental Mill tests and putting it through a process outlined in Figure 5. The process entailed washing the bran in a 20 mesh wire deep seive with 30°C water until the wash water was clear and did not appear to contain any endosperm. The bran was then air dried at room temperature and placed through an Alpine Pin Mill at 1750 RPM. The resulting product was bolted over a 10xx flour cloth in a Smico Experimental Sifter for 2 minutes and the throughs were considered bran flour. This process was carried out for all three wheats grown at each of the ten experimental stations. The bran flour was then added to the existing Buhler Straight Grade flours in increasing amounts and color grade readings were taken using both the Agtron and Kent-Jones reflectance meters. The discoloring power of each bran flour was compared by plotting the color grade values versus the percent of bran flour added. Ash values were also determined for each level of bran flour addition and plotted. The ash values versus color grade values for the respective amount of bran flour added were also plotted and correlations were run on percent bran added, ash, Agtron Color Grade and Kent-Jones Color Grade. The AACC method for Agtron color grade determination was used with one exception. Due to abnormally dark flour colors after bran



FLOW OF BRAN FLOUR SYSTEM

FIGURE 5

flour additions, discs 52 and 85 were used for standardization instead of the prescribed 63-85. This change allowed color values to be obtained for 1% through 6% bran addition by weight. The green mode for the M-500 Agtron was used for all flour color determinations and each color grade observation was taken in duplicate.

Cumulative Color Curve Determination

Flour color determinations were made with the Agtron model M-500A reflectance meter and the Kent-Jones Series II color grader. The materials and procedures used were either as per the operating instructions in the operator's manual or the official AACC method. Each flour stream from the Multomat and Ross Mill experiments was analyzed for either Agtron color or both Kent-Jones and Agtron. All color readings were done in duplicate. It was necessary to determine the color of individual streams so as to add the flours in the proper order of decreasing color. Once the order was established, the flour streams were blended together, one stream at a time and color readings were taken on the cumulative flour produced. Each color grade observation was taken in duplicate. These cumulative color values were then plotted against the percent extraction which allowed for the quantitative comparison of one variety with another in respect to flour color versus percent extraction.

General Flour Color Investigation

Two general flour color investigations were performed. The first involved the question of the additive effect of Agtron and Ken-Jones Color Grades. In these experiments flour streams from the Multomat runs were blended together in equal amounts and tested for color grade. Three differ-

ent flour streams were used (1M, 3M, 3BR) because it was necessary to test the blending of flours with similar color grade values and diverse color grade values. Two similar color grade flours were blended together and tested and two diverse color grade flours were blended and tested. The green mode was used for the M-500 Model Agtron and all color grade readings were taken in duplicate.

The last general flour color grade investigation involved the change of flour color over a specified period of time. The flour streams from the Multomat were used in this experiment. Initial flour color grade determinations were made on each individual stream using the M-500 Model Agtron in the green mode. The flour was then stored at room temperature (68°F) for three weeks. After the three week period, the flour was stored for nine weeks in a cold room (45°F). When the twelve week storage time had elapsed, the flour streams were rechecked for Agtron color grade. Once again each stream was run in duplicate with the M-500 Model Agtron using the green wave length. The after storage flour stream color grade values were also taken on a model M-400 Agtron to see if the results obtained could be duplicated on another Agtron reflectance meter. The M-400 Model Agtron was supplied by the USDA Grain Marketing Research Center.

RESULTS AND DISCUSSION

Physical and Chemical Tests

The physical and chemical wheat tests were all very similar within each location. Location seemed to be the dominant factor as opposed to genetic wheat variety. Test weight and percent protein would be either low or high in all three varieties according to location. In no case did one variety have a low value while another was high within the same location. The most noticeable physical difference was that the Clark's Cream variety had a distinctly larger proportion of plumper kernels. Because of this advantage, Clark's Cream had a much higher theoretical yield value in 6 of the 10 locations. This suggests that a higher practical yield might be obtainable with Clark's Cream. (See Graphs 1-10 for Physical and Chemical Tests).

Bran Flour Discoloring Power

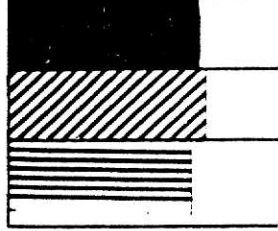
The bran flour discoloring power experiments were performed for a twofold purpose. The first was to determine the exact relationship between bran flour contamination and Agtron and Kent-Jones Color Grade values. The second purpose was to ascertain if there was any difference in the discoloring power in the bran layers of the three different genetic wheat varieties tested. If such a difference existed, then it would be theoretically possible to produce more flour at the same color grade value using a genetic wheat variety that had a bran layer with a low discoloring power.

The production of what was considered 100% bran flour was accomplished as stated in the Methods section. The bran flour was added to the Buhler straight grade flours in increments of .25% up to 2% and then added

PHYSICAL AND CHEMICAL TESTS

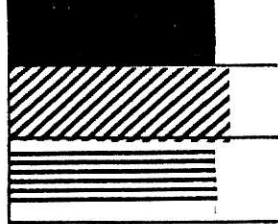
U.S. BUSHEL WT. IN
POUNDS

52 56 60 64



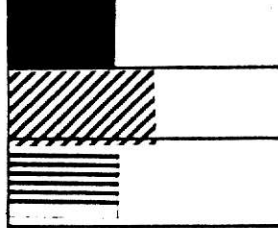
THEORETICAL YIELD
(%)

60 70 80



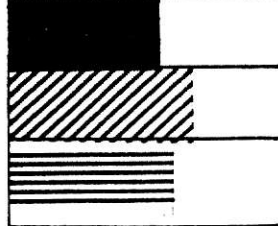
WHEAT DENSITY

136 140 144



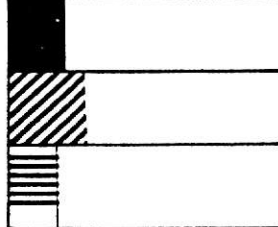
AGTRON FLOUR COLOR

55 65 75 85



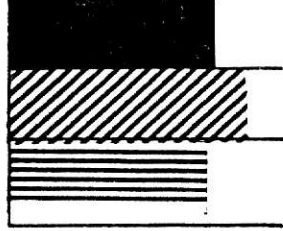
FLOUR PROTEIN
(%)

8 12 16 20



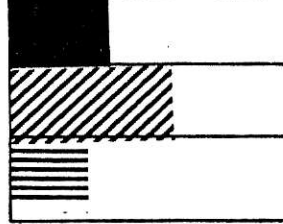
1000 KERNEL WEIGHT
(GRAMS)

20 30 40



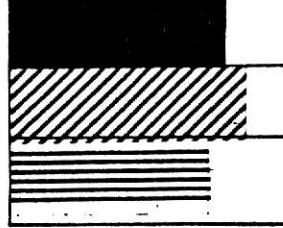
PERCENTAGE OF ASH
(14% m.b.)

1.3 1.5 1.7 1.9



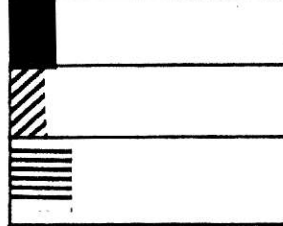
HECTOR WT.

69 73 77 81



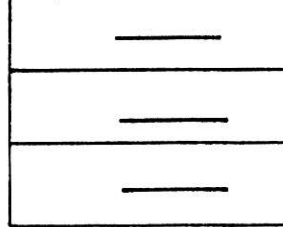
KENT JONES
FLOUR COLOR

1 2 3 4 5 6



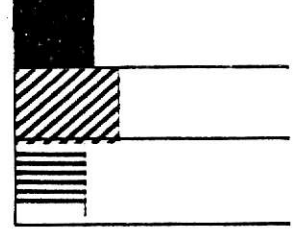
MIXOGRAM PEAK TIME
(min.)

2 3 4 5



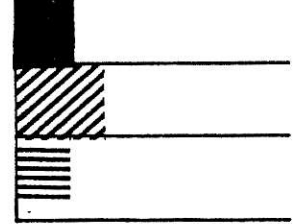
PEARLING VALUE
(%)

60 70 80



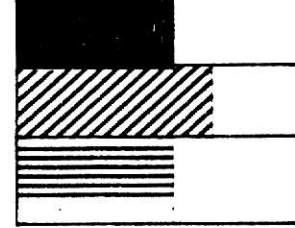
PERCENTAGE OF PROTEIN
(14% m.b.)

10 12 14 16



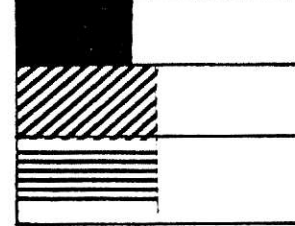
BUHLER YIELD
(%)

68 70 72



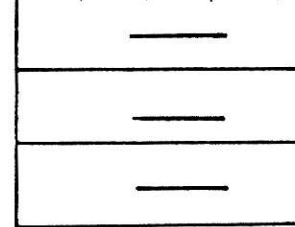
FLOUR ASH
(%)

.2 .3 .4 .5 .6



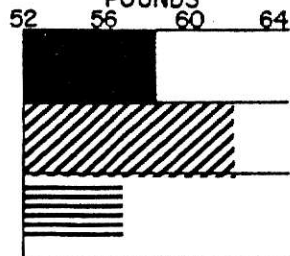
LOAF VOL./FL. PROTEIN
(cc/%)

60 70 80

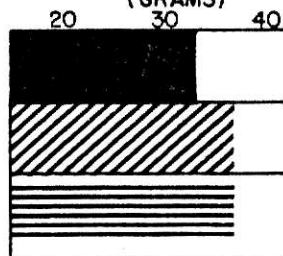


PHYSICAL AND CHEMICAL TESTS

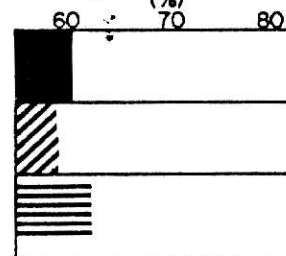
U.S. BUSHEL WT. IN
POUNDS



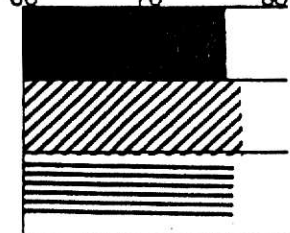
1000 KERNEL WEIGHT
(GRAMS)



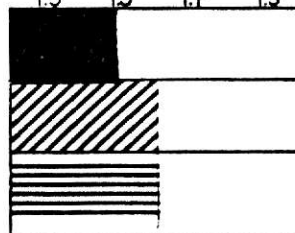
PEARLING VALUE
(%)



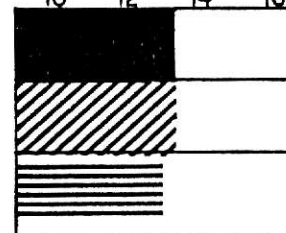
THEORETICAL YIELD
(%)



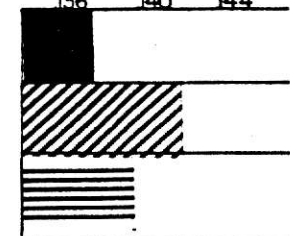
PERCENTAGE OF ASH
(14% m.b.)



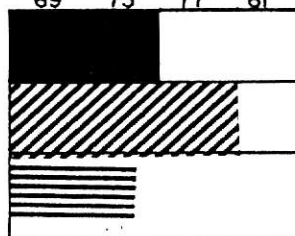
PERCENTAGE OF PROTEIN
(14% m.b.)



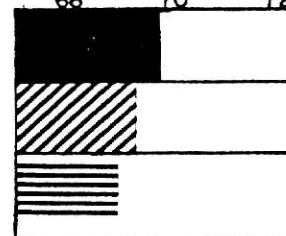
WHEAT DENSITY



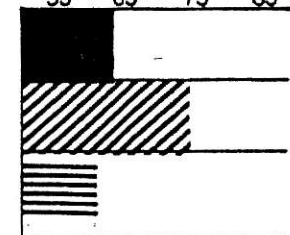
HECTOR WT.



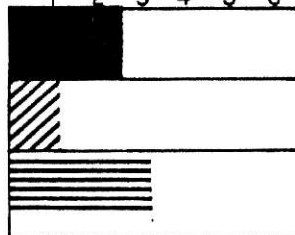
BUHLER YIELD
(%)



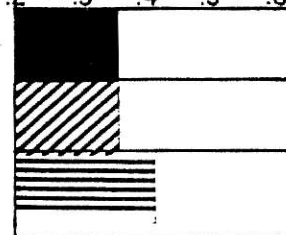
AGSTRON FLOUR COLOR



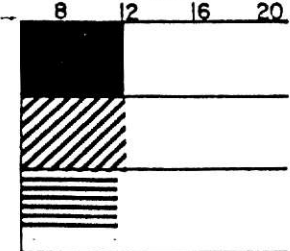
KENT JONES
FLOUR COLOR



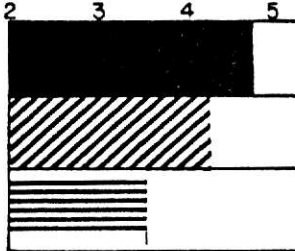
FLOUR ASH
(%)



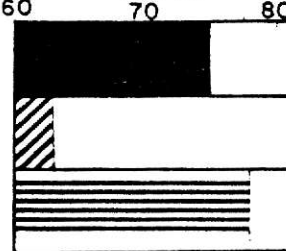
FLOUR PROTEIN
(%)



MIXOGRAM PEAK TIME
(min.)



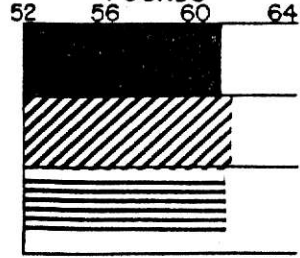
LOAF VOL./FL. PROTEIN
(cc/%)



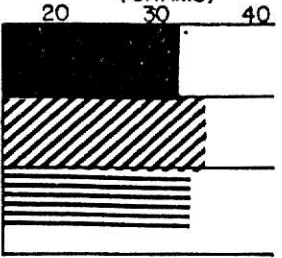
EAGLE
CLARK'S CREAM
KSU73256

PHYSICAL AND CHEMICAL TESTS

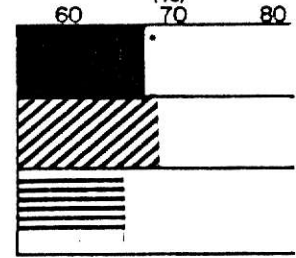
U.S. BUSHEL WT. IN
POUNDS



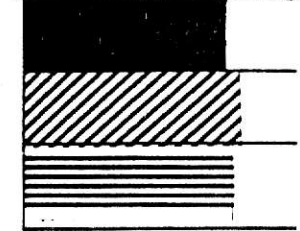
1000 KERNEL WEIGHT
(GRAMS)



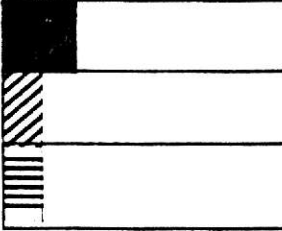
PEARLING VALUE
(%)



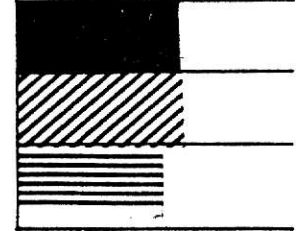
THEORETICAL YIELD
(%)



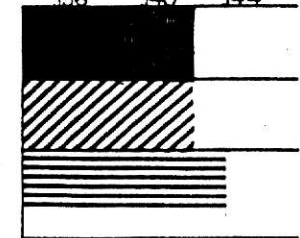
PERCENTAGE OF ASH
(14% m.b.)



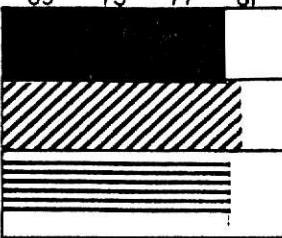
PERCENTAGE OF PROTEIN
(14% m.b.)



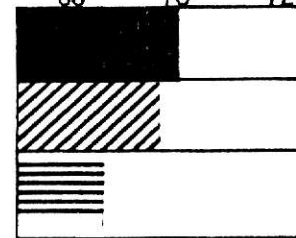
WHEAT DENSITY



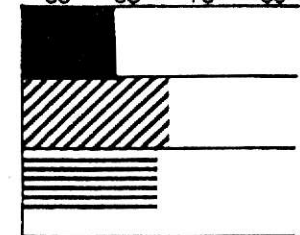
HECTOR WT.



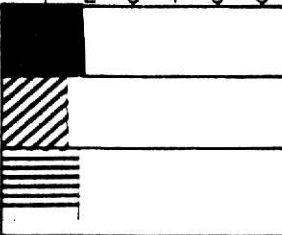
BUHLER YIELD
(%)



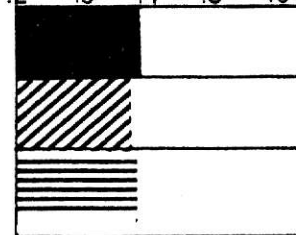
AGSTRON FLOUR COLOR



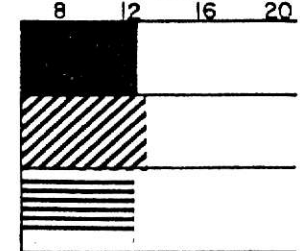
KENT JONES
FLOUR COLOR



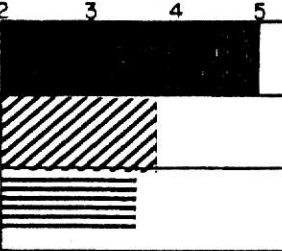
FLOUR ASH
(%)



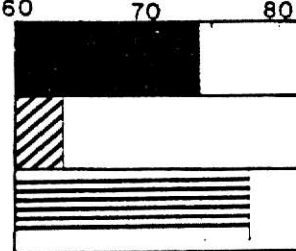
FLOUR PROTEIN
(%)



MIXOGRAM PEAK TIME
(min.)



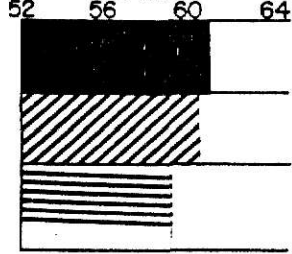
LOAF VOL./FL. PROTEIN
(cc/%)



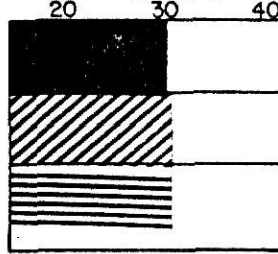
EAGLE
CLARK'S CREAM
KSU73256

PHYSICAL AND CHEMICAL TESTS

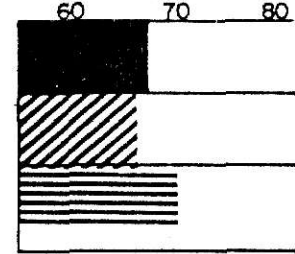
U.S. BUSHEL WT. IN
POUNDS



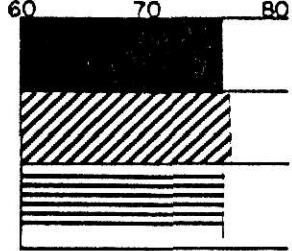
1000 KERNEL WEIGHT
(GRAMS)



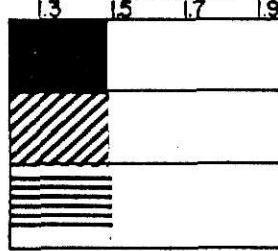
PEARLING VALUE
(%)



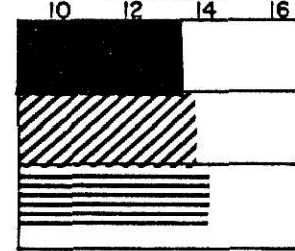
THEORETICAL YIELD
(%)



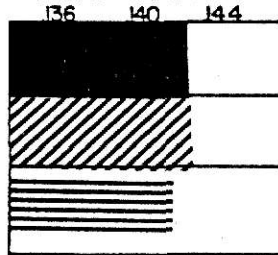
PERCENTAGE OF ASH
(14% m.b.)



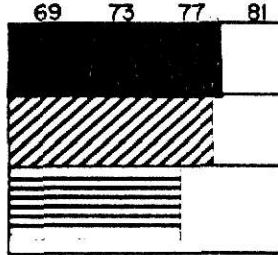
PERCENTAGE OF PROTEIN
(14% m.b.)



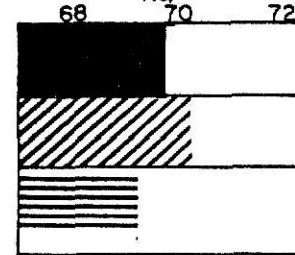
WHEAT DENSITY



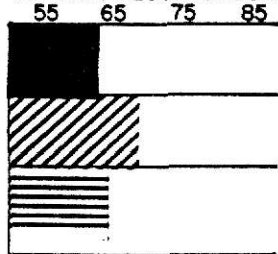
HECTOR WT.



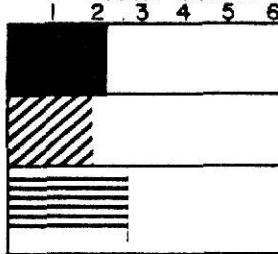
BUHLER YIELD
(%)



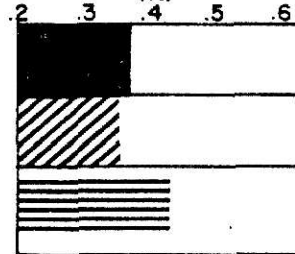
AGTRON FLOUR COLOR



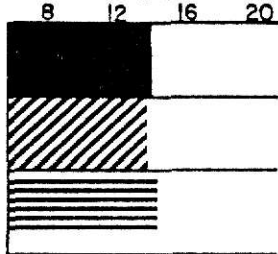
KENT JONES
FLOUR COLOR



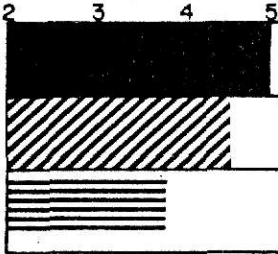
FLOUR ASH
(%)



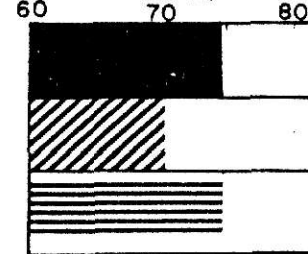
FLOUR PROTEIN
(%)



MIXOGRAM PEAK TIME
(min.)



LOAF VOL./FL. PROTEIN
(cc/%)



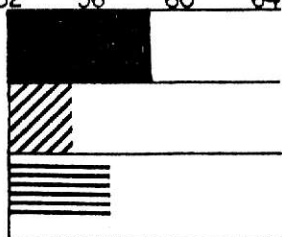
 EAGLE
 CLARK'S CREAM
 KSU73256

HESSTON
GRAPH 4

PHYSICAL AND CHEMICAL TESTS

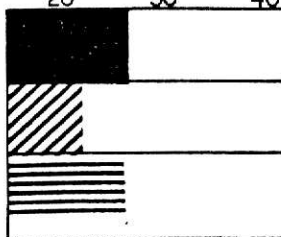
U.S. BUSHEL WT. IN
POUNDS

52 56 60 64



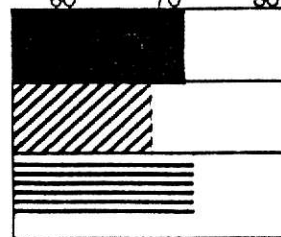
1000 KERNEL WEIGHT
(GRAMS)

20 30 40



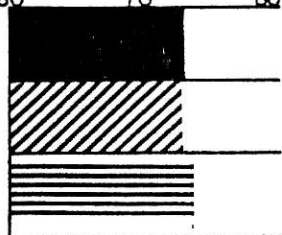
PEARLING VALUE
(%)

60 70 80



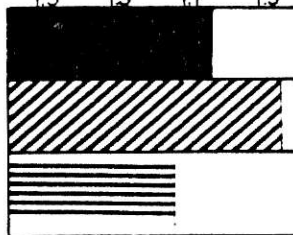
THEORETICAL YIELD
(%)

60 70 80



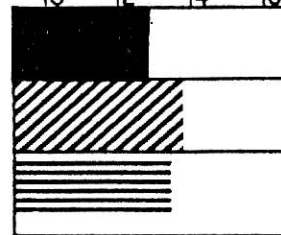
PERCENTAGE OF ASH
(14% m.b.)

1.3 1.5 1.7 1.9



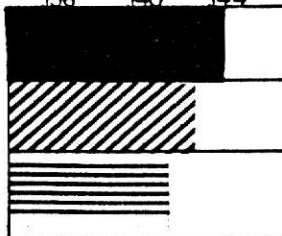
PERCENTAGE OF PROTEIN
(14% m.b.)

10 12 14 16



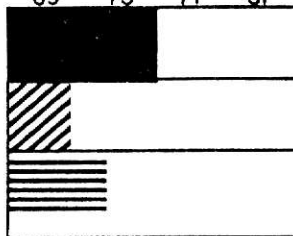
WHEAT DENSITY

136 140 144



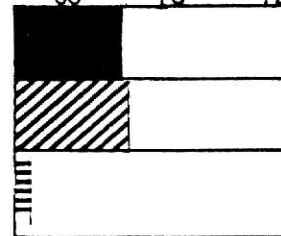
HECTOR WT.

69 73 77 81



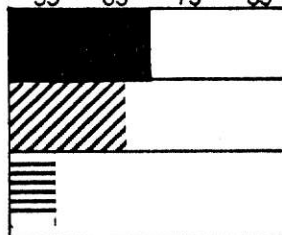
BUHLER YIELD
(%)

68 70 72



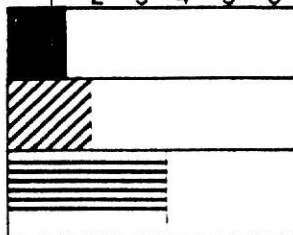
AGTRON FLOUR COLOR

55 65 75 85



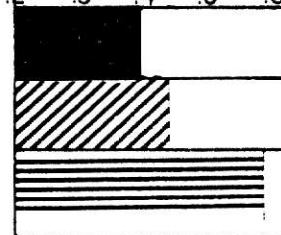
KENT JONES
FLOUR COLOR

1 2 3 4 5 6



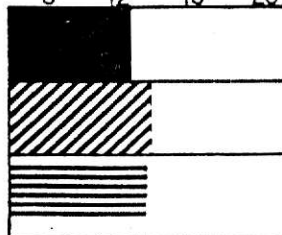
FLOUR ASH
(%)

2 3 4 5 6



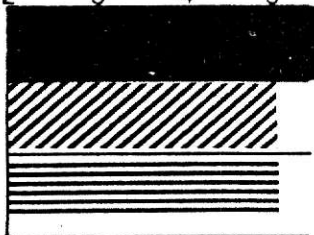
FLOUR PROTEIN
(%)

8 12 16 20



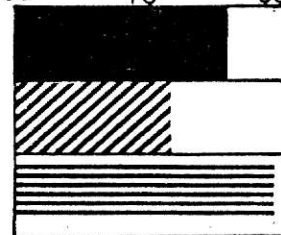
MIXOGRAM PEAK TIME
(min.)

2 3 4 5



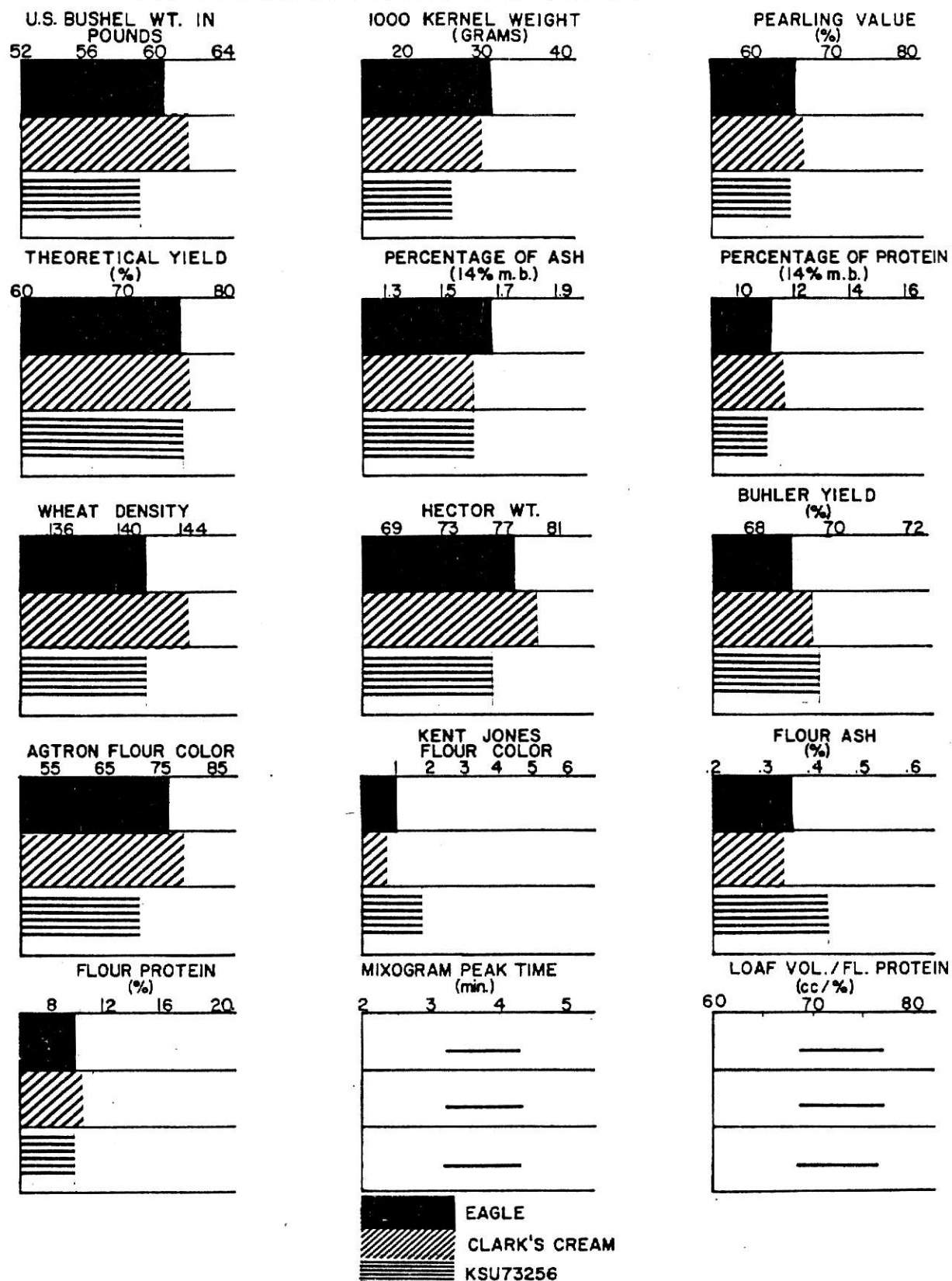
LOAF VOL./FL. PROTEIN
(cc/%)

60 70 80



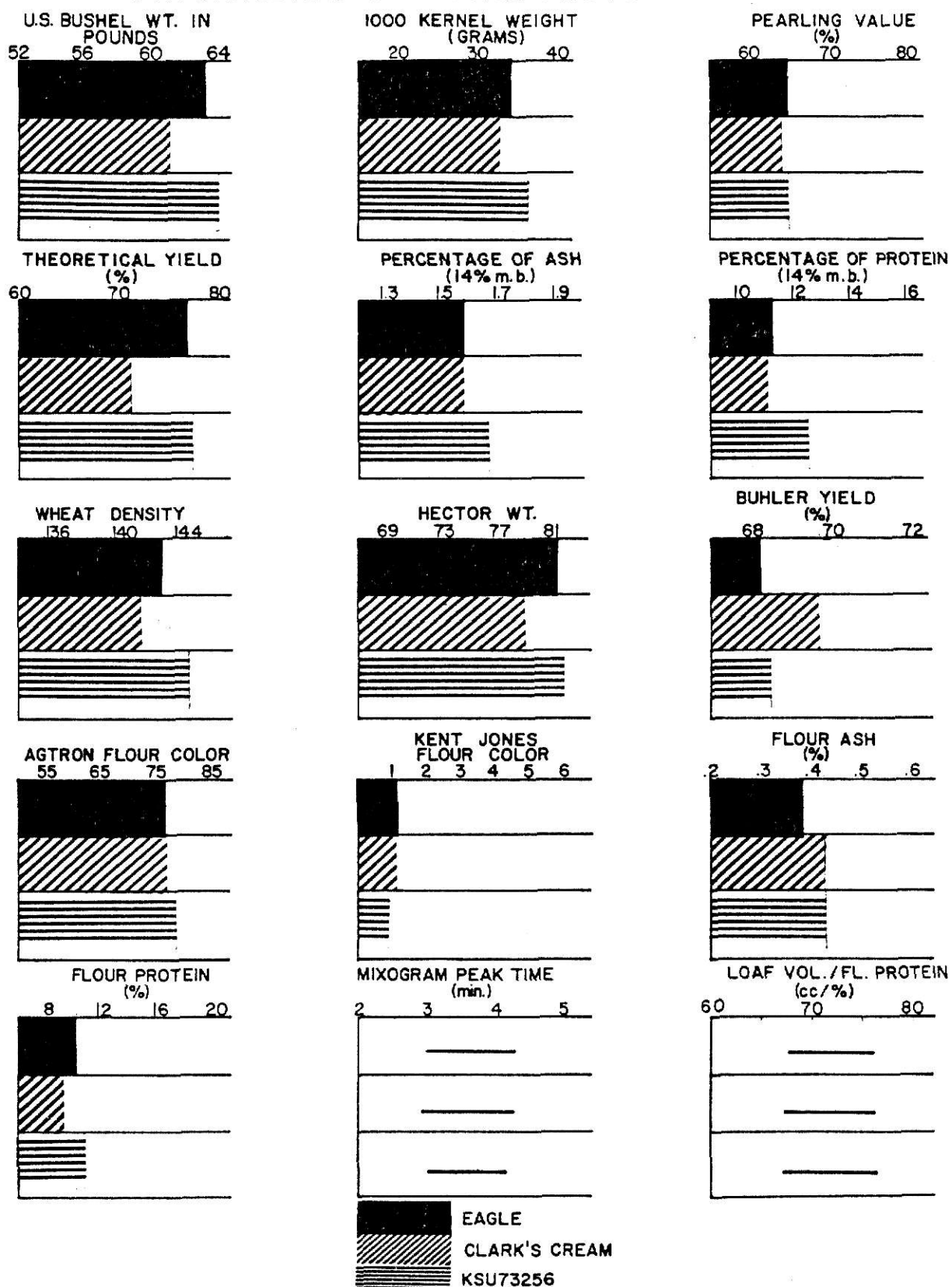
EAGLE
CLARK'S CREAM
KSU73256

PHYSICAL AND CHEMICAL TESTS



POWHATTAN
GRAPH 6

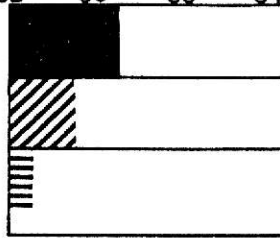
PHYSICAL AND CHEMICAL TESTS



PHYSICAL AND CHEMICAL TESTS

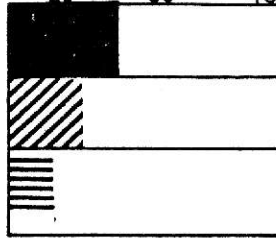
U.S. BUSHEL WT. IN
POUNDS

52 56 60 64



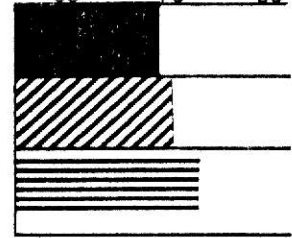
1000 KERNEL WEIGHT
(GRAMS)

20 30 40



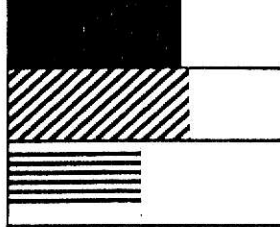
PEARLING VALUE
(%)

60 70 80



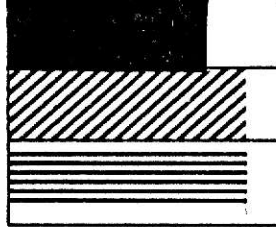
THEORETICAL YIELD
(%)

60 70 80



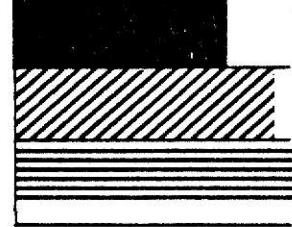
PERCENTAGE OF ASH
(14% m.b.)

1.3 1.5 1.7 1.9



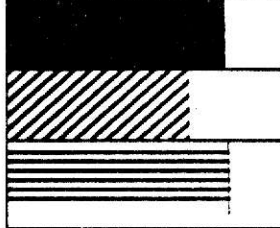
PERCENTAGE OF PROTEIN
(14% m.b.)

10 12 14 16



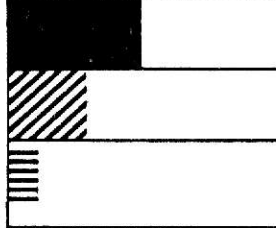
WHEAT DENSITY

136 140 144



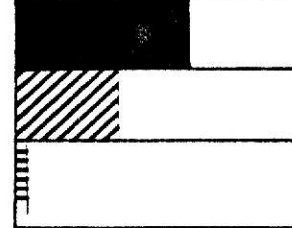
HECTOR WT.

69 73 77 81



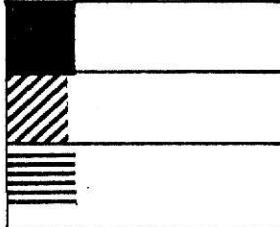
BUHLER YIELD
(%)

68 70 72



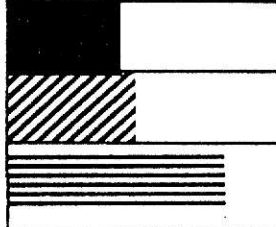
AGTRON FLOUR COLOR

55 65 75 85



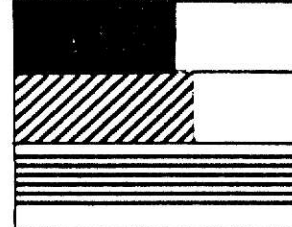
KENT JONES
FLOUR COLOR

1 2 3 4 5 6



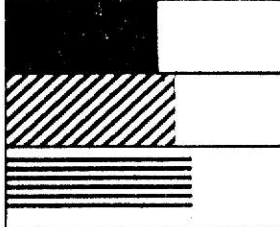
FLOUR ASH
(%)

.2 .3 .4 .5 .6



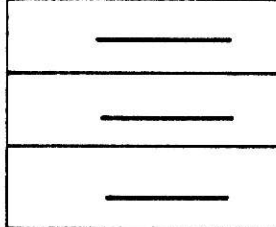
FLOUR PROTEIN
(%)

8 12 16 20



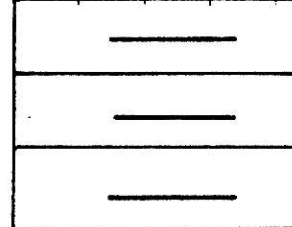
MIXOGRAM PEAK TIME
(min.)

2 3 4 5



LOAF VOL./FL. PROTEIN
(cc/%)

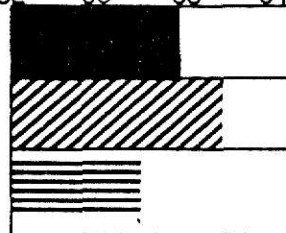
60 70 80



PHYSICAL AND CHEMICAL TESTS

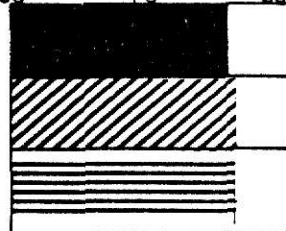
U.S. BUSHEL WT. IN
POUNDS

52 56 60 64



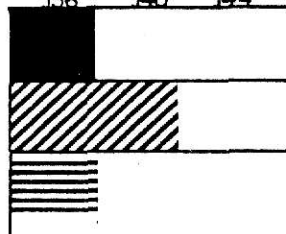
THEORETICAL YIELD
(%)

60 70 80



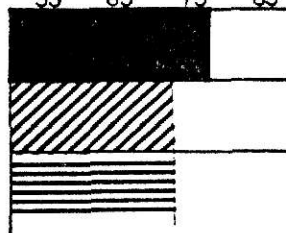
WHEAT DENSITY

136 140 144



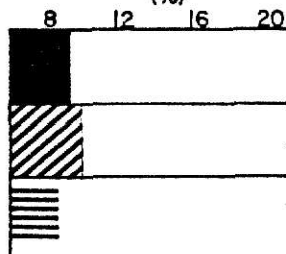
AGTRON FLOUR COLOR

55 65 75 85



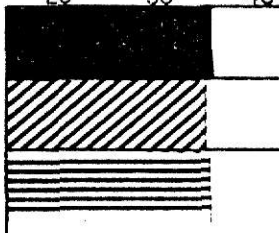
FLOUR PROTEIN
(%)

8 12 16 20



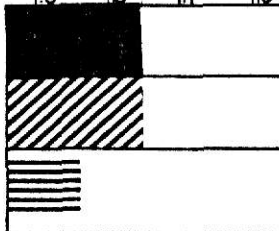
1000 KERNEL WEIGHT
(GRAMS)

20 30 40



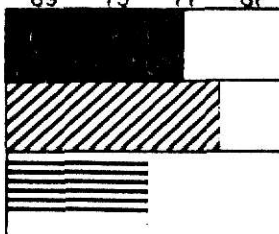
PERCENTAGE OF ASH
(14% m.b.)

1.3 1.5 1.7 1.9



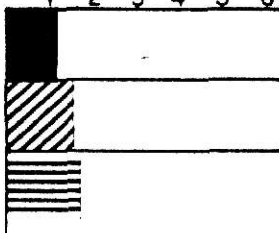
HECTOR WT.

69 73 77 81



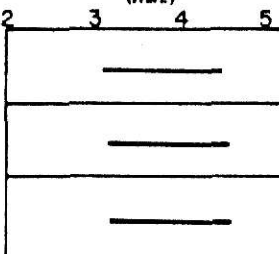
KENT JONES
FLOUR COLOR

1 2 3 4 5 6



MIXOGRAM PEAK TIME
(min.)

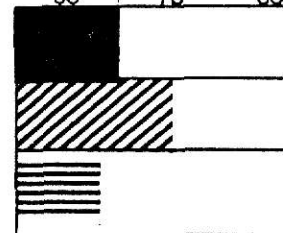
2 3 4 5



EAGLE
CLARK'S CREAM
KSU73256

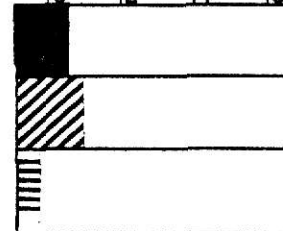
PEARLING VALUE
(%)

60 70 80



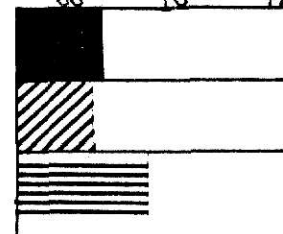
PERCENTAGE OF PROTEIN
(14% m.b.)

10 12 14 16



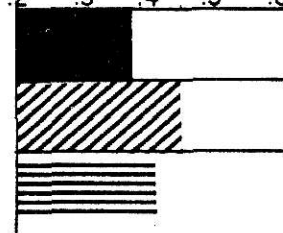
BUHLER YIELD
(%)

68 70 72



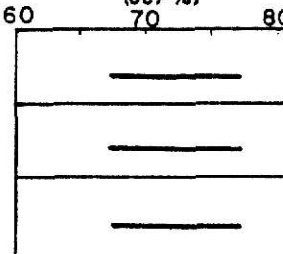
FLOUR ASH
(%)

2 3 4 5 6



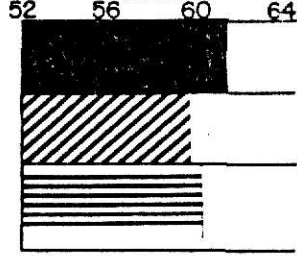
LOAF VOL./FL. PROTEIN
(cc/%)

60 70 80

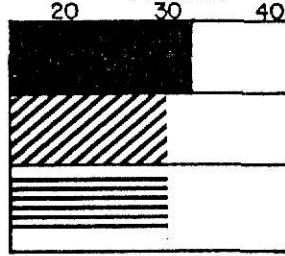


PHYSICAL AND CHEMICAL TESTS

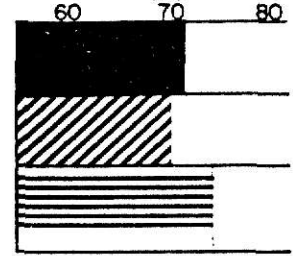
U.S. BUSHEL WT. IN
POUNDS



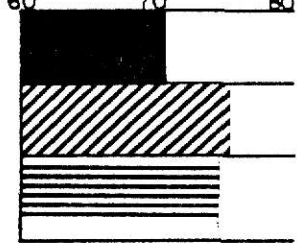
1000 KERNEL WEIGHT
(GRAMS)



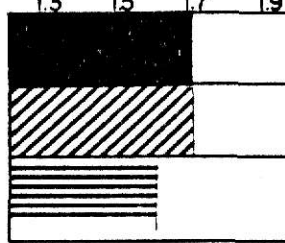
PEARLING VALUE
(%)



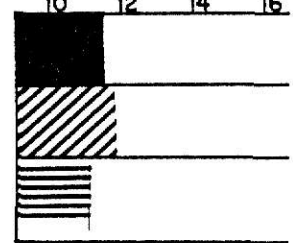
THEORETICAL YIELD
(%)



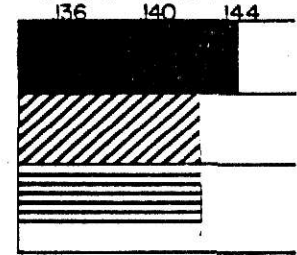
PERCENTAGE OF ASH
(14% m.b.)



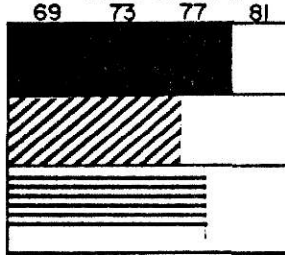
PERCENTAGE OF PROTEIN
(14% m.b.)



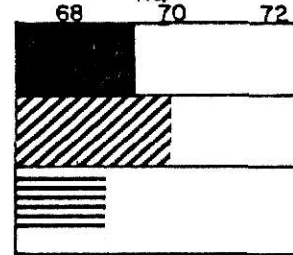
WHEAT DENSITY



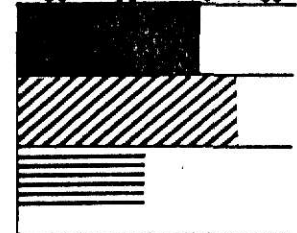
HECTOR WT.



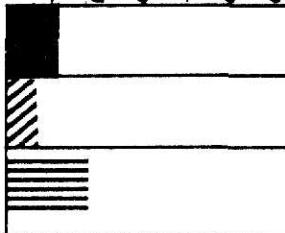
BUHLER YIELD
(%)



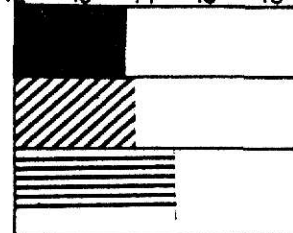
AGTRON FLOUR COLOR



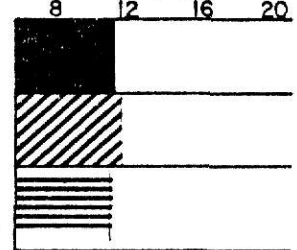
KENT JONES
FLOUR COLOR



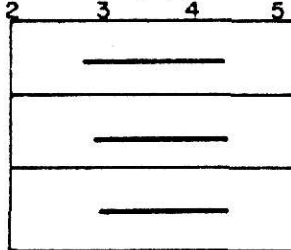
FLOUR ASH
(%)



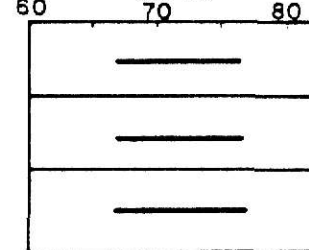
FLOUR PROTEIN
(%)



MIXOGRAM PEAK TIME
(min.)



LOAF VOL./FL. PROTEIN
(cc/%)

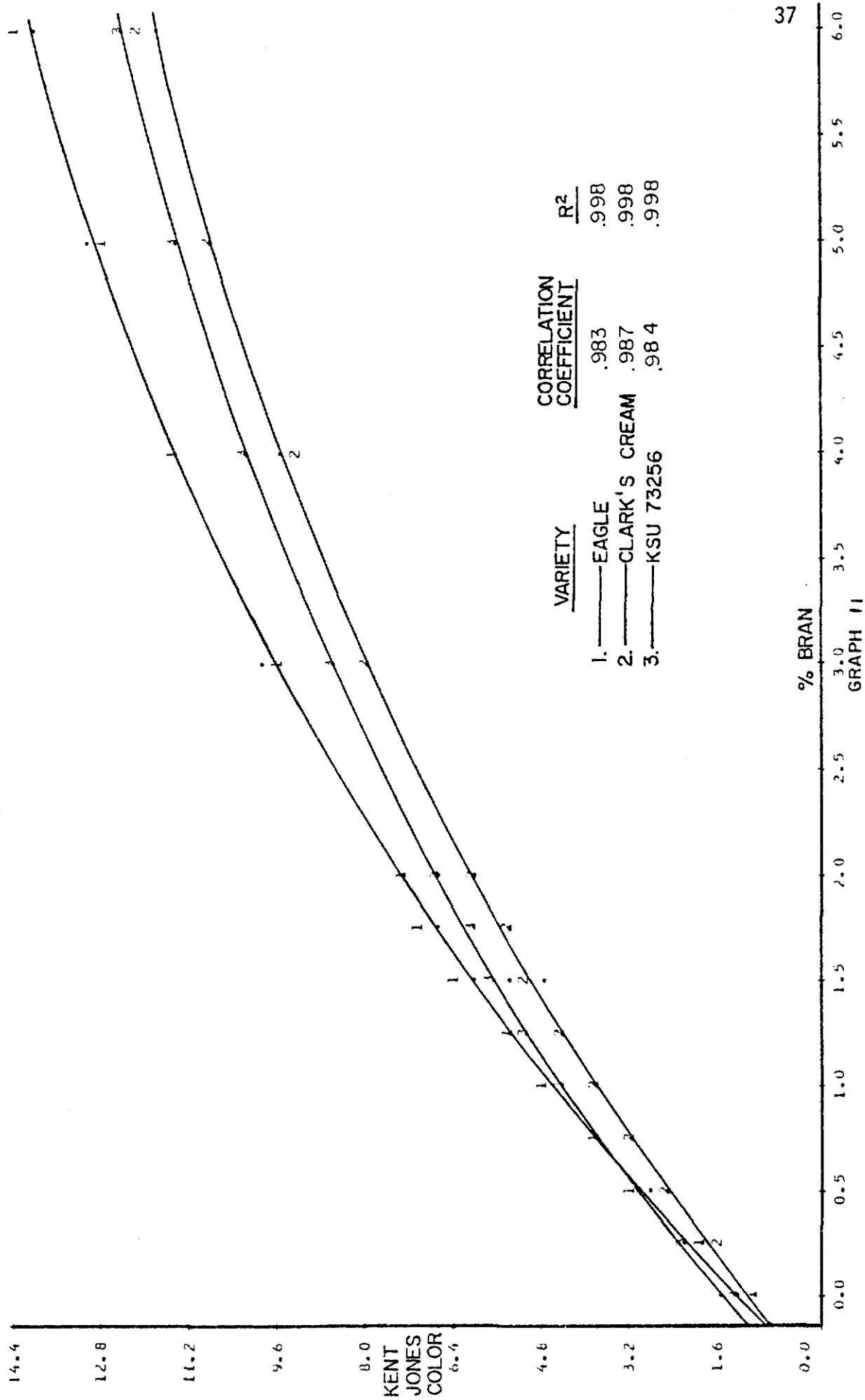


in increments of 1% up to and including 6%. Kent-Jones and Agtron color grades as well as ash values were taken in duplicate on each increment of bran flour addition. The discoloring power of each respective bran flour was analyzed by plotting the color grade values versus the percent of bran flour added for each location. The Kent-Jones and Agtron discoloring power curves can be found on graphs 11-20 and 21-30, respectively. The dots represent the predicted color grade values, while the numerals are the actual color grade values.

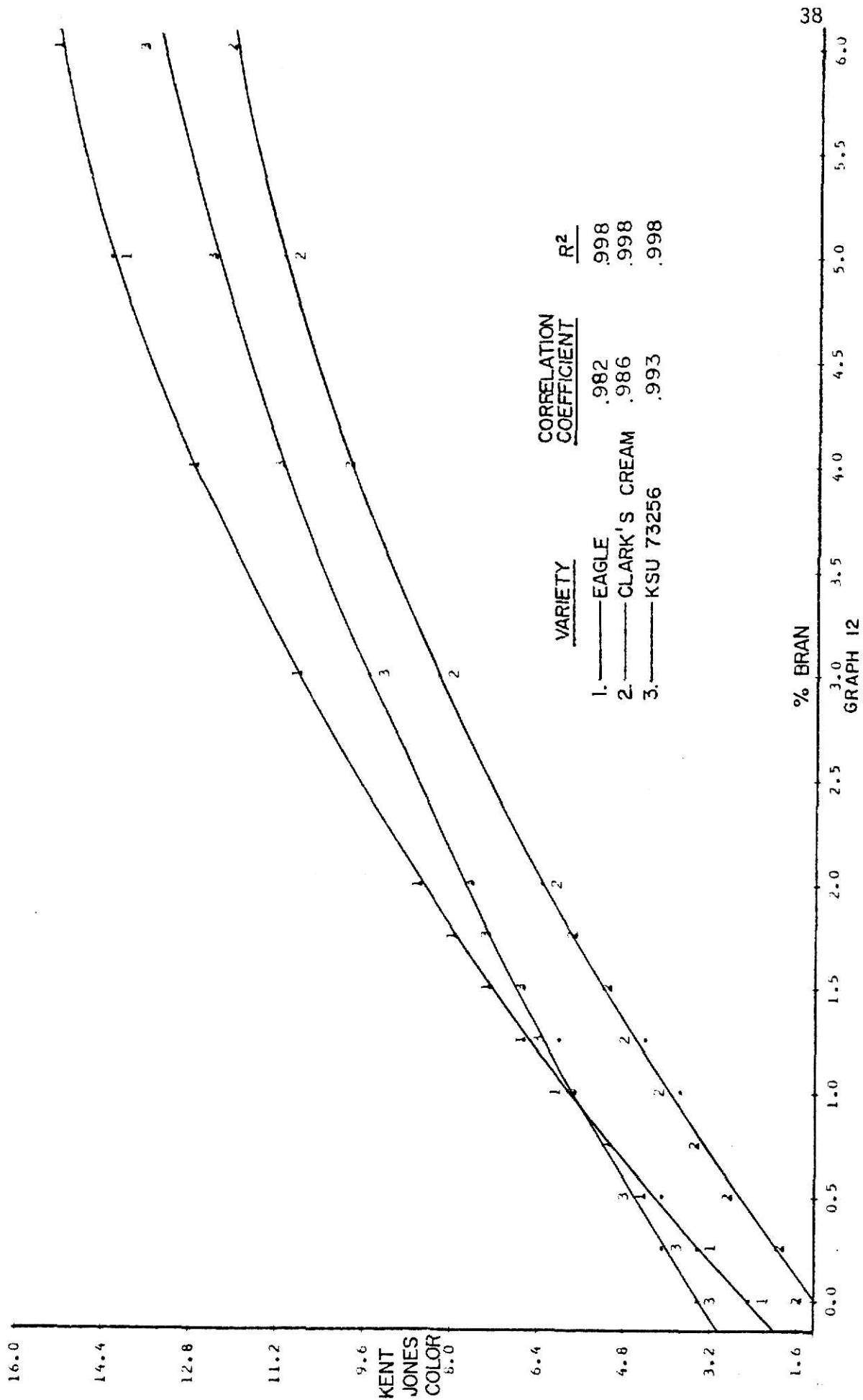
It is obvious from the bran flour discoloring power graphs that bran flour has a quadratic effect on Kent-Jones and Agtron color grade values. Several researchers have found that the Agtron and Kent-Jones color grade values versus percent additional extraction yielded a linear type relationship as opposed to a quadratic relationship (Shuey et al, 1977; Skarsaune et al, 1975). In their work, they were adding up to 3 and 4% additional extraction through tail end regrinding. A 3 or 4% addition in extraction obtained in this manner would probably contain the same amount of bran flour contamination as was present in some of the lower bran flour discoloring samples. If the 0 to 3% bran flour addition color grade values were plotted by themselves, a linear or straight line relationship could easily be obtained.

The differences in the degree of discoloring power of each of the genetic wheat varieties' bran was also very apparent. The Clark's Cream variety bran flour had the least discoloring effect in nine of the ten locations. The Eagle variety bran flour had the greatest discoloring effect in all ten locations. The KSU 73256 experimental variety bran flour and the Clark's Cream variety bran flour were very similar in discoloring power in four of the ten locations. There was a significant

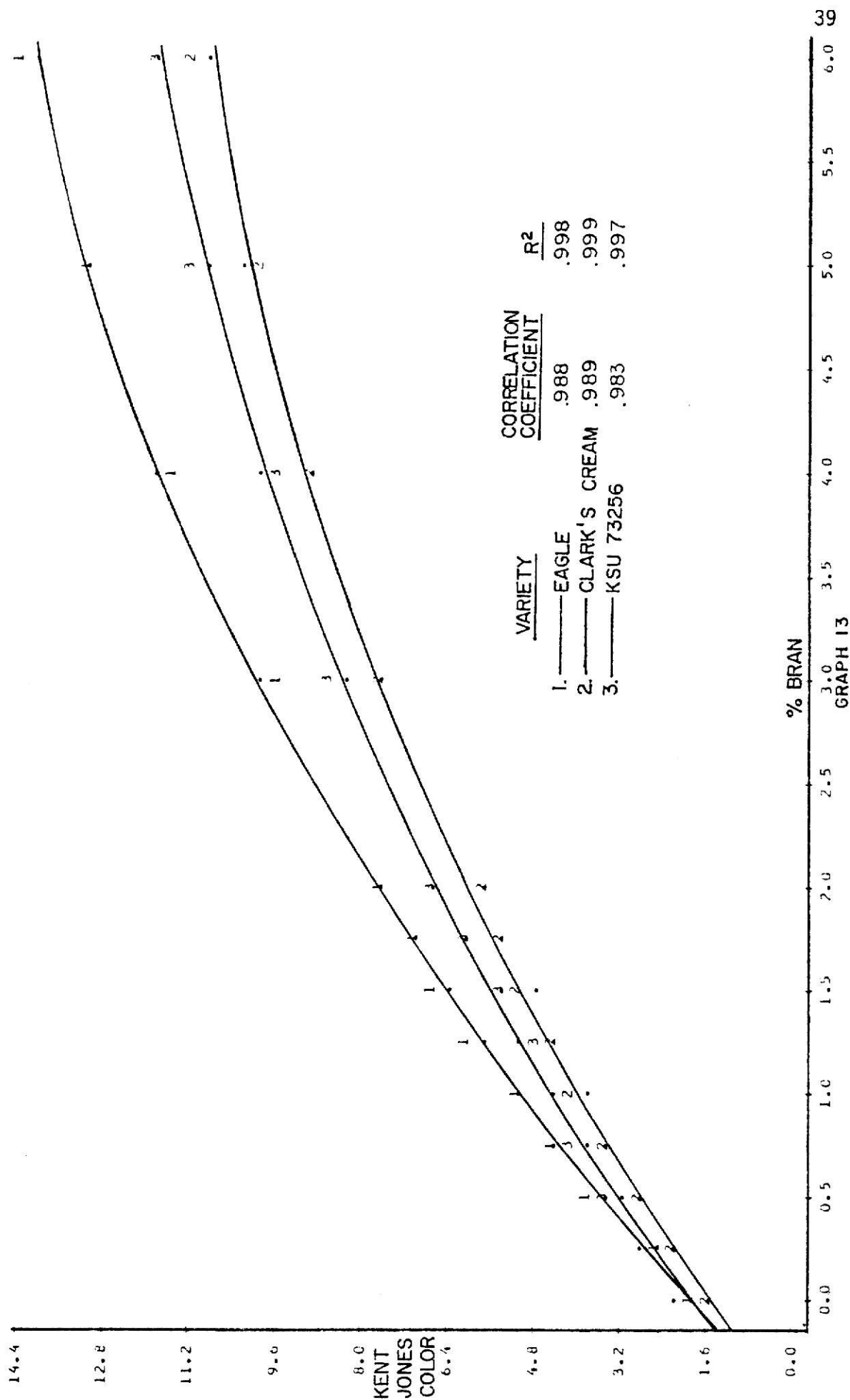
HUTCHINSON. KENT JONES COLOR GRADE.



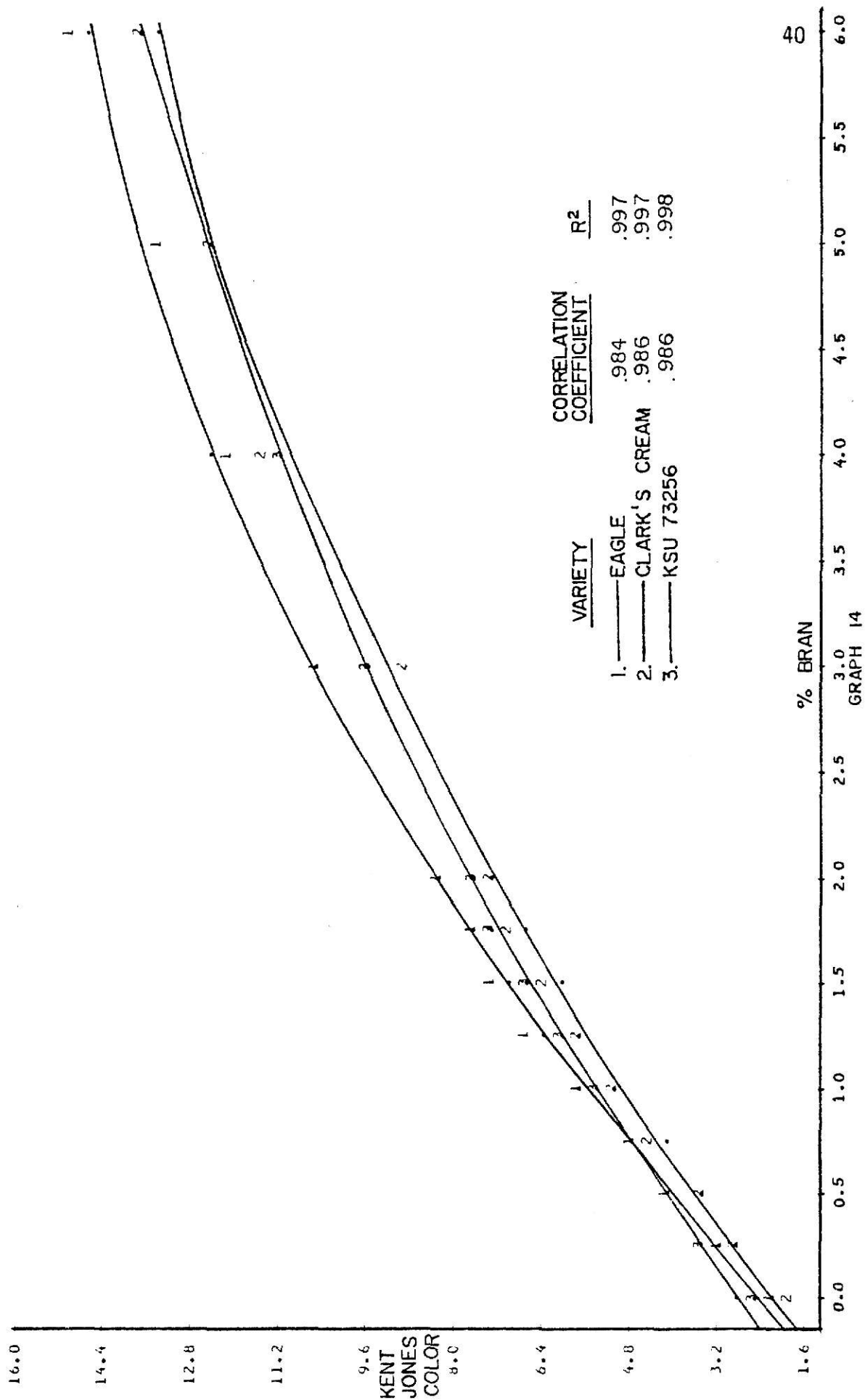
OTTAWA. KENT JONES COLOR GRADE.



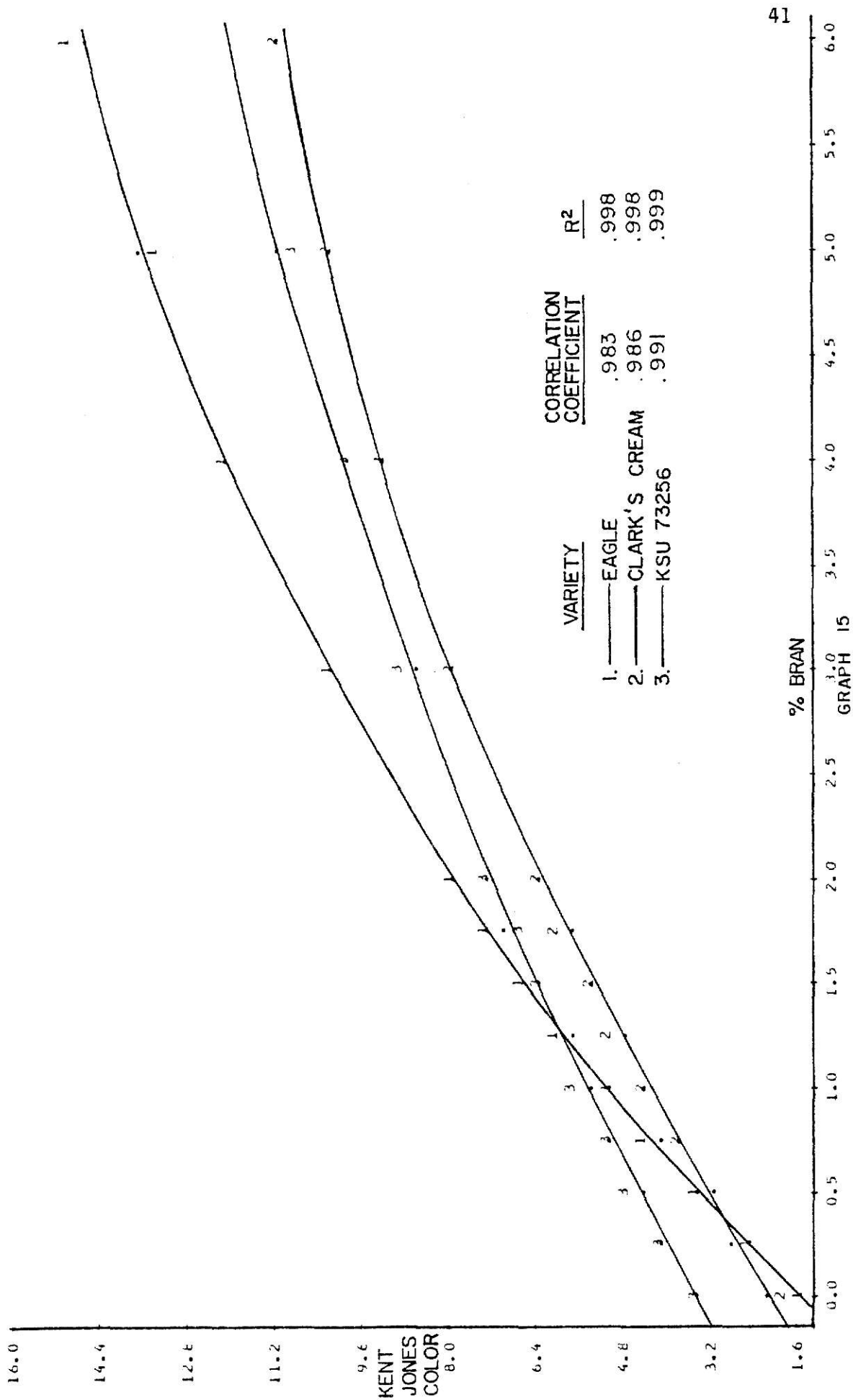
HAYS. KENT JONES COLOR GRADE.



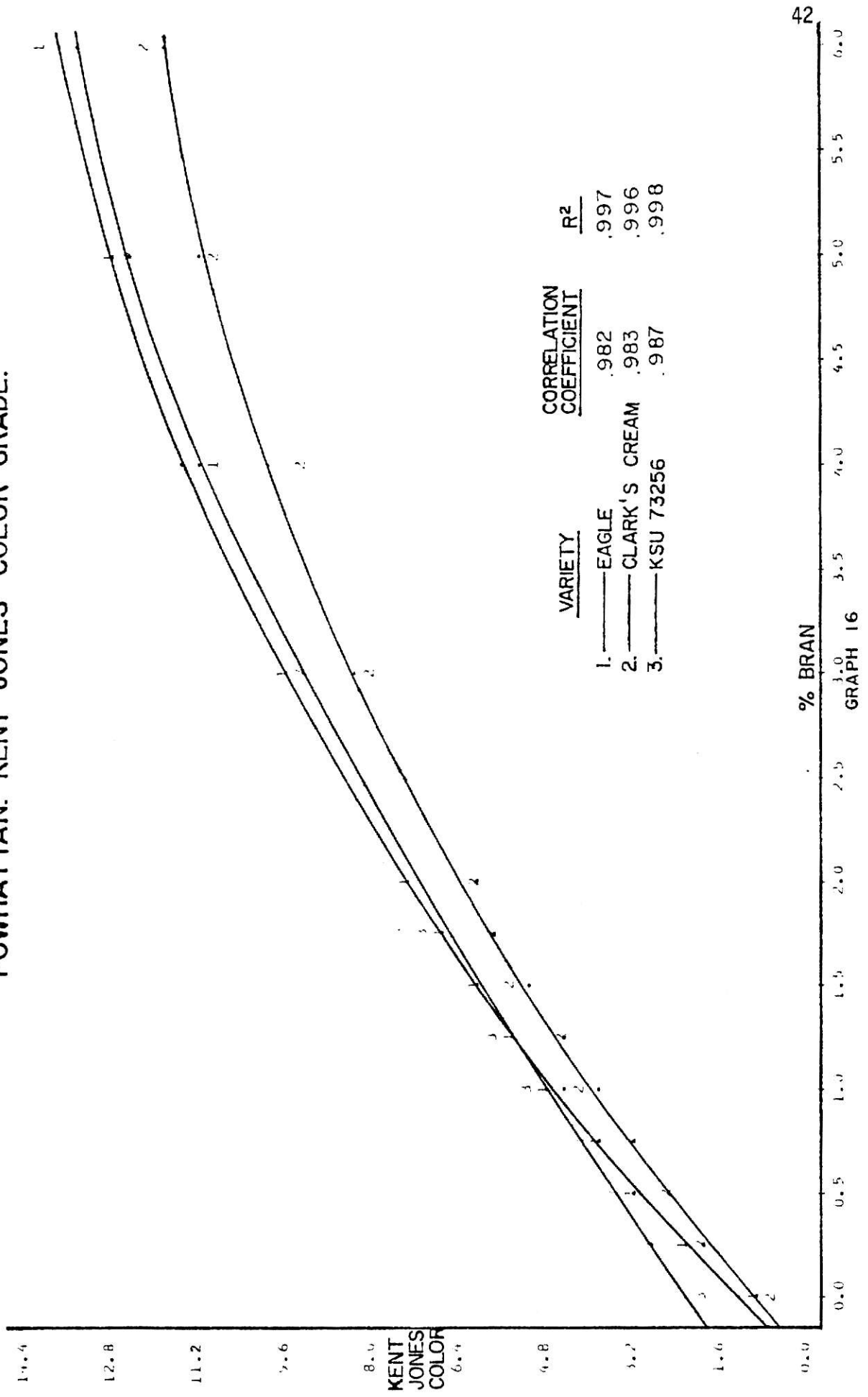
HESSTON. KENT JONES COLOR GRADE.



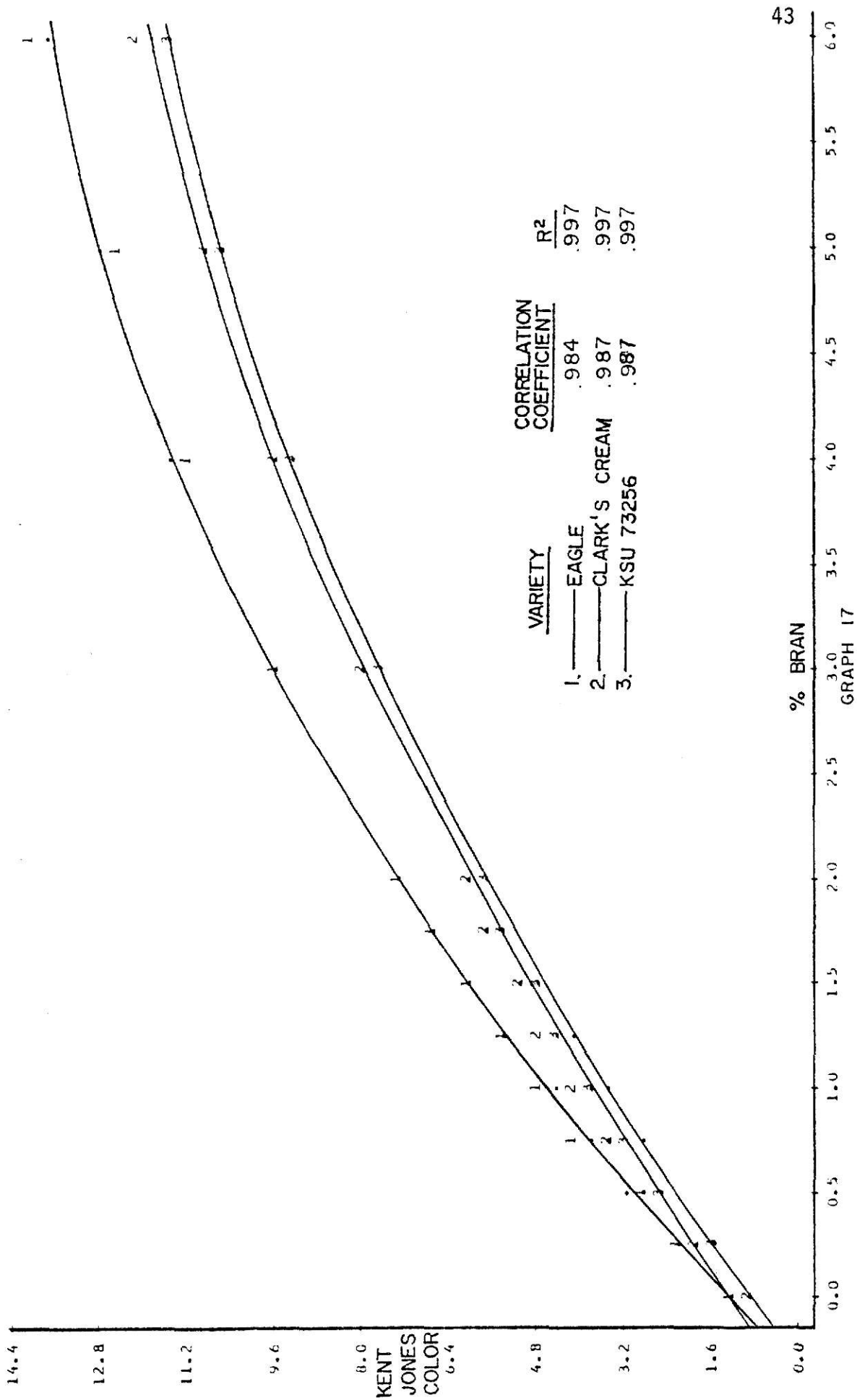
SWK.. KENT JONES COLOR GRADE.



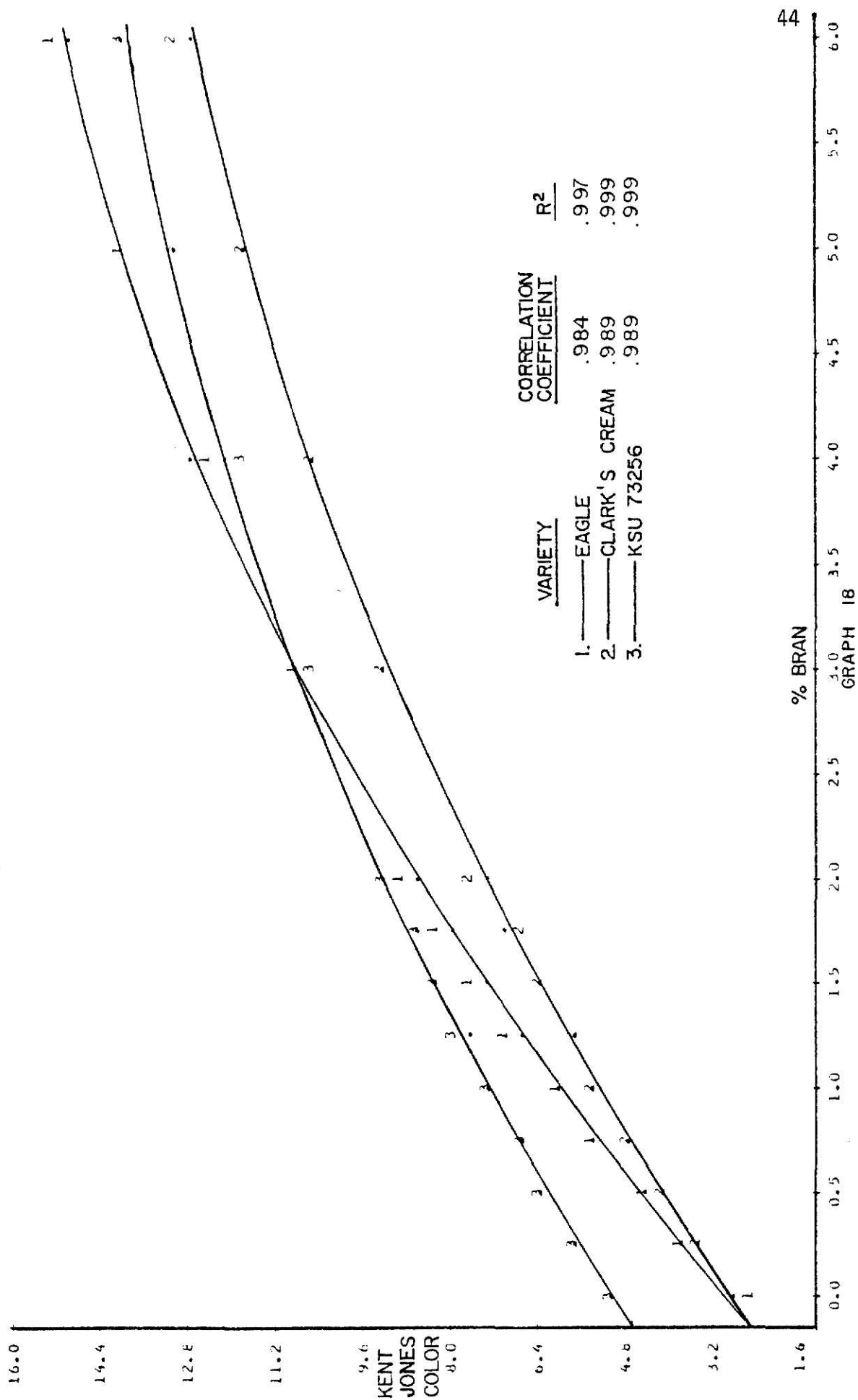
POWHATTAN. KENT JONES COLOR GRADE.



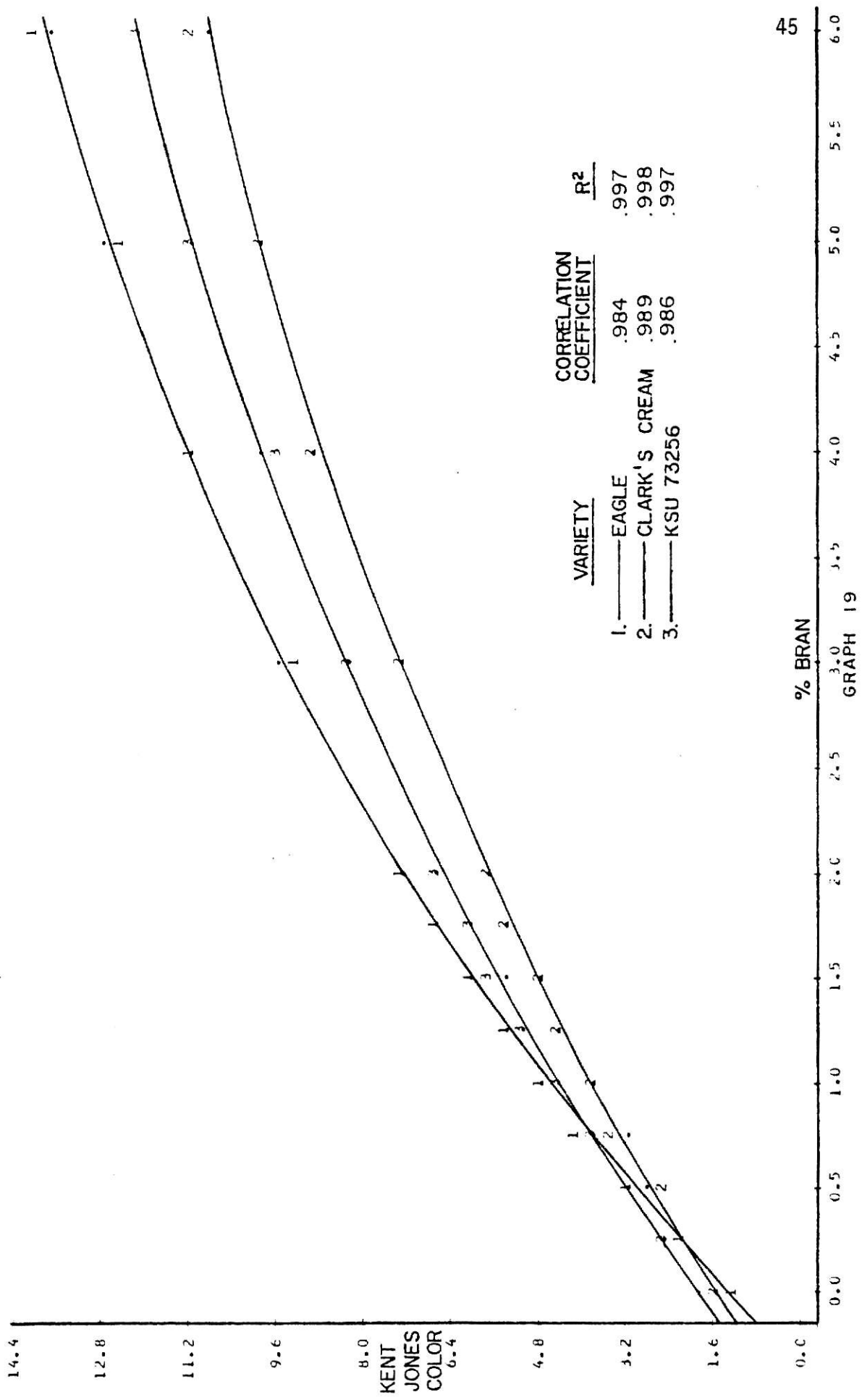
TRIBUNE. KENT JONES COLOR GRADE.



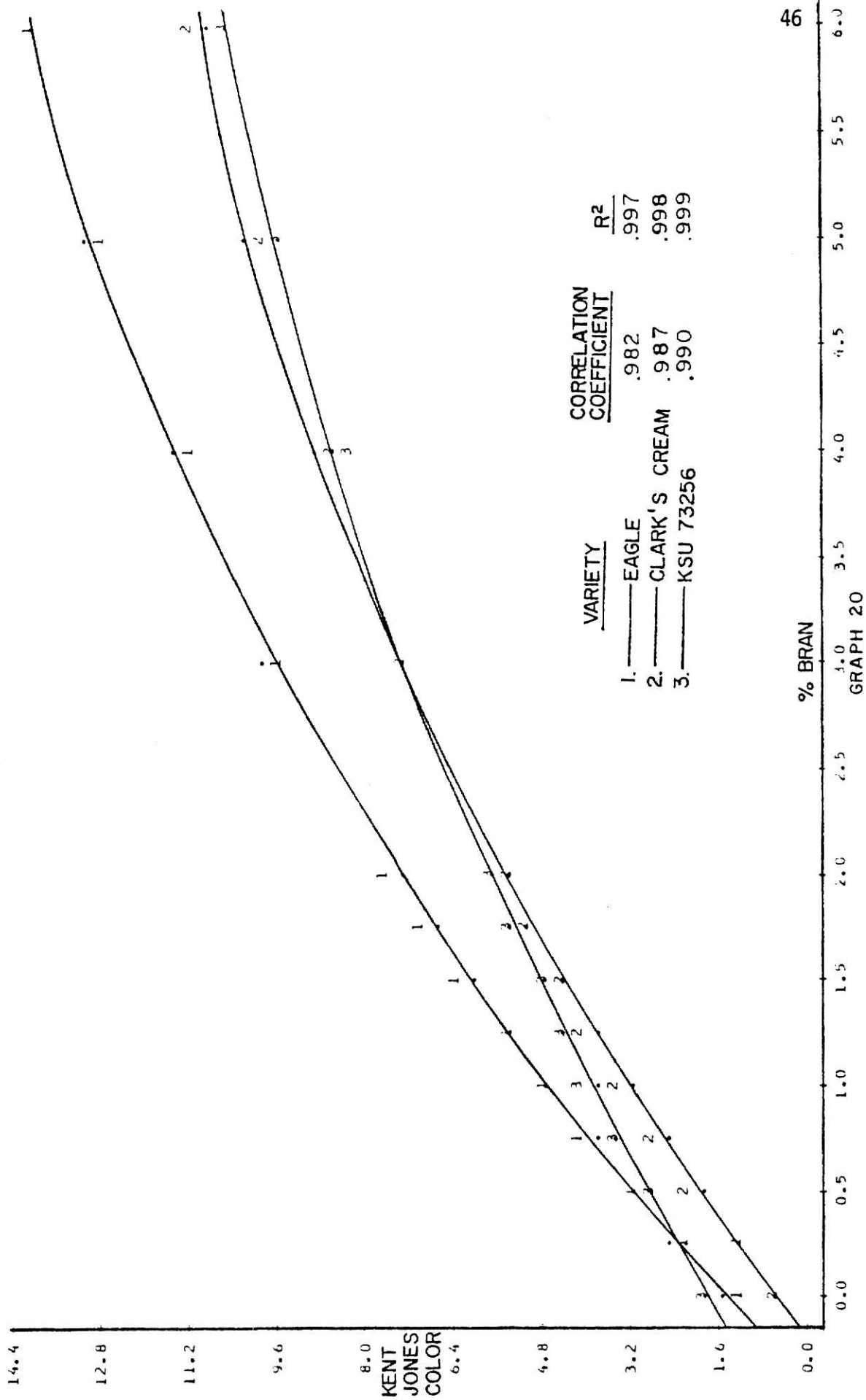
BELLEVILLE. KENT JONES COLOR GRADE.



MANHATTAN. KENT JONES COLOR GRADE.

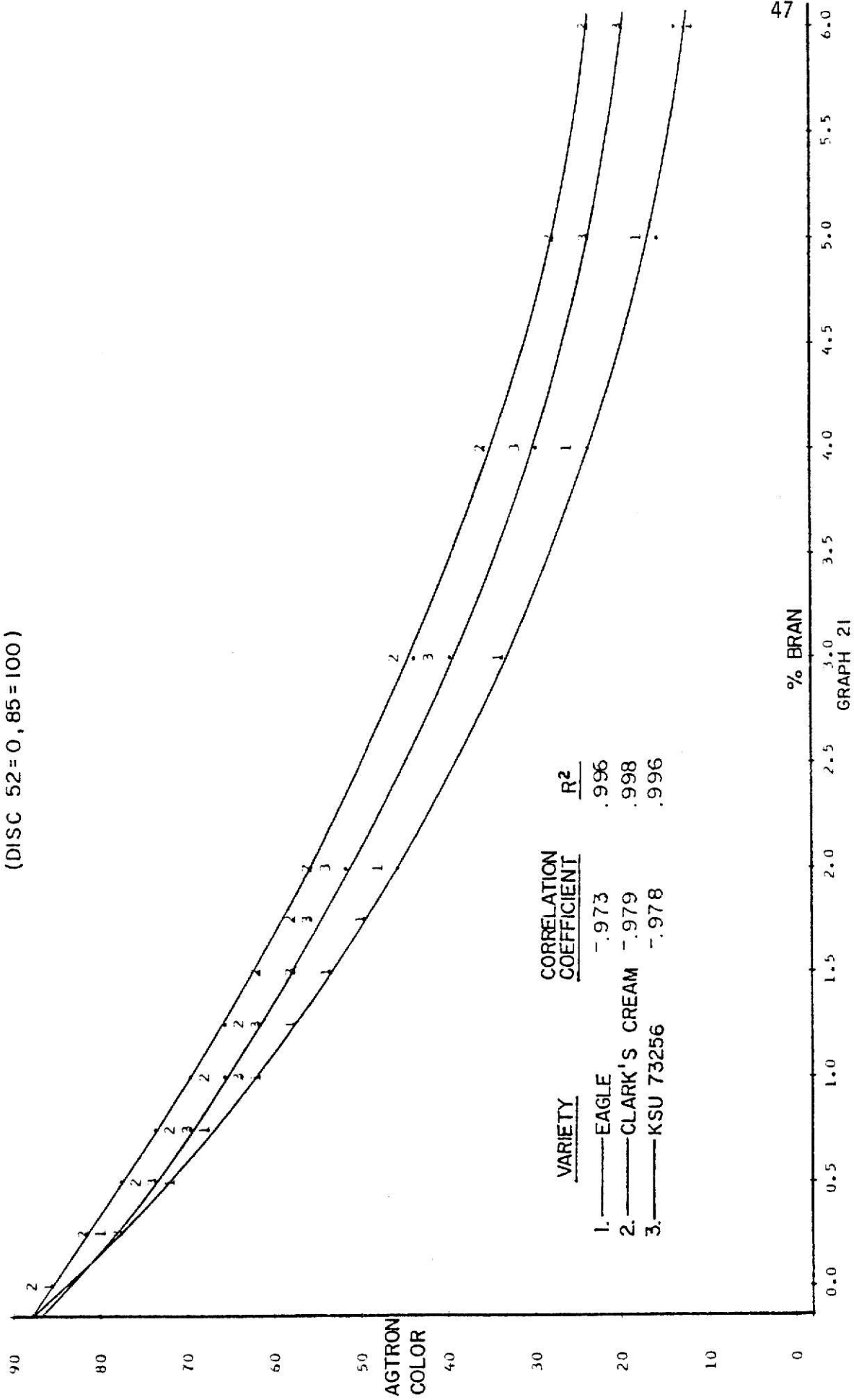


COLBY. KENT JONES COLOR GRADE.



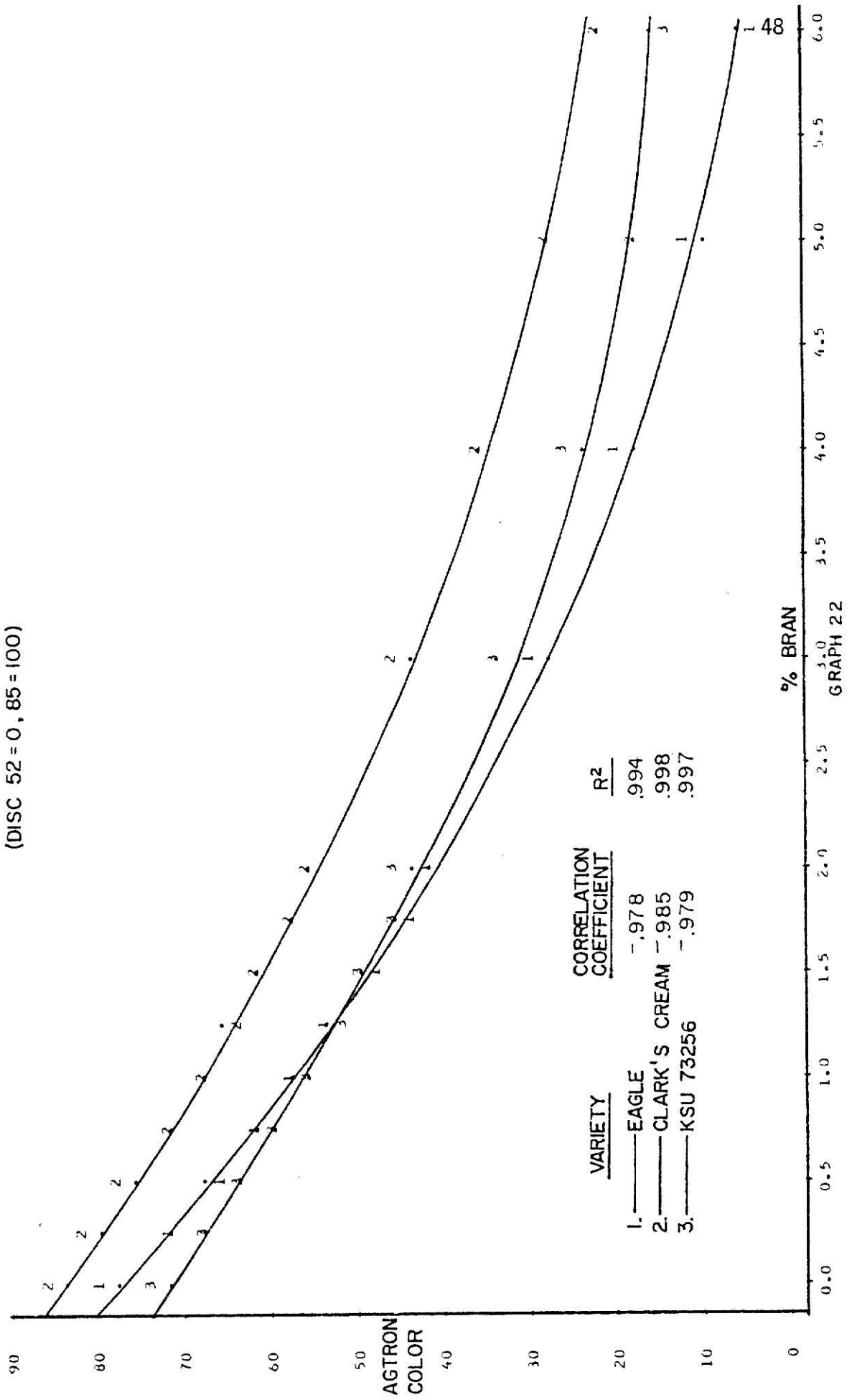
HUTCHINSON. AGTRON COLOR GRADE.

(DISC 52=0, 85=100)



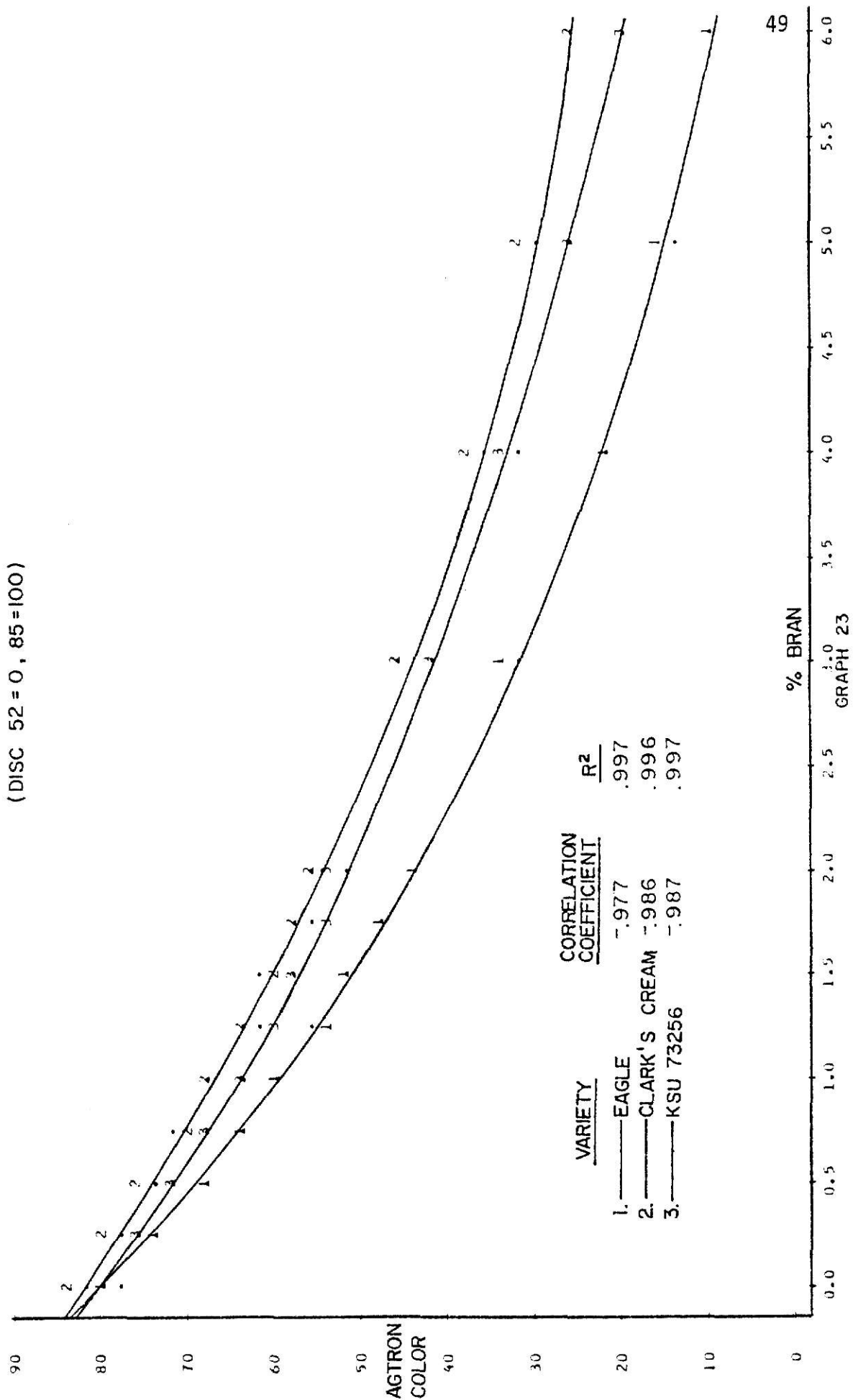
OTTAWA. AGTRON COLOR GRADE.

(DISC 52 = 0, 85 = 100)



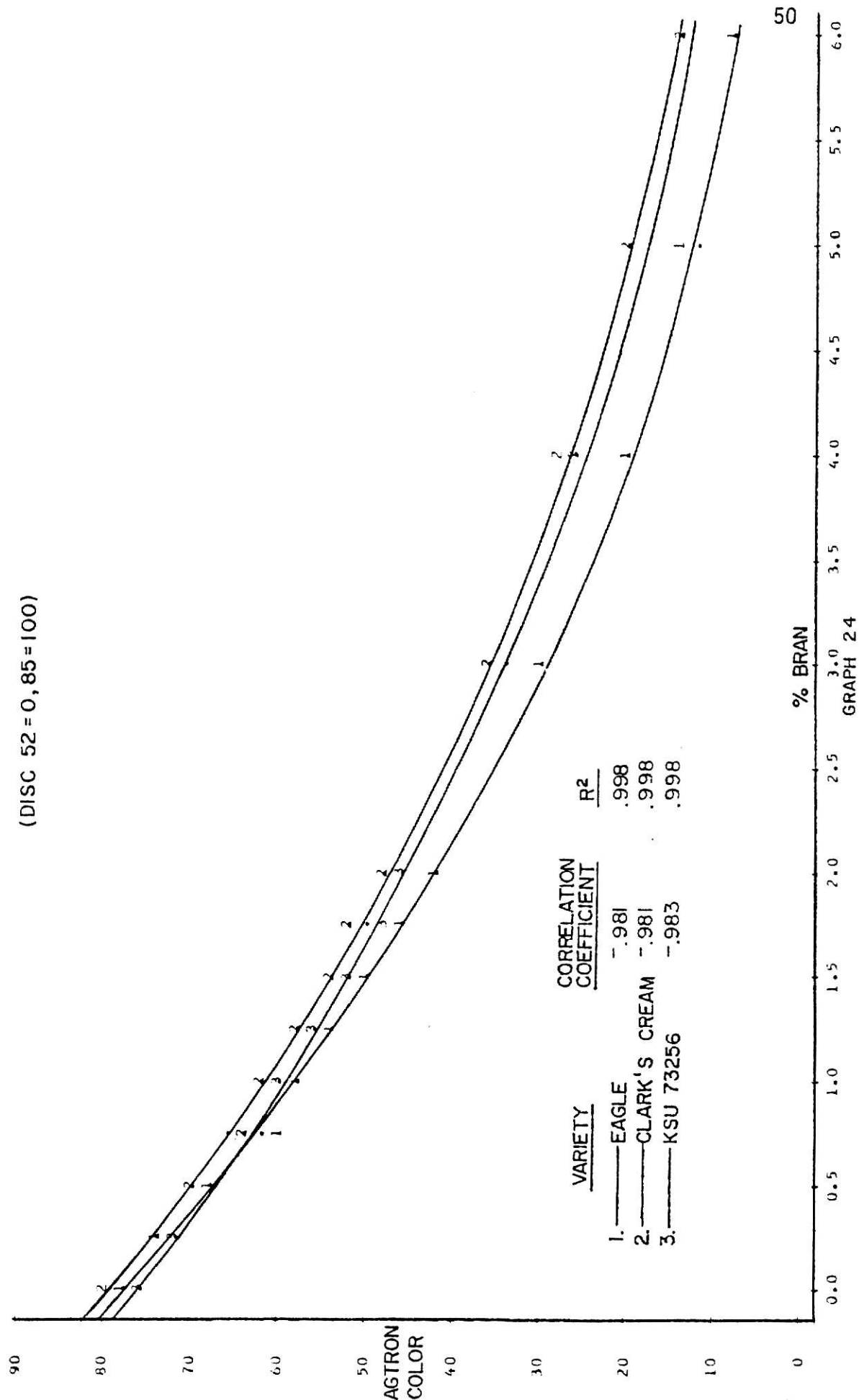
HAYS. AGTRON COLOR GRADE.

(DISC 52 = 0, 85 = 100)



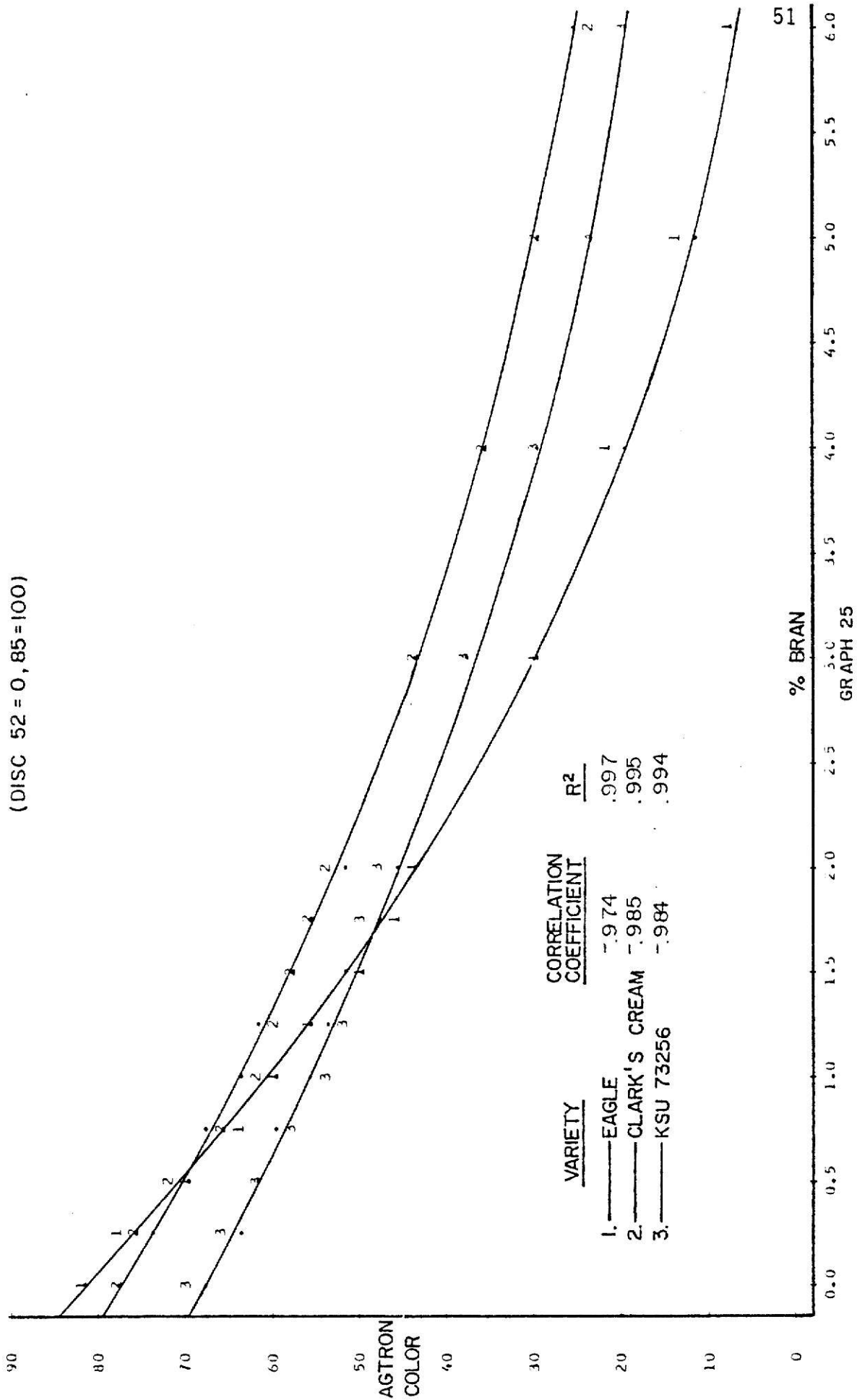
HESSTON. AGTRON COLOR GRADE.

(DISC 52 = 0, 85 = 100)



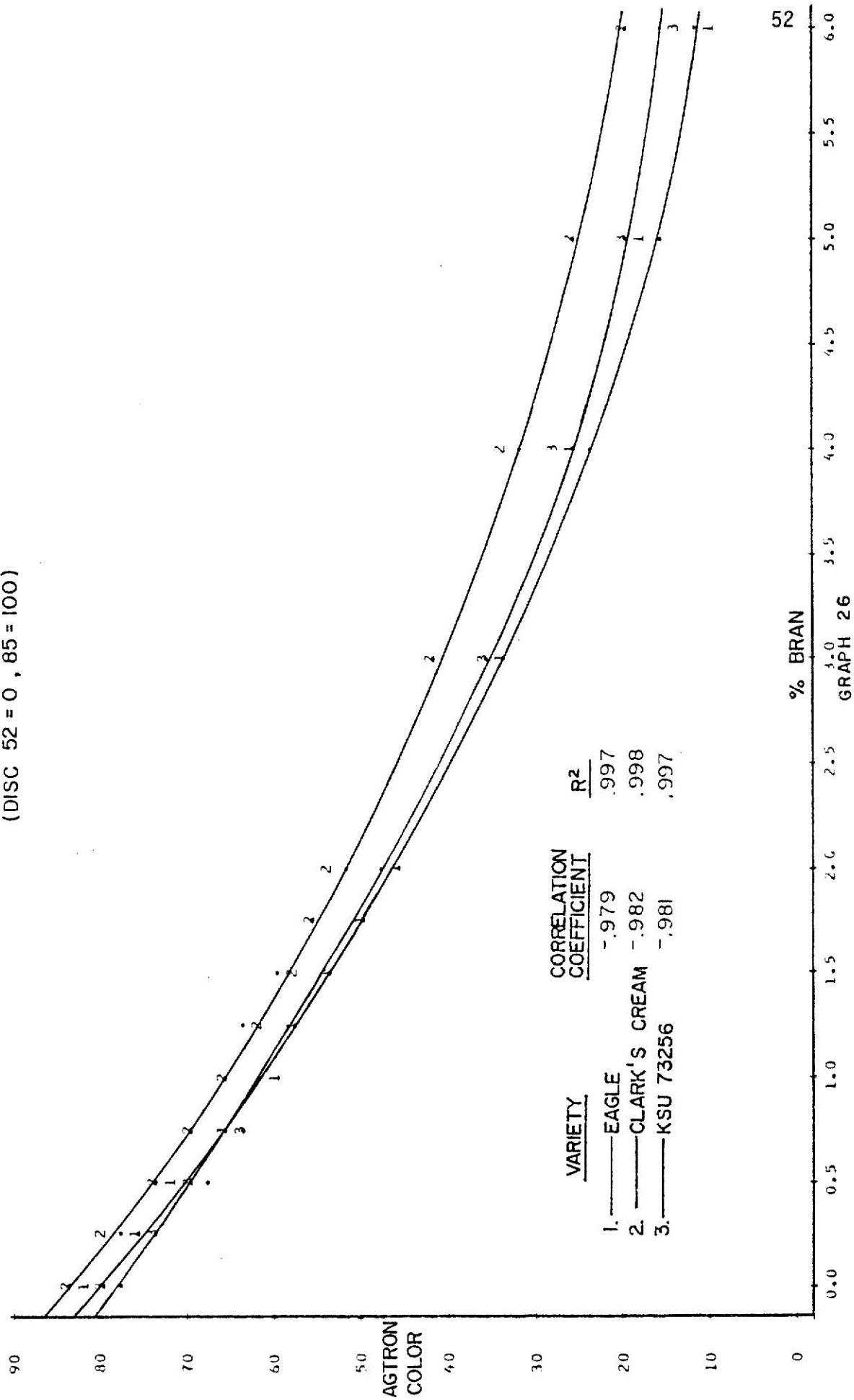
SWK. AGTRON COLOR GRADE.

(DISC 52 = 0, 85 = 100)



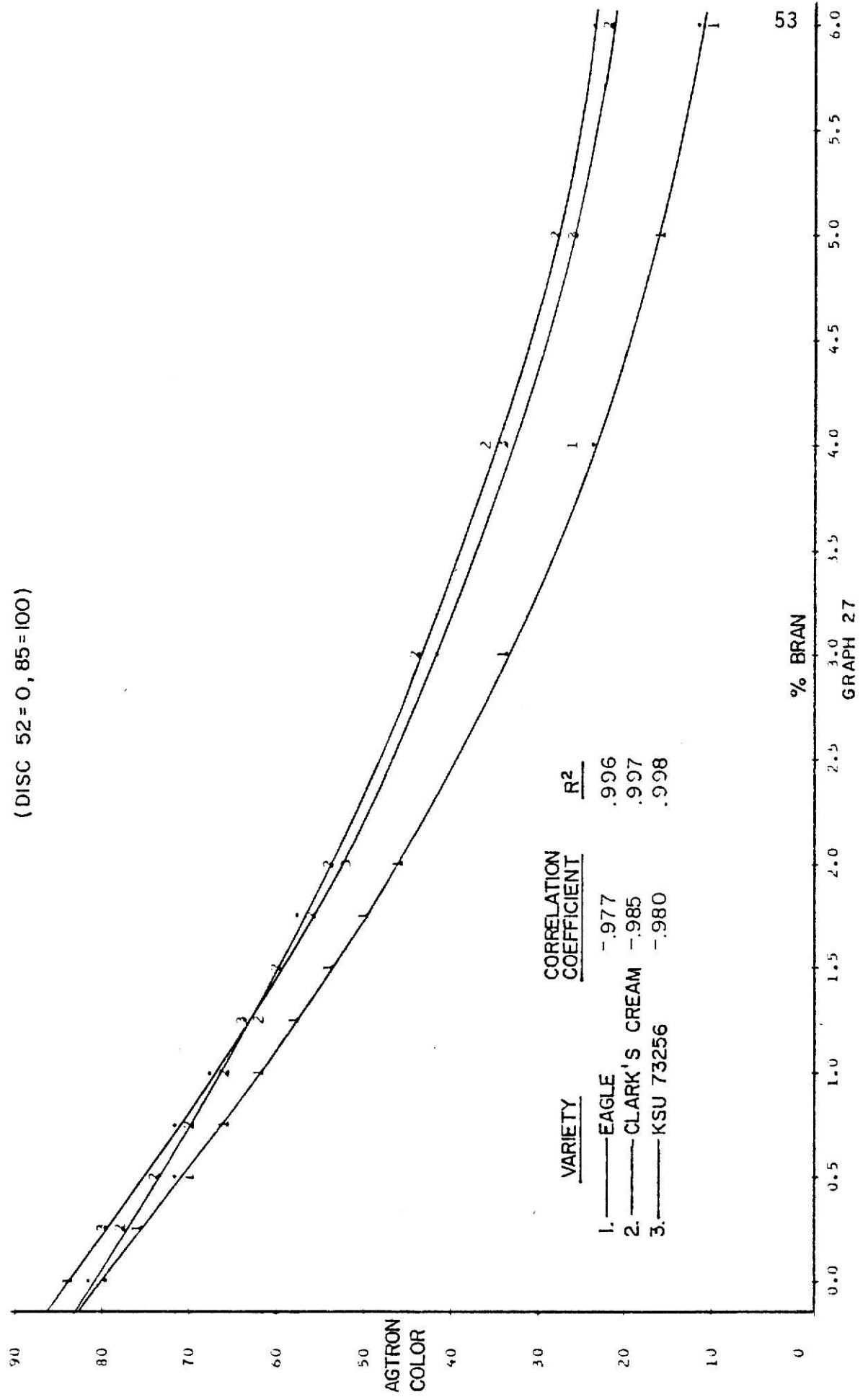
POWHATTAN. AGTRON COLOR GRADE.

(DISC 52 = 0 , 85 = 100)



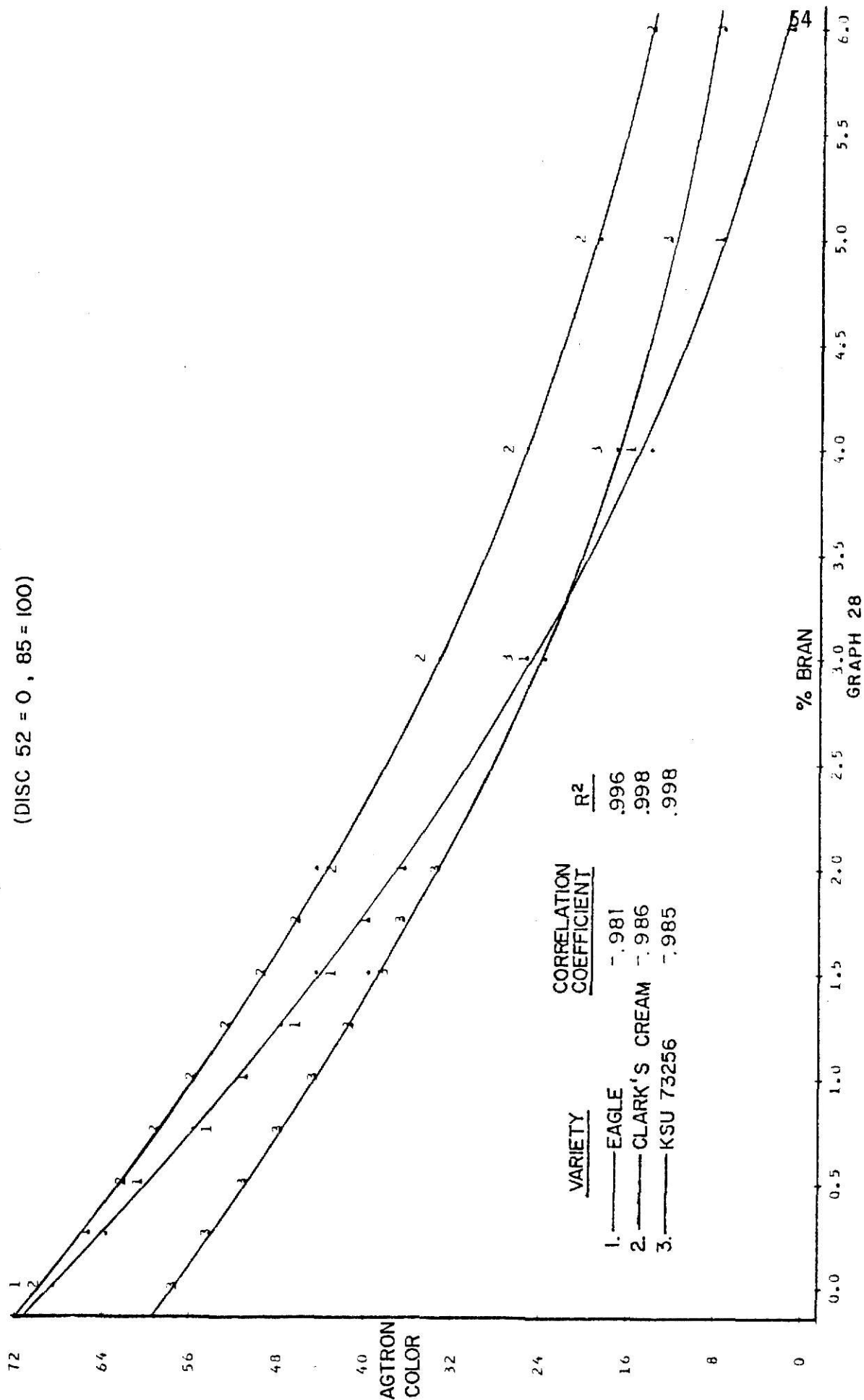
TRIBUNE. AGTRON COLOR GRADE.

(DISC 52 = 0, 85 = 100)



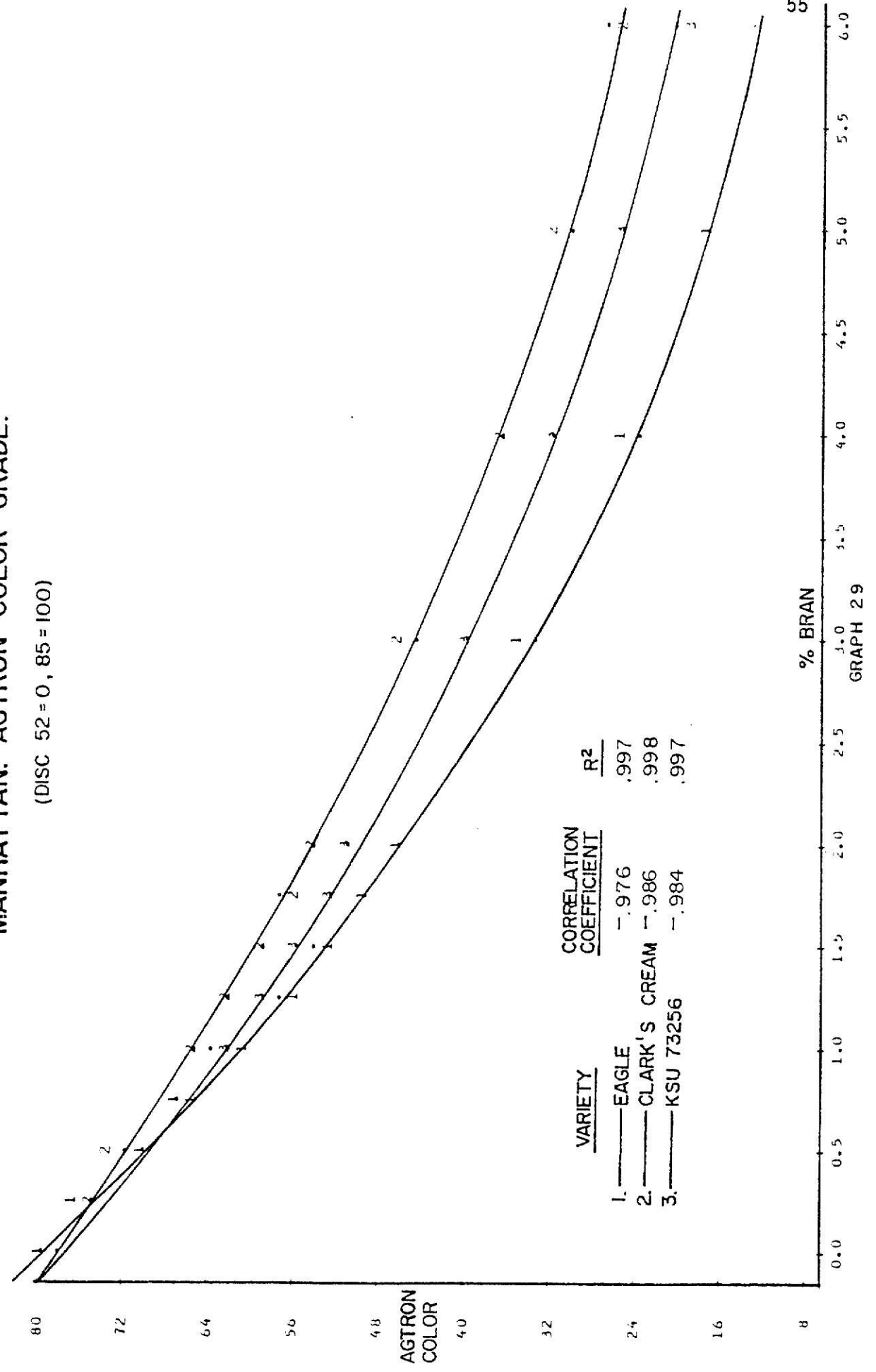
BELLEVILLE. AGTRON COLOR GRADE.

(DISC 52 = 0, 85 = 100)



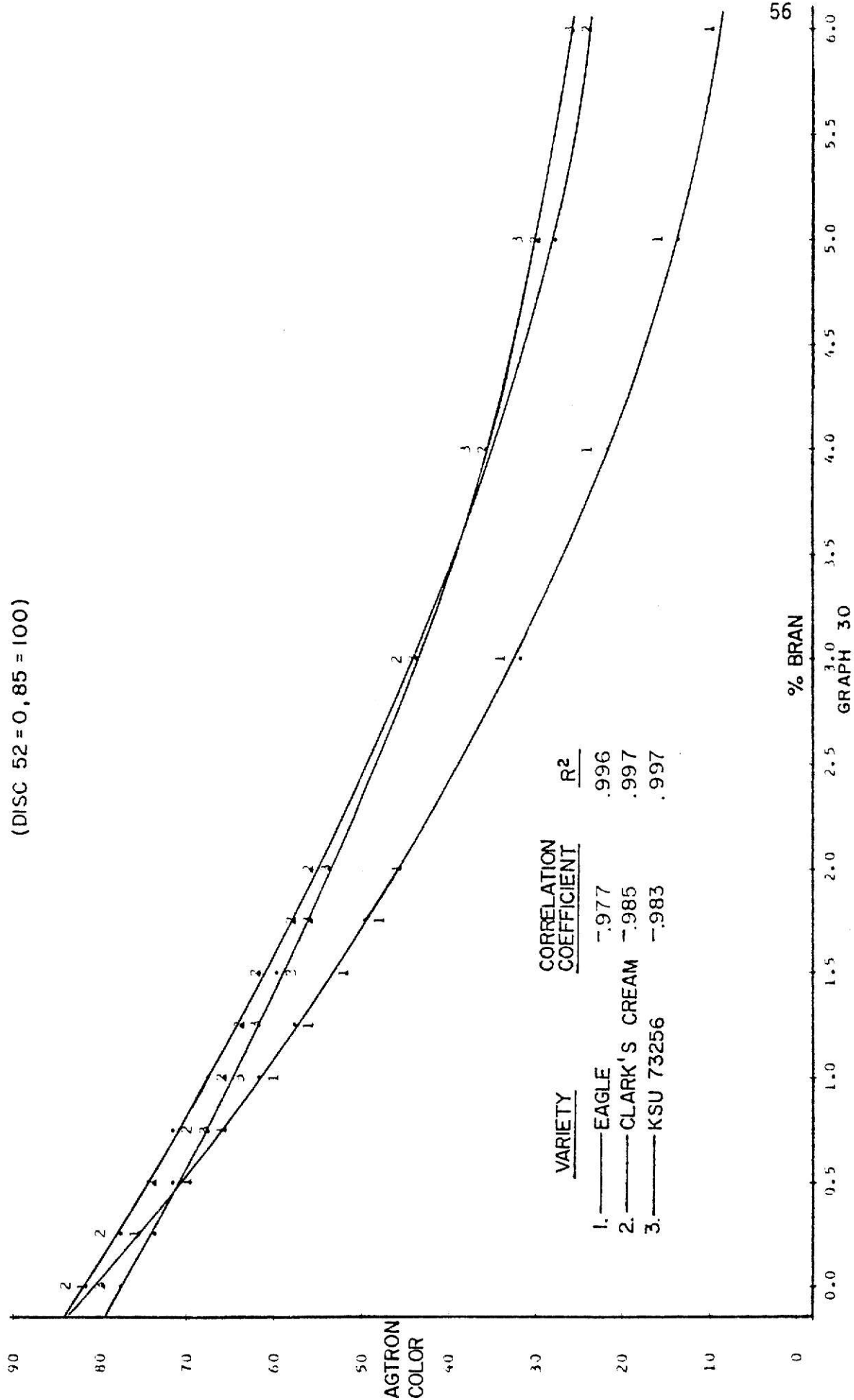
MANHATTAN. AGTRON COLOR GRADE.

(DISC 52 = 0, 85 = 100)



COLBY. AGTRON COLOR GRADE

(DISC 52 = 0, 85 = 100)



difference in discoloring power between the Eagle variety and the Clark's Cream or KSU 73256 experimental varieties in eight of the ten locations. A quantitative example of this difference can be shown by considering the total number of Agtron and Kent-Jones color units contained within the 0 to 6% bran flour addition limits. Table 1 shows the Buhler straight grade color values and the color values of the flour after the addition of 6% bran flour. The total number of color units (Agtron and Kent-Jones) contained within the 0 to 6% bran flour addition limits is much greater for the Eagle variety than for the Clark's Cream or KSU 73256 varieties. The flour color for the Eagle variety always ended up with the worst color grade value after the addition of 6% bran flour. Another means of observing the Eagle variety's greater discoloring power is by checking how the Eagle variety discoloring power curve crosses both the Clark's Cream and KSU 73256 varieties discoloring power curve. Initially, the Eagle variety may have produced a Buhler straight grade flour which had a superior color grade. Upon addition of bran flour, the Eagle's discoloring power curve would cross over the curves for the Clark's Cream and KSU 73256 varieties and continue to worsen in color as more bran flour was added.

Ash values were also obtained for each addition of bran flour. The representation of these results can be found on graphs 31-40. Once again, the dots represent the predicted ash values, while the numerals are the actual ash values obtained. The amount of bran flour added had a linear effect on the ash values of the resultant flour.

Correlations and R^2 values were obtained for both the discoloring power and ash graphs. High correlations were obtained for any of the combinations of percent bran flour added and Agtron color, Kent-Jones color or ash. These values are noted in the legends of each respective

BRAN FLOUR DISCOLORING POWER BY LOCATION

58

TRIBUNE

VARIETY	BUHLER STRAIGHT GRADE FLOUR COLOR		6% BRAN ADDITION FLOUR COLOR		TOTAL COLOR UNITS IN 0-6% BRAN FLOUR ADDITION	
	AGTRON	KJC	AGTRON	KJC	AGTRON	KJC
EAGLE	83.5	1.1	10.7	13.9	72.7	12.8
CLARKS CREAM	83.2	1.10	22.5	12.0	60.7	11.1
KSU 73256	84.7	.9	21.2	11.6	63.5	10.8

HUTCHINSON

VARIETY	BUHLER STRAIGHT GRADE FLOUR COLOR		6% BRAN ADDITION FLOUR COLOR		TOTAL COLOR UNITS IN 0-6% BRAN FLOUR ADDITION	
	AGTRON	KJC	AGTRON	KJC	AGTRON	KJC
EAGLE	85.5	1.0	11.2	14.2	74.2	13.2
CLARKS CREAM	87.0	.9	23.7	12.0	63.2	11.1
KSU 73256	85.5	1.4	19.2	12.6	66.2	11.2

SWK

VARIETY	BUHLER STRAIGHT GRADE FLOUR COLOR		6% BRAN ADDITION FLOUR COLOR		TOTAL COLOR UNITS IN 0-6% BRAN FLOUR ADDITION	
	AGTRON	KJC	AGTRON	KJC	AGTRON	KJC
EAGLE	82.5	1.4	7.5	15.0	75.0	13.6
CLARKS CREAM	78.5	1.9	24.5	11.3	54.0	9.4
KSU 73256	69.5	3.5	20.0	12.2	49.5	8.7

POWHATTAN

VARIETY	BUHLER STRAIGHT GRADE FLOUR COLOR		6% BRAN ADDITION FLOUR COLOR		TOTAL COLOR UNITS IN 0-6% BRAN FLOUR ADDITION	
	AGTRON	KJC	AGTRON	KJC	AGTRON	KJC
EAGLE	82.0	1.0	10.7	13.9	71.2	12.9
CLARKS CREAM	84.0	.7	20.0	12.0	64.0	11.3
KSU 73256	79.0	1.8	13.7	13.6	65.2	11.8

* KJC IS KENT-JONES COLOR

TABLE I

BRAN FLOUR DISCOLORING POWER BY LOCATION

OTTAWA

VARIETY	BUHLER STRAIGHT GRADE FLOUR COLOR		6% BRAN ADDITION FLOUR COLOR		TOTAL COLOR UNITS IN 0-6% BRAN FLOUR ADDITION	
	AGTRON	KJC	AGTRON	KJC	AGTRON	KJC
EAGLE	63.0	2.6	4.2	15.4	58.7	12.8
CLARK'S CREAM	74.25	1.10	22.5	12.2	51.7	11.1
KSU 73256	60.0	3.1	14.7	13.8	45.2	10.7

HAYS

VARIETY	BUHLER STRAIGHT GRADE FLOUR COLOR		6% BRAN ADDITION FLOUR COLOR		TOTAL COLOR UNITS IN 0-6% BRAN FLOUR ADDITION	
	AGTRON	KJC	AGTRON	KJC	AGTRON	KJC
EAGLE	80.0	1.9	9.5	14.3	70.5	12.3
CLARK'S CREAM	83.0	1.6	25.2	11.0	57.7	9.4
KSU 73256	80.5	1.9	19.7	11.7	60.7	9.8

HESSTON

VARIETY	BUHLER STRAIGHT GRADE FLOUR COLOR		6% BRAN ADDITION FLOUR COLOR		TOTAL COLOR UNITS IN 0-6% BRAN FLOUR ADDITION	
	AGTRON	KJC	AGTRON	KJC	AGTRON	KJC
EAGLE	77.0	2.2	7.0	14.9	70.0	12.7
CLARK'S CREAM	80.0	1.9	14.0	13.7	66.0	11.8
KSU 73256	76.0	2.5	13.5	13.7	62.5	11.2

BELLEVILLE

VARIETY	BUHLER STRAIGHT GRADE FLOUR COLOR		6% BRAN ADDITION FLOUR COLOR		TOTAL COLOR UNITS IN 0-6% BRAN FLOUR ADDITION	
	AGTRON	KJC	AGTRON	KJC	AGTRON	KJC
EAGLE	71.5	2.6	1.0	15.3	70.5	12.7
CLARK'S CREAM	70.2	2.9	13.7	13.0	56.5	10.0
KSU 73256	58.2	5.0	8.0	14.1	50.2	9.1

* KJC IS KENT-JONES COLOR

TABLE I

BRAN FLOUR DISCOLORING POWER BY LOCATION

60

MANHATTAN

VARIETY	BUHLER STRAIGHT GRADE FLOUR COLOR		6% BRAN ADDITION FLOUR COLOR		TOTAL COLOR UNITS IN 0-6% BRAN FLOUR ADDITION	
	ASTRON	KJC	ASTRON	KJC	ASTRON	KJC
EAGLE	83.0	1.2	12.2	14.0	70.7	12.8
CLARK'S CREAM	80.0	1.5	26.0	11.1	54.0	9.6
KSU 73256	79.5	1.6	19.5	12.1	60.0	10.5

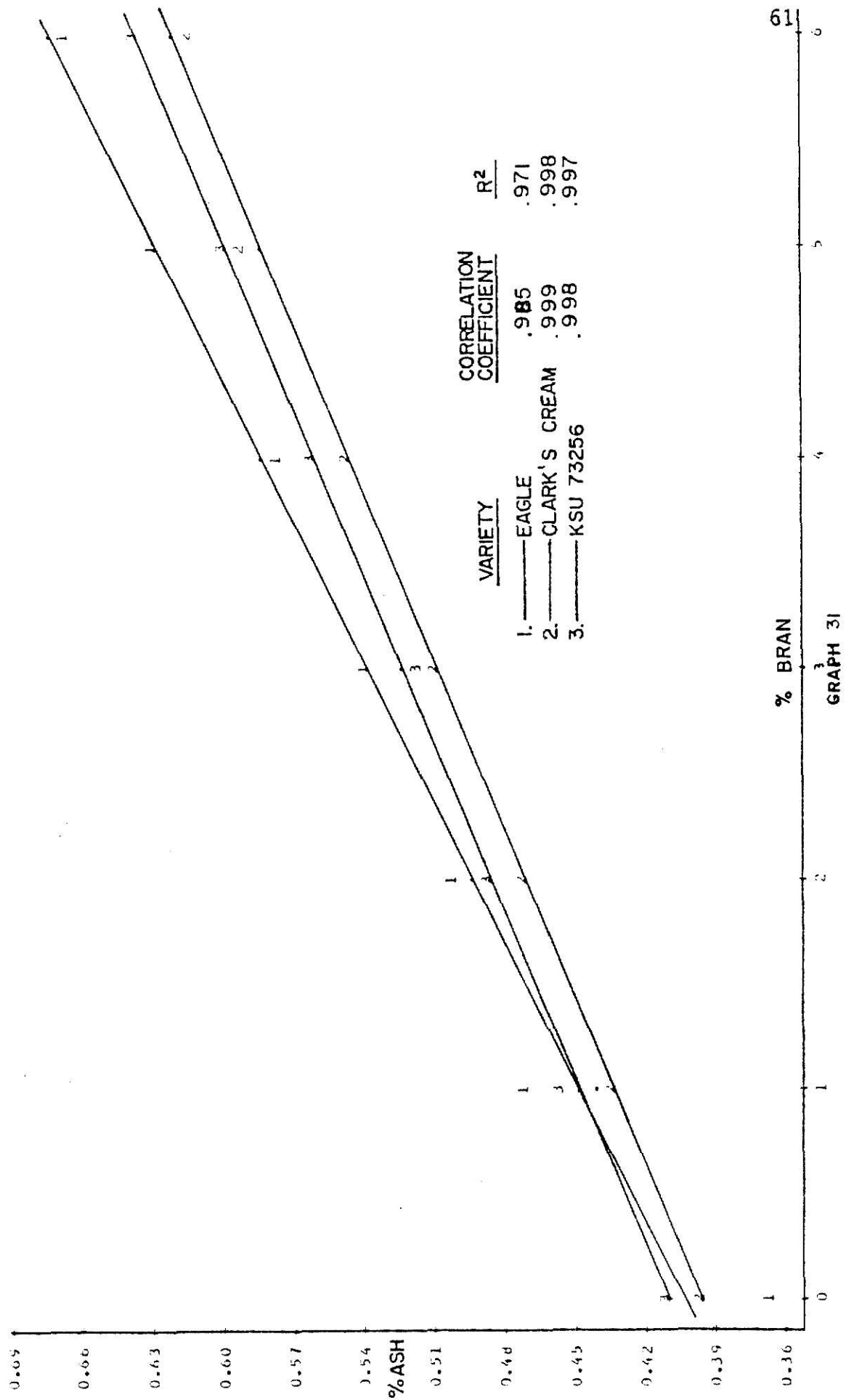
COLBY

VARIETY	BUHLER STRAIGHT GRADE FLOUR COLOR		6% BRAN ADDITION FLOUR COLOR		TOTAL COLOR UNITS IN 0-6% BRAN FLOUR ADDITION	
	ASTRON	KJC	ASTRON	KJC	ASTRON	KJC
EAGLE	82.5	1.1	9.5	14.2	73.0	13.1
CLARK'S CREAM	83.7	.5	23.2	11.1	60.5	10.5
KSU 73256	79.7	1.8	26.0	10.6	53.7	8.8

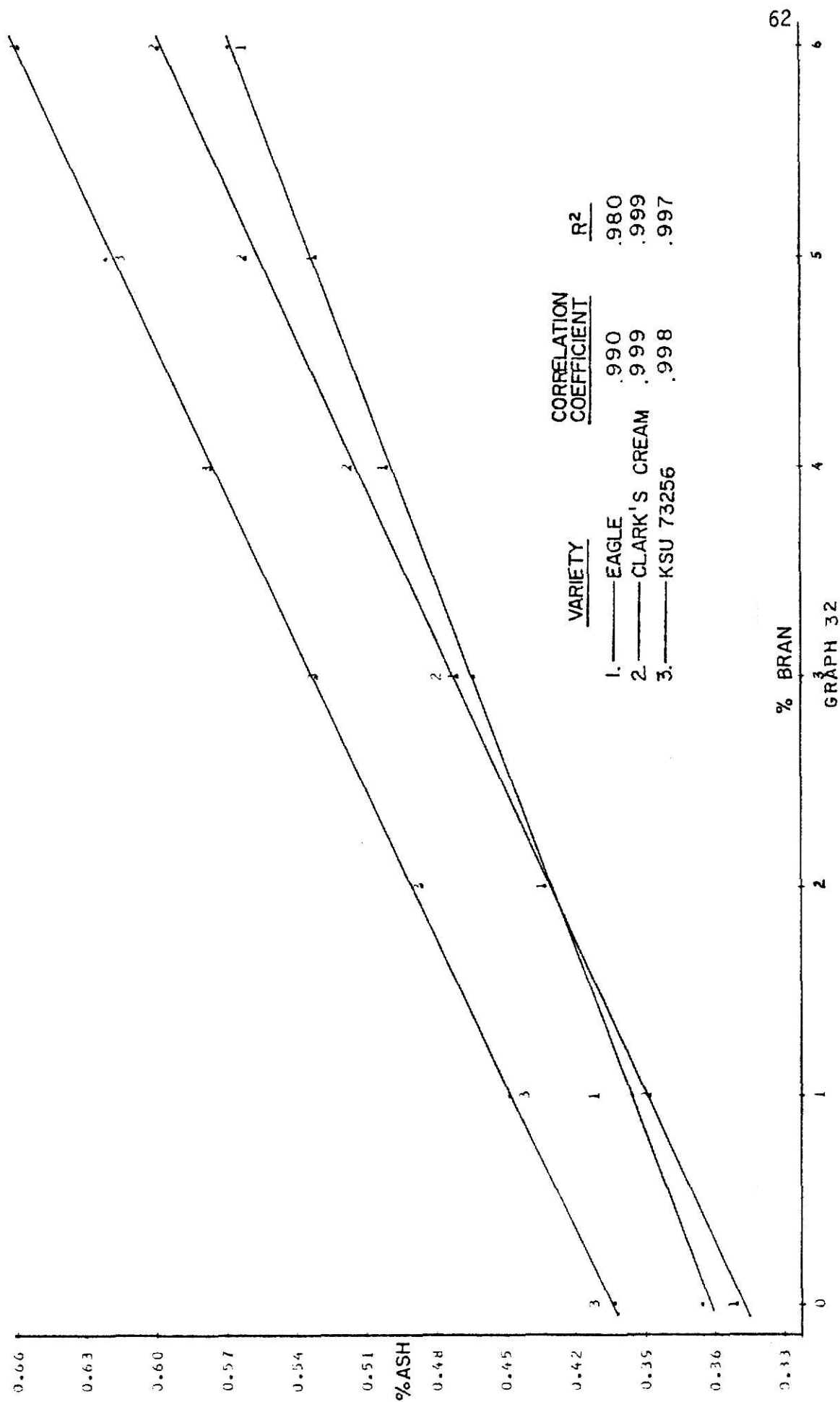
*KJC IS KENT-JONES COLOR

TABLE I

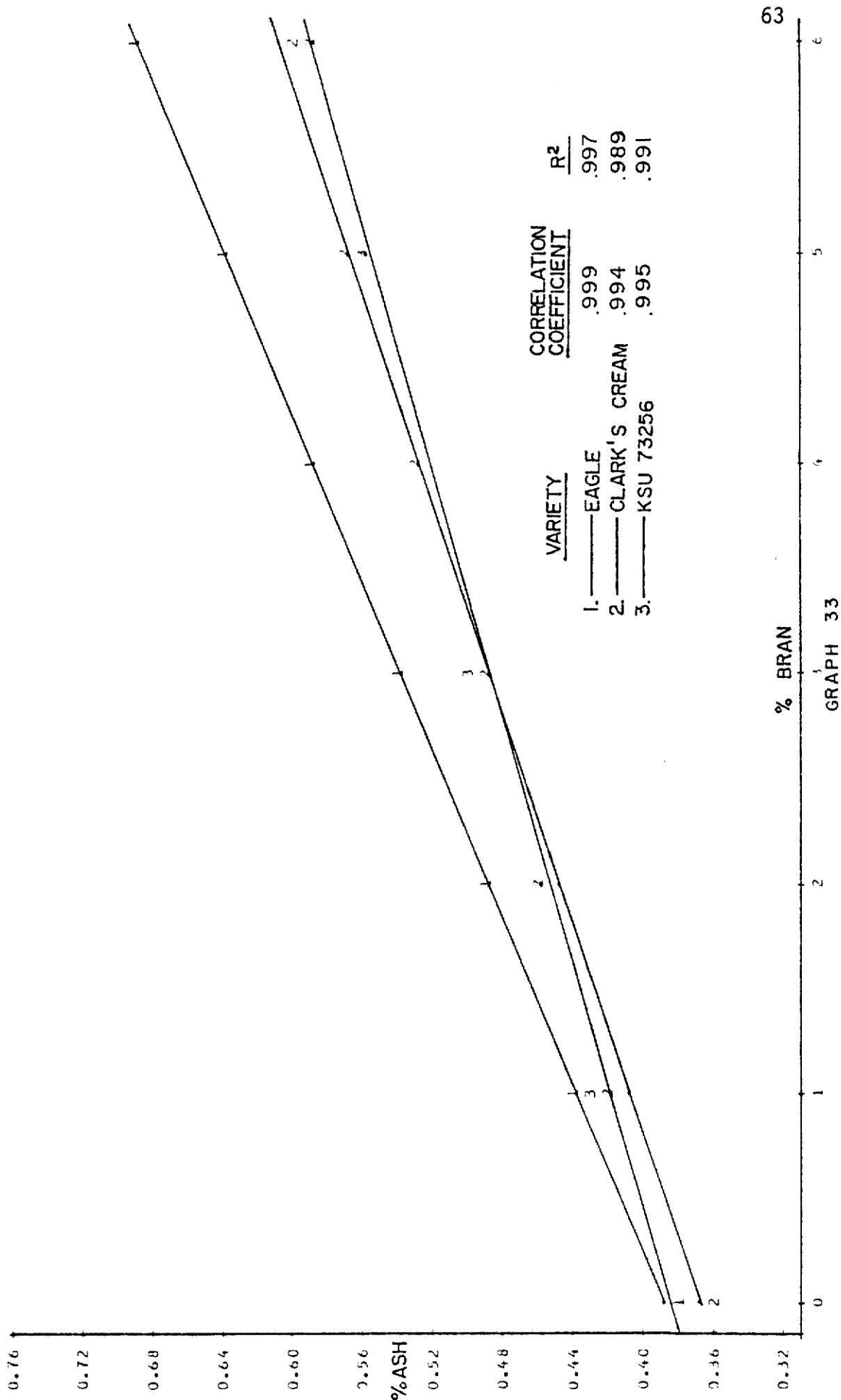
HUTCHINSON. ASH VALUES



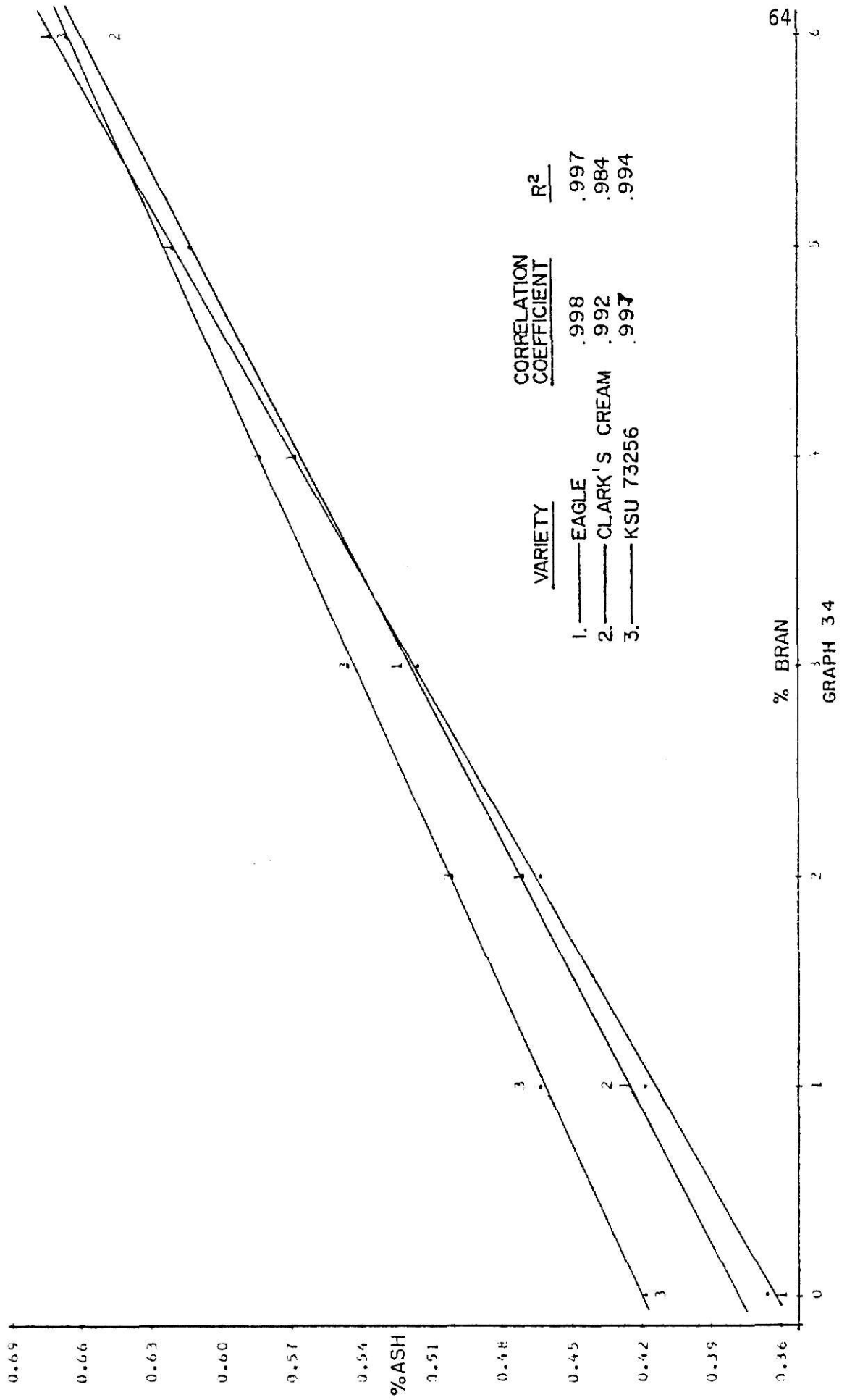
OTTOWA. ASH VALUES



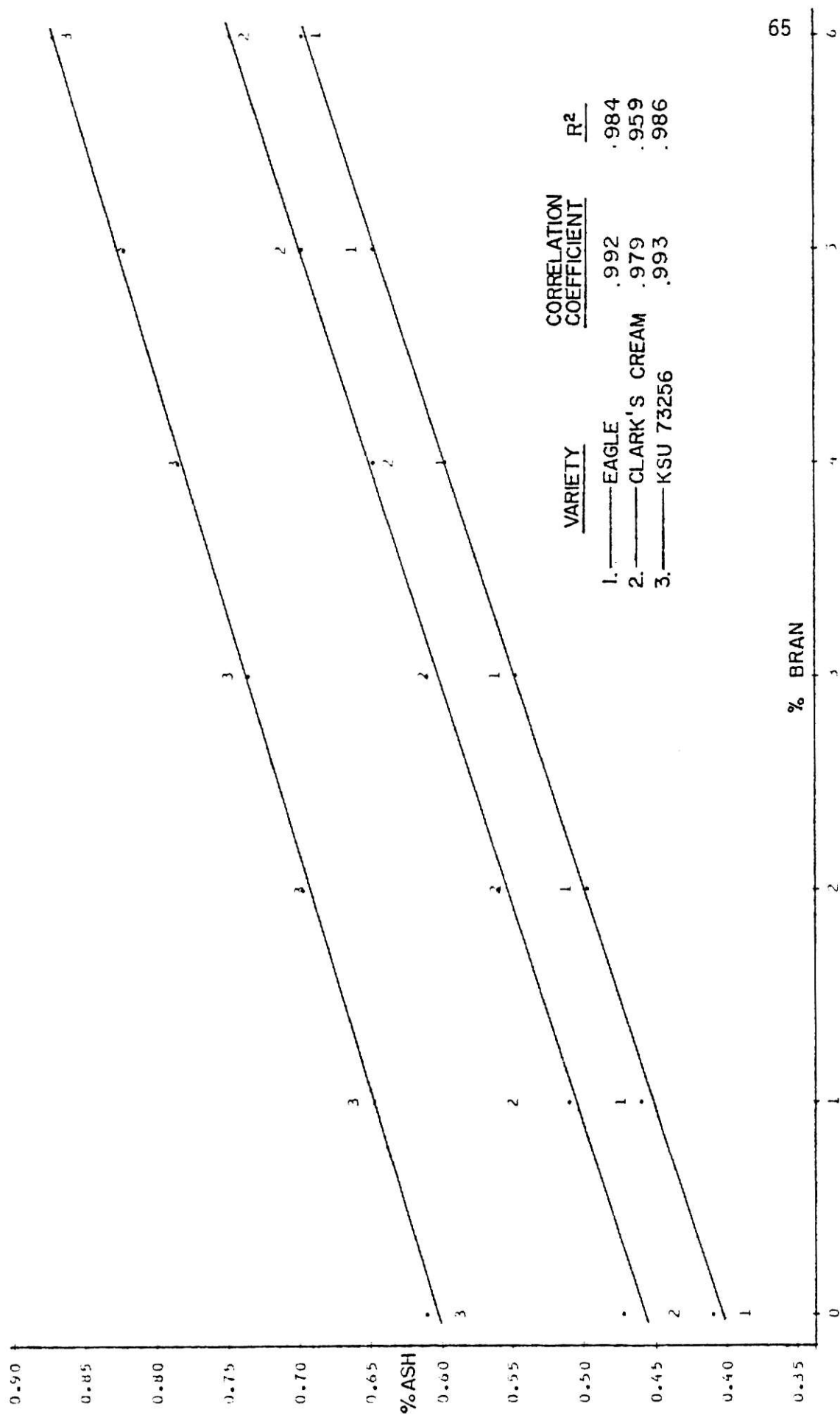
HAYS. ASH VALUES



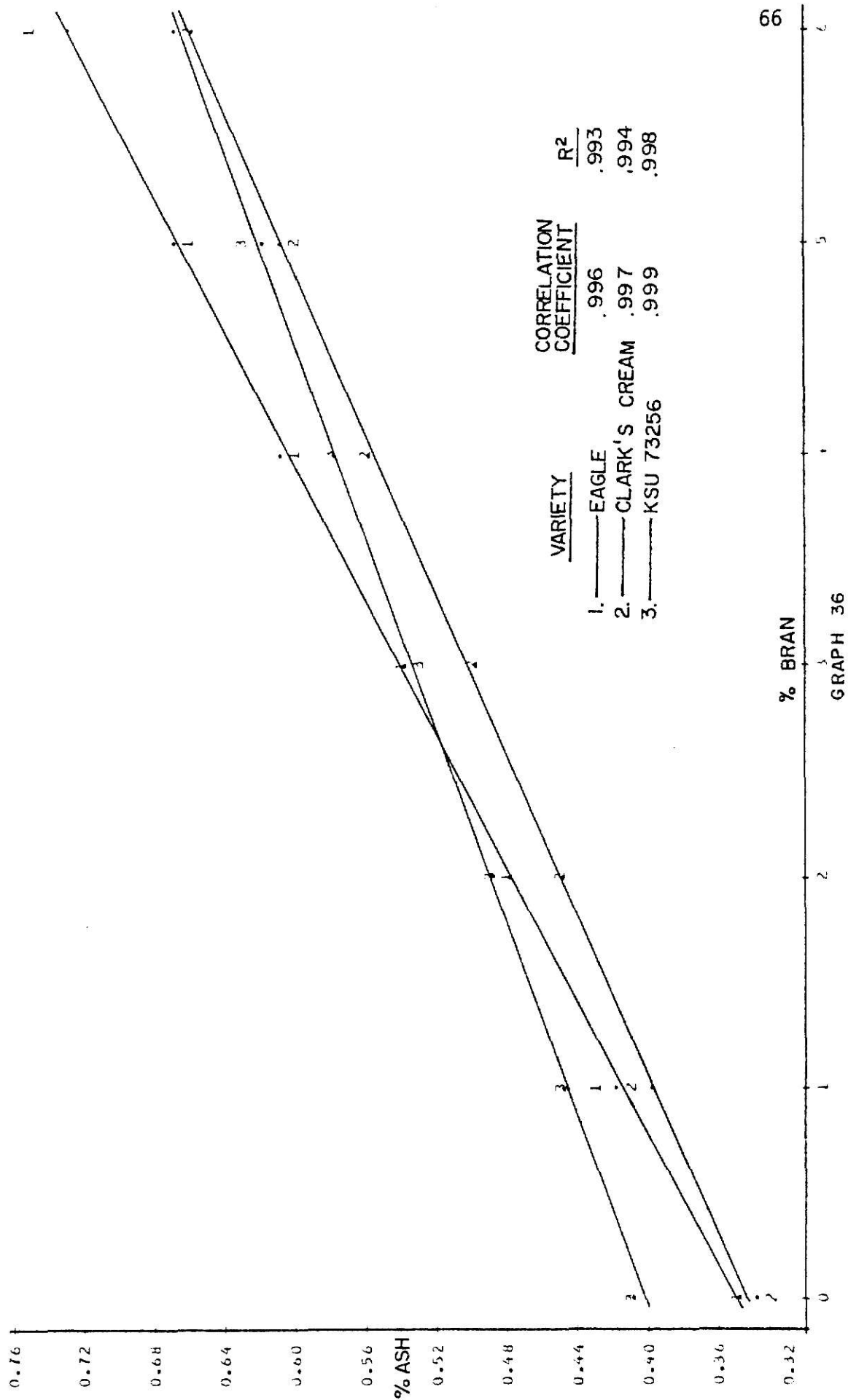
HESSTON. ASH VALUES



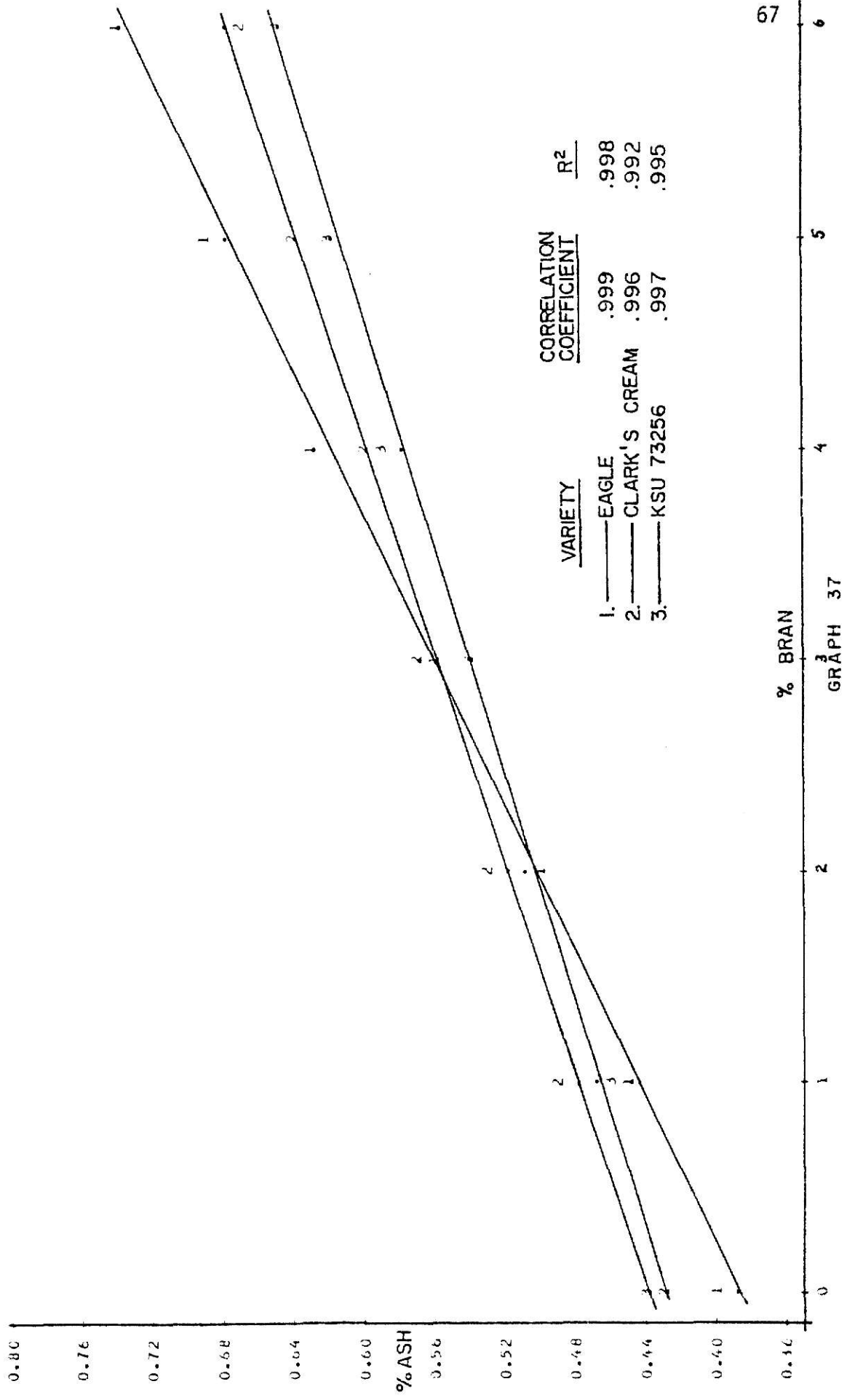
SWK ASH VALUES



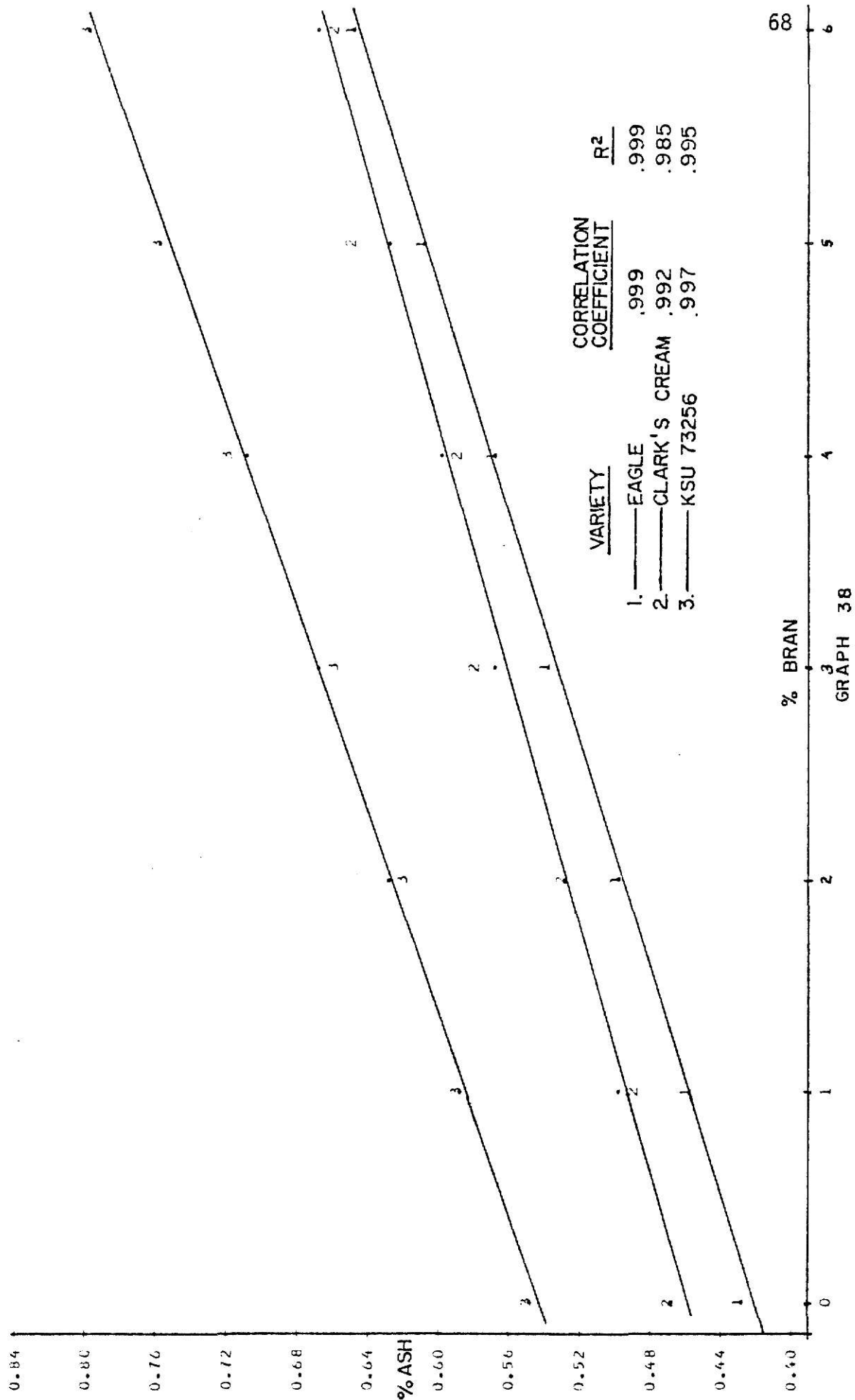
POWHATTAN ASH VALUES



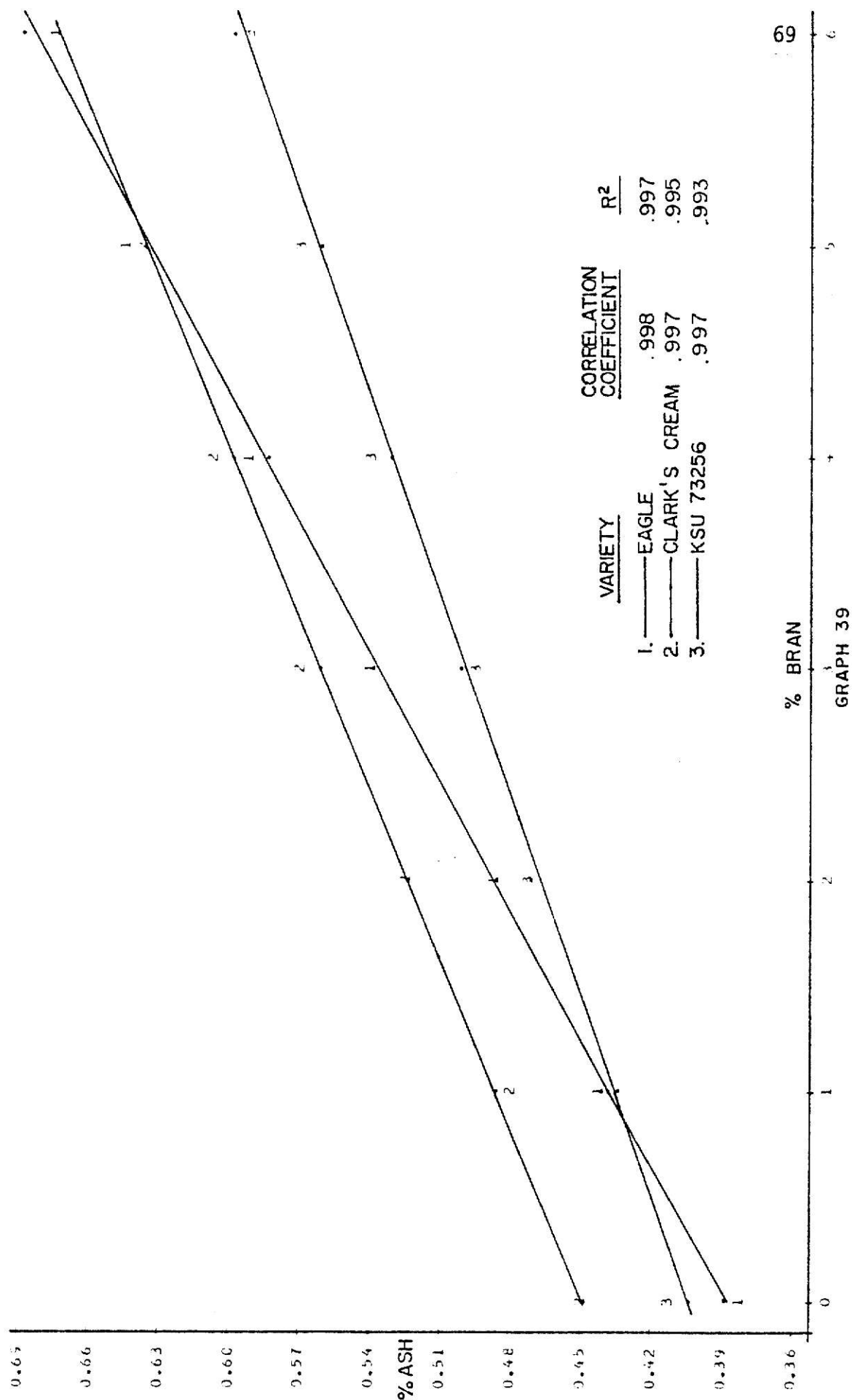
TRIBUNE ASH VALUES



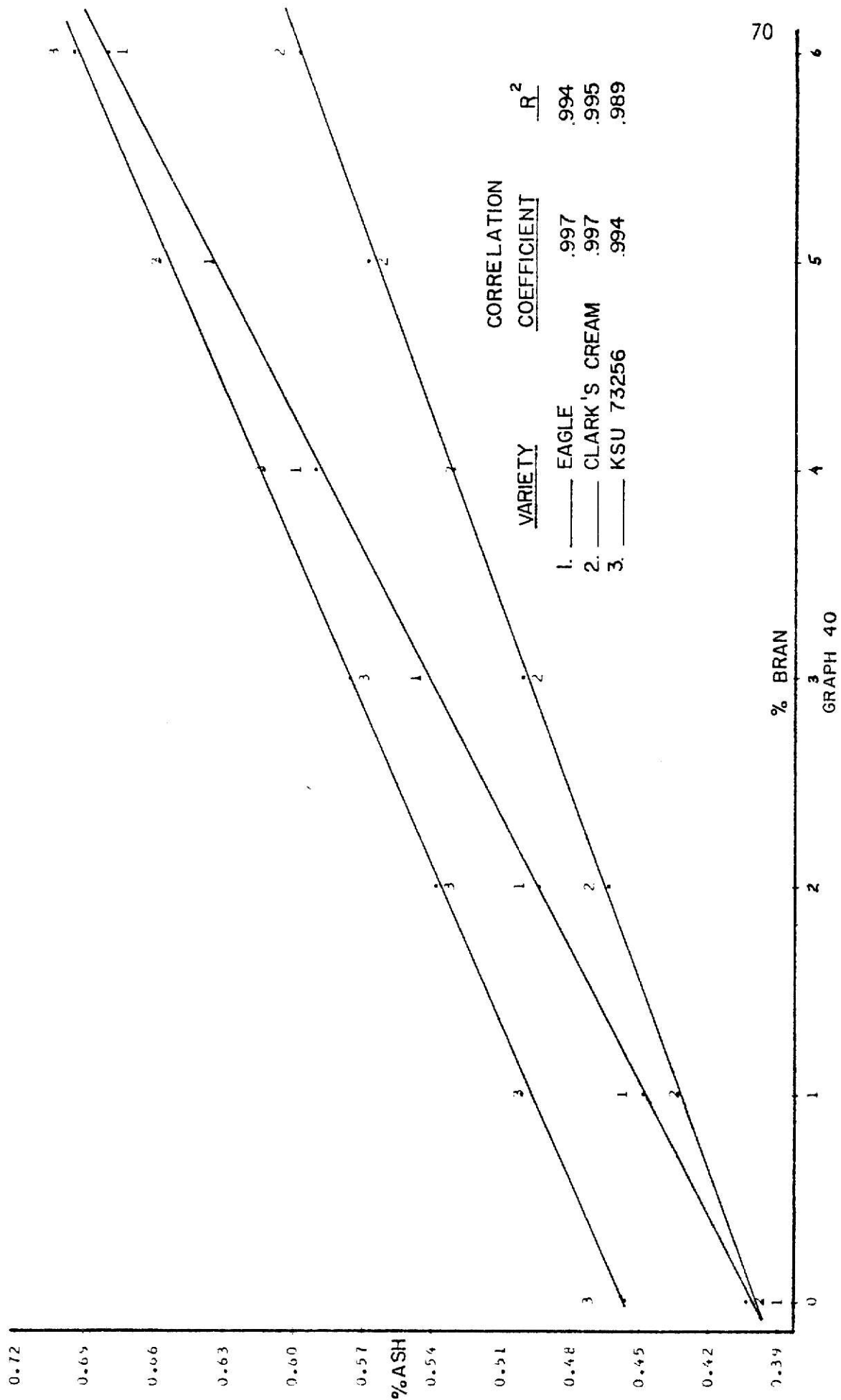
BELLEVILLE ASH VALUES



MANHATTAN ASH VALUES



COLBY ASH VALUES



graph. The high R^2 values obtained indicate that the models used to predict flour color (color=percent bran flour + percent bran flour²) and flour ash (ash=percent bran flour) were quite good. A linear type model (color=percent bran flour) was initially used to predict color grade values but the plots were obviously quadratic. The R^2 values also improved when using the quadratic equation. Ash versus Agtron and Kent-Jones color grades were also plotted. Linear relationships, with high correlations and R^2 values were obtained for all ten locations. This finding agrees with several researchers who attempted to use flour color as a quality control device (Fujh and Ukita, 1956; Gillis, 1963; Kent-Jones et al, 1950).

The bran flour discoloring experiments clearly indicated that there are significant differences in the discoloring power of genetic wheat varieties. The Eagle variety clearly had the greatest discoloring effect of the three wheats tested. If the Clark's Cream and KSU 73256 varieties had a significantly lower discoloring power, it seems that they should be capable of producing more flour at a better color grade. This possibility was investigated using several different experimental milling systems.

Buhler Experimental Milling

The Buhler Experimental Mill was the initial milling system used to investigate the three genetic wheat varieties for milling quality. The mill was set to produce a 70% extraction flour for each variety at each location. The 70% extraction level was easily obtained for the Clark's Cream variety at nine of the ten locations (Manhattan 68.4%). The Eagle variety had little difficulty in meeting the 70% extraction level and only failed in two of the ten locations (Tribune 68.1%, Manhattan 68.6%). The KSU 73256 experimental variety had some difficulty in obtaining the 70% extraction level and failed in five of ten locations (Hays 68.6%, SWK 67.6%, Tribune 68.4%, Belleville 67.1%, Colby 68.7%).

Flour quality for the Buhler milling experiments was determined by flour color, flour ash and extraction level. The Clark's Cream variety showed promise because it not only excelled in extraction level, but also had the best color values (high Agtron and low Kent-Jones) and ash readings in six of the ten locations. The Eagle variety had little trouble obtaining the 70% extraction level and had the best color readings and ash values in three of the ten locations. The KSU 73256 experimental variety had some difficulty obtaining the 70% extraction level and had the best color readings and ash values in only one of the ten locations. Although the KSU 73256 experimental variety had the best color values and ash readings in only one of the ten locations, its values when compared to the Eagle variety were quite similar. Eagle had better color and ash values in five locations and the KSU 73256 experimental variety had better values in four of the locations. The two varieties had equal values in one location.

The most noticeable difference in the Buhler experimental milling tests results were those of Clark's Cream. While the Eagle and KSU 73256 varieties were producing flours of comparable color and ash, the Clark's Cream variety was producing flour with not only higher extraction levels but significantly better flour color. In the six locations where Clark's Cream had better flour color readings, the average difference in Agtron units from the Eagle variety was 5.5 and the average difference from the KSU 73256 variety was 7.0. The average difference in Kent-Jones units was also similar. The average difference in Kent-Jones units from Eagle was .5 and the average difference from the KSU 73256 was .9. The differences are significant because the standard experimental error for an Agtron color meter reading is $\pm .50$ units and the standard experimental error for a Kent-Jones reading is $\pm .10$ units. In the three locations where the Eagle

BUHLER MILLING RESULTS

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LOCATION	VARIETY	* YIELD	AGTRON COLOR GRADE	KENT JONES COLOR GRADE	FLOUR ASH
HUTCHINSON	EAGLE	70.0	72.5	1.0	0.37
	CLARK'S CREAM	70.7	76.5	0.8	0.40
	KSU73256	69.8	73.5	1.3	0.40
OTTAWA	EAGLE	69.8	63.0	2.6	0.35
	CLARK'S CREAM	69.3	74.2	1.1	0.35
	KSU73256	69.0	60.0	3.1	0.40
HAYS	EAGLE	70.2	64.0	1.9	0.38
	CLARK'S CREAM	69.7	70.5	1.6	0.36
	KSU73256	68.6	68.5	1.9	0.37
HESSTON	EAGLE	69.8	63.0	2.2	0.36
	CLARK'S CREAM	70.3	67.7	1.9	0.34
	KSU73256	69.2	64.0	2.5	0.41
SWK	EAGLE	69.1	70.5	1.4	0.39
	CLARK'S CREAM	69.2	66.0	1.9	0.43
	KSU73256	67.6	55.0	3.5	0.58
POWHATTAN	EAGLE	69.0	76.2	1.0	0.35
	CLARK'S CREAM	69.5	78.5	0.7	0.33
	KSU73256	69.6	71.0	1.8	0.41
TRIBUNE	EAGLE	68.1	77.0	1.1	0.39
	CLARK'S CREAM	69.7	77.0	1.1	0.43
	KSU73256	68.4	78.0	0.8	0.43
BELLEVILLE	EAGLE	70.4	59.7	2.6	0.44
	CLARK'S CREAM	69.0	58.0	2.9	0.46
	KSU73256	67.1	59.5	5.0	0.63
MANHATTAN	EAGLE	68.6	77.2	1.2	0.37
	CLARK'S CREAM	68.4	72.0	1.5	0.44
	KSU73256	69.5	72.0	1.6	0.40
COLBY	EAGLE	69.3	75.0	1.1	0.38
	CLARK'S CREAM	70.0	80.0	0.5	0.39
	KSU73256	68.7	67.5	1.8	0.46

* YIELD = $\frac{\text{TOTAL FLOUR}}{\text{TOTAL PRODUCT}}$

TABLE 2

variety had the superior color readings, the average difference in Agtron units from Clark's Cream was 4.0 and the average difference from the KSU 73256 experimental variety was 7.0. The Kent-Jones values had a similar relationship. The average difference in Kent-Jones units from Clark's Cream was .4 and the average difference from the KSU 73256 experimental variety was 1.6 units. In the location where the KSU 73256 variety had superior color values, the Agtron readings deviated by only 1.0 units and the Kent-Jones readings deviated by only .3 units.

The Buhler experimental mill results (See Table 2) indicate that the Clark's Cream variety will yield the largest quantity of flour with the best color grade. The Eagle and KSU 73256 varieties produced about the same extraction rates but more importantly their color grade values were not as good. It is significant that the higher theoretical yield predictions for the Clark's Cream variety seem to be actualized in the Buhler experiments. It is very difficult to obtain high extraction flours with acceptable color grade values using a short milling system such as the one employed in the Buhler mill. If higher flour extraction levels are to be obtained, while maintaining color quality, a more extensive milling system must be employed. In an effort to investigate the milling qualities of the three varieties on a more extensive milling system, the Ross and Multomat experimental mill flows were utilized.

Ross Experimental Milling

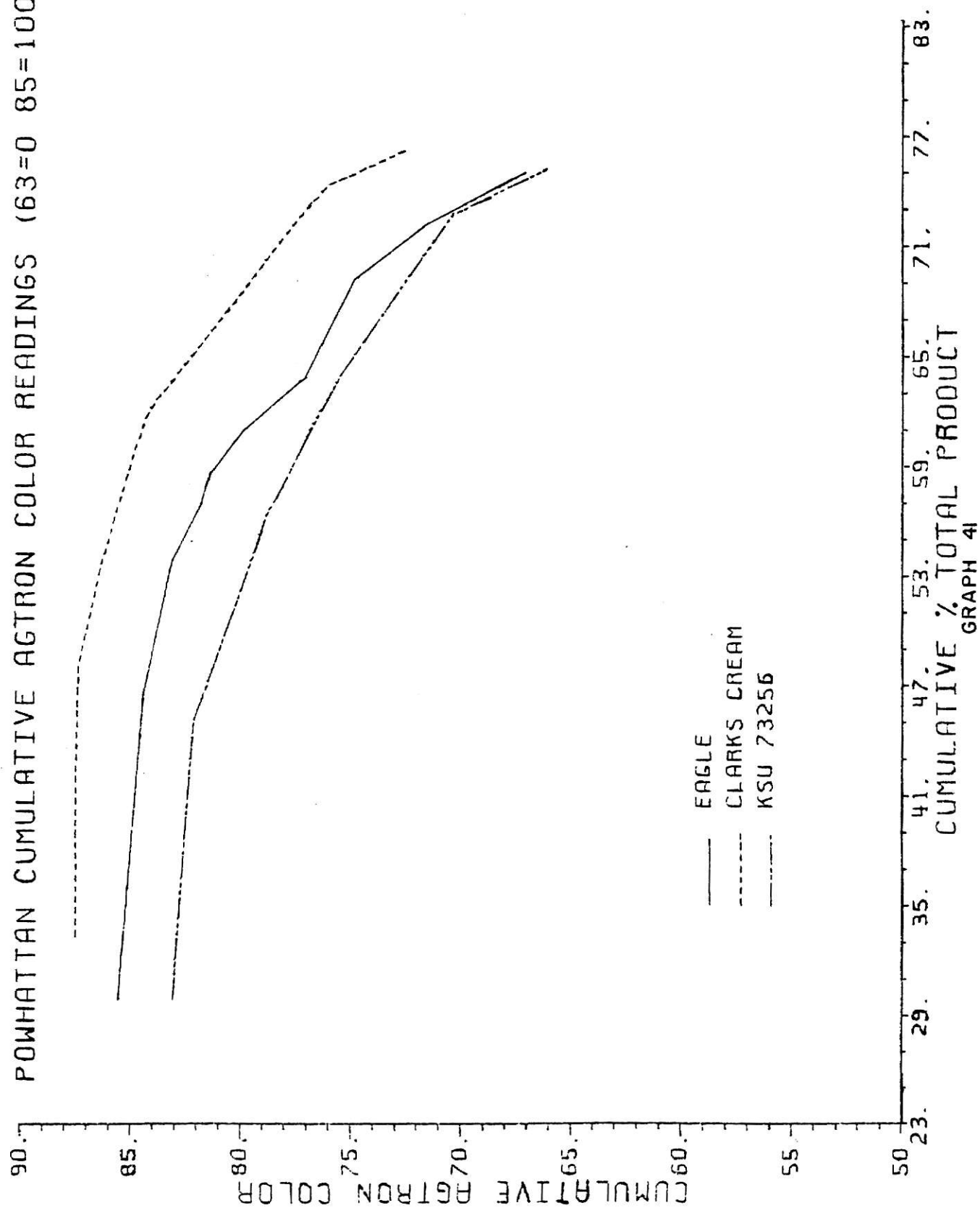
Two locations (Powhattan, Tribune) were selected to be milled on the Ross experimental mills. The Tribune location was selected because all three of its varieties from the Buhler experimental mill tests produced similar color versus extraction relationships. The Powhattan location was chosen because it was representative of the six locations in

the Buhler experimental mill results where the Clark's Cream variety produced not only higher extraction levels but better flour color values.

Each individual flour stream from the Ross Flow was tested for Agtron color value and each stream was added in decreasing flour color order until ultimately a straight grade flour was produced. Through this method, it was possible to produce the actual flour cumulative color curve with which a quantitative comparison of one wheat variety with another could be analyzed on the basis of flour color versus extraction level.

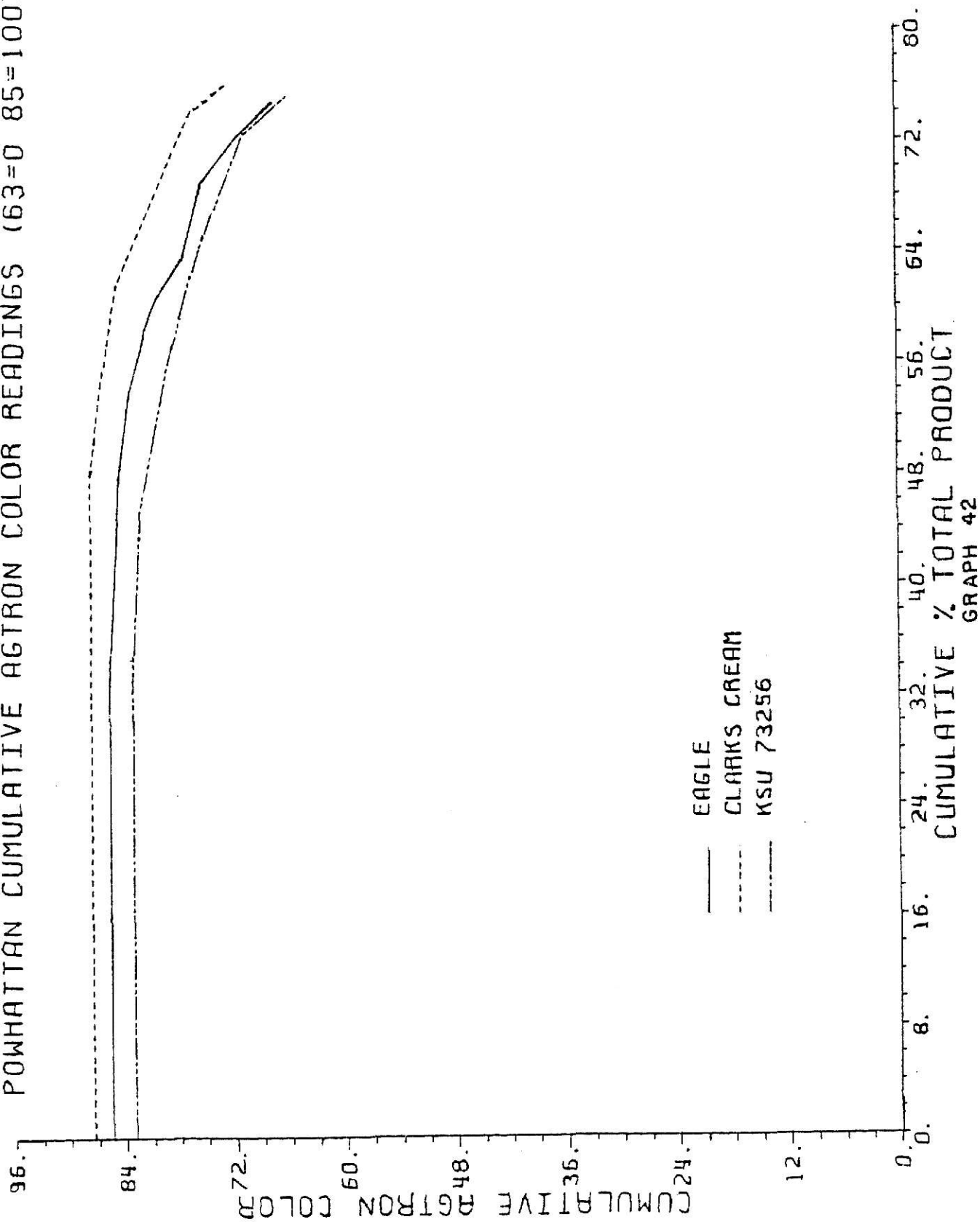
The results of the Ross milling tests for the Powhattan location are depicted on graphs 41 through 45. In terms of flour color and extraction level, an obvious advantage exists for the Clark's Cream variety. If a 75% extraction level is chosen as a reference point for the Powhattan milling results, the Clark's Cream variety's Agtron color value is 5.5 units better than the Eagle variety and 6.5 units better than the KSU 73256 experimental variety. The Eagle and KSU 73256 cumulative color curves converge once they reach about the 71% extraction level. This is not surprising if reference is made to the discoloring power curves (Kent-Jones and Agtron Graphs 16 & 26) from this location. Both bran discoloring power curves denote that the bran from Eagle and KSU 73256 have very similar discoloring powers. If the same amount of bran flour is present in both flours then the flour color grades should be very similar. Graphs 43 & 45 which denote the amount of tail end streams (1st Bk, 4M, 4 & 5 BK, 1st tail and 5M) present in each flour indicate that 14.18% of the total flour in the Eagle variety is made up of low grade streams and 13.98% of the total flour in the KSU 73256 experimental variety is composed of low grade streams. Low grade streams would be most responsible for bran contamination.

POWHATTAN CUMULATIVE AGTRON COLOR READINGS (63=0 85=100)

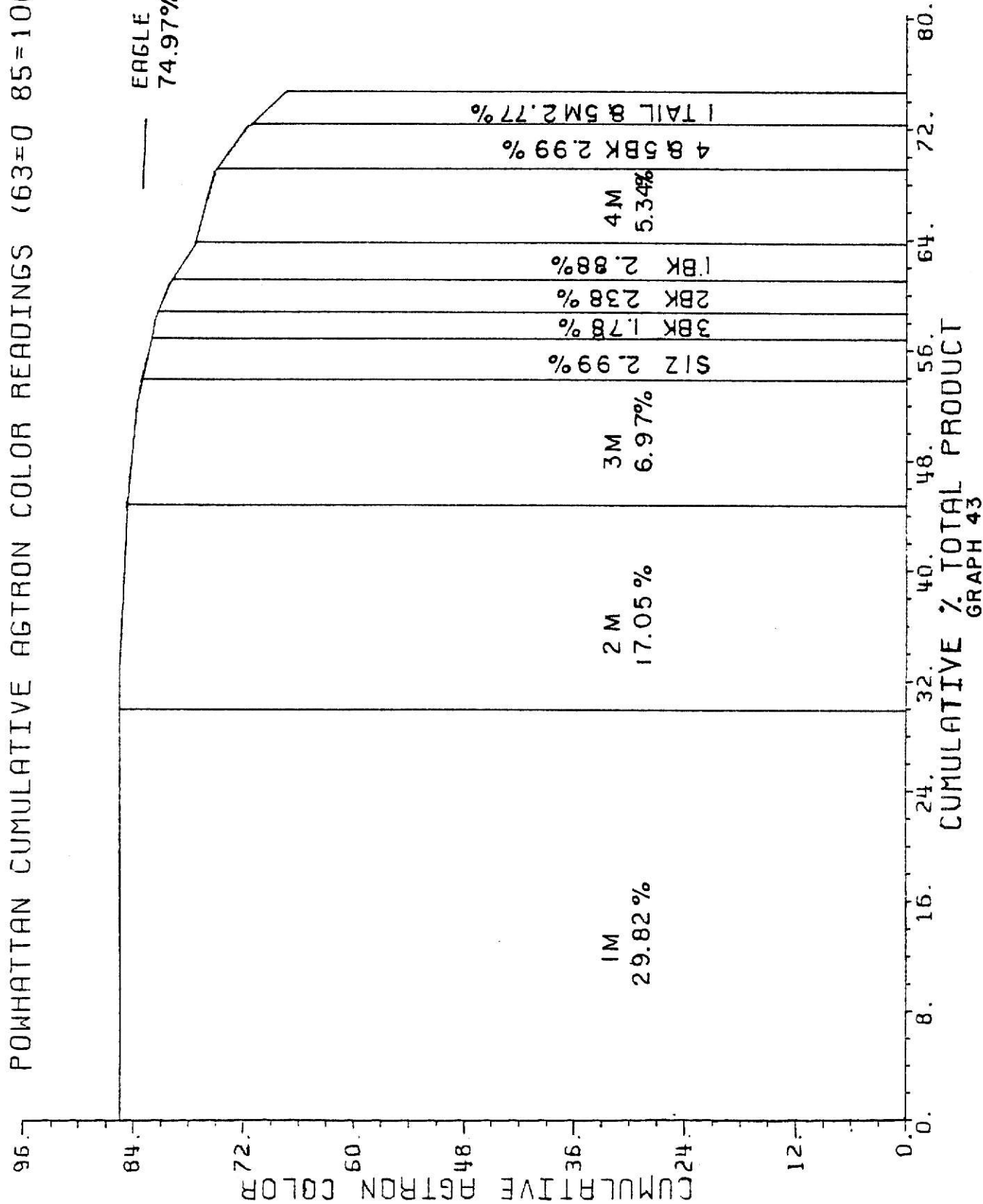


GRAPH 41

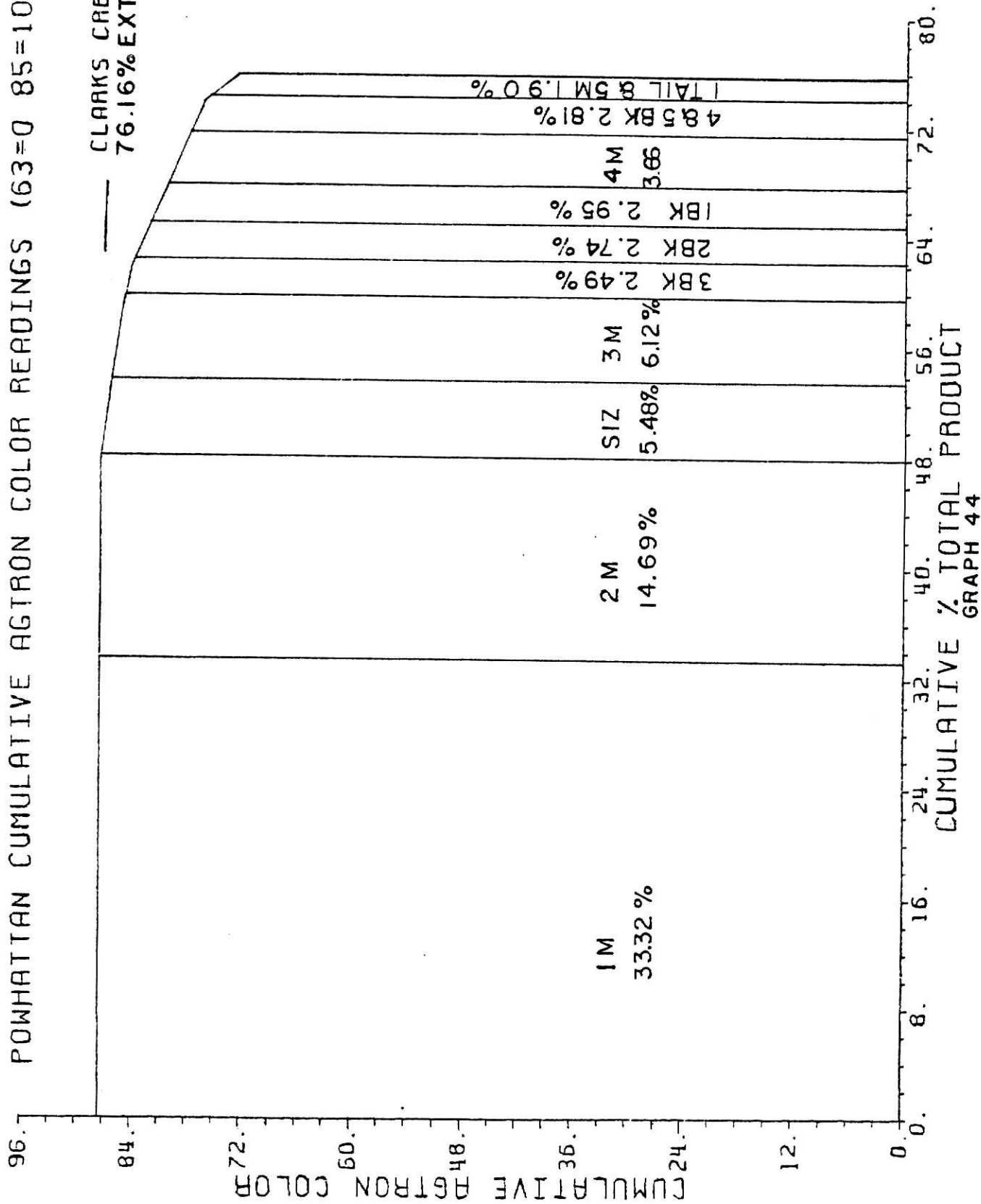
POWHATTAN CUMULATIVE AGTRON COLOR READINGS (63=0 85=100)



POWHATTAN CUMULATIVE AGTRON COLOR READINGS (63±0 85=100)

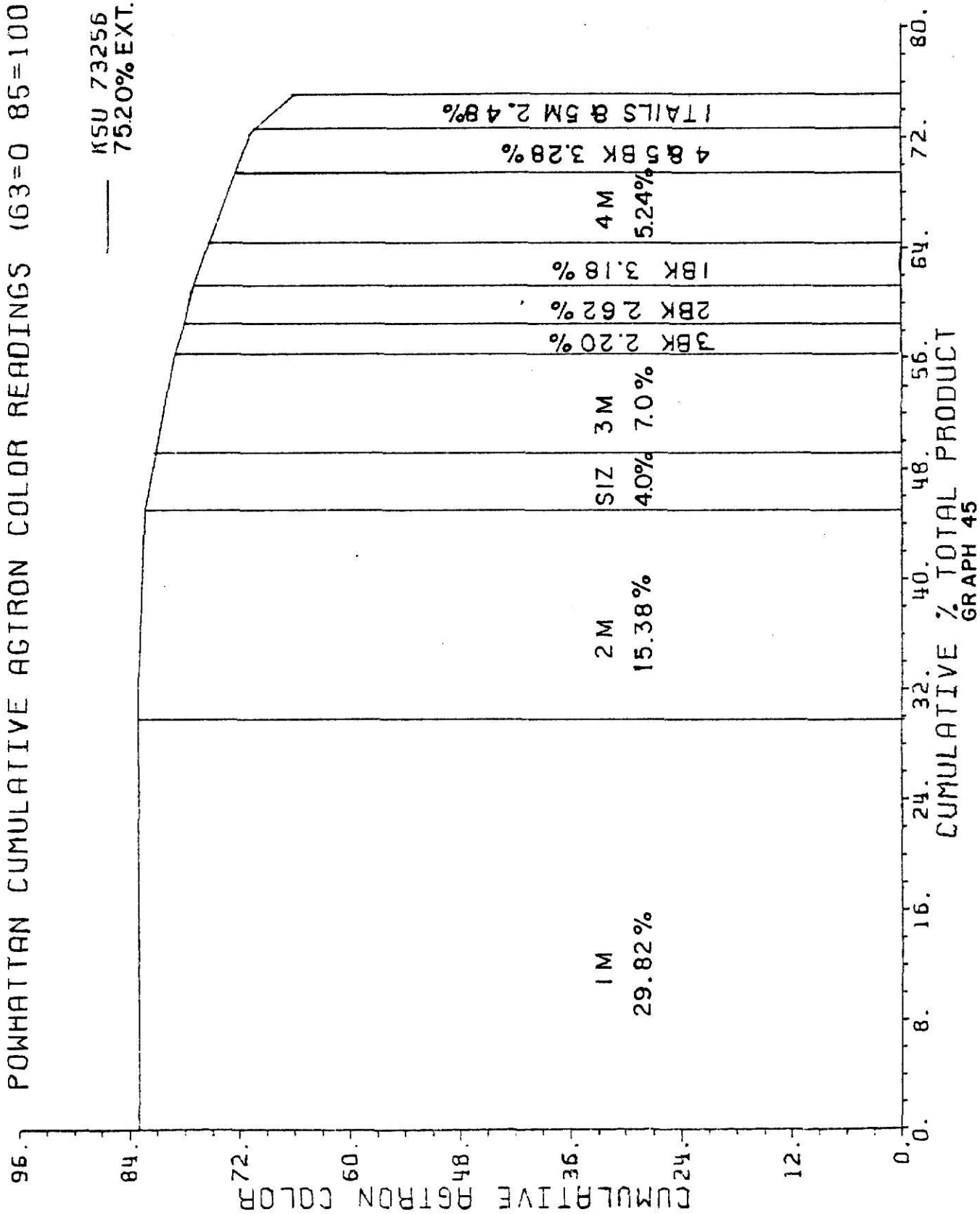


POWHATTAN CUMULATIVE AGTRON COLOR READINGS (63=0 85=100)



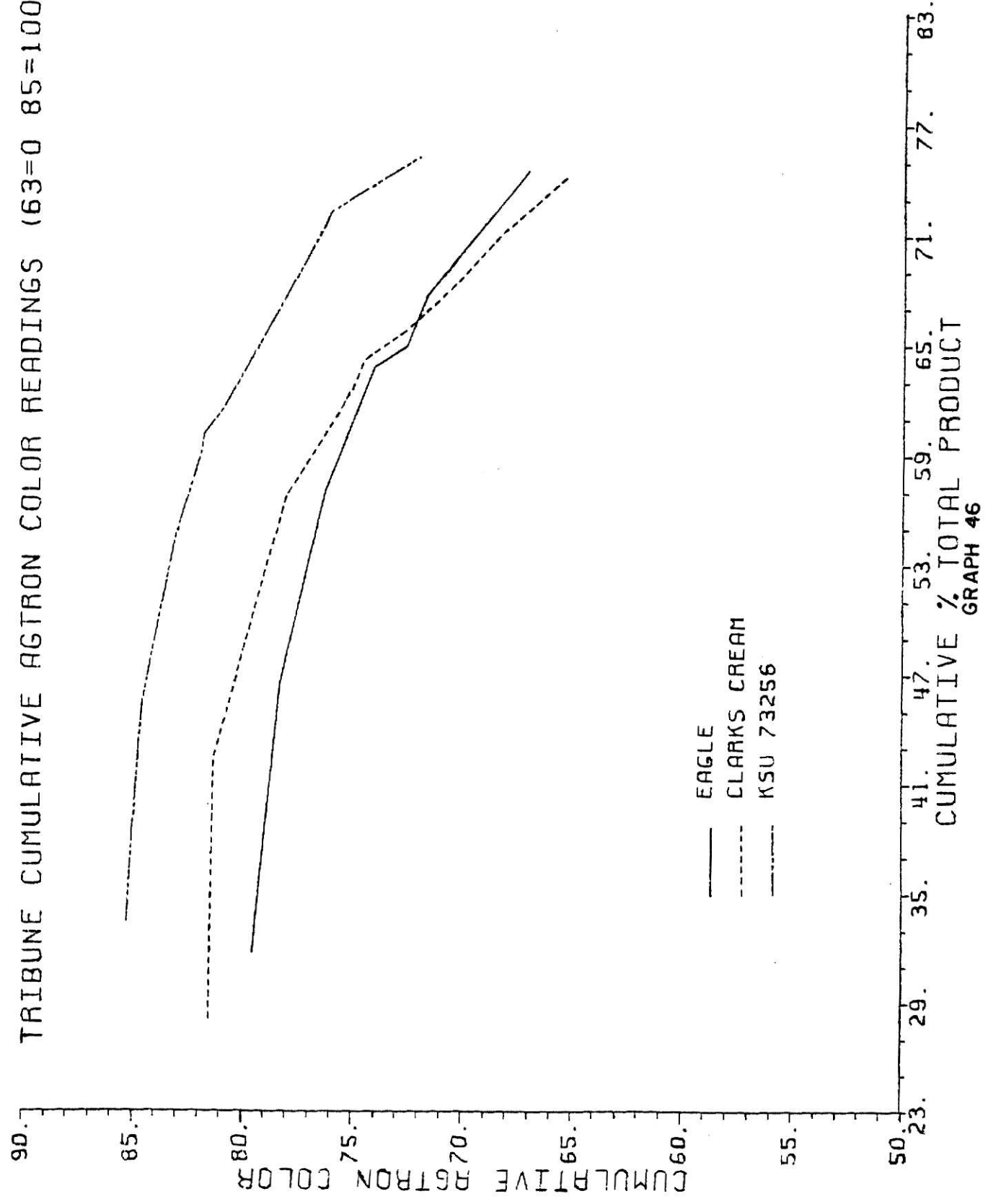
POWHATTAN CUMULATIVE AGTRON COLOR READINGS (63=0 85=100)

— KSU 73256
7520% EXT.

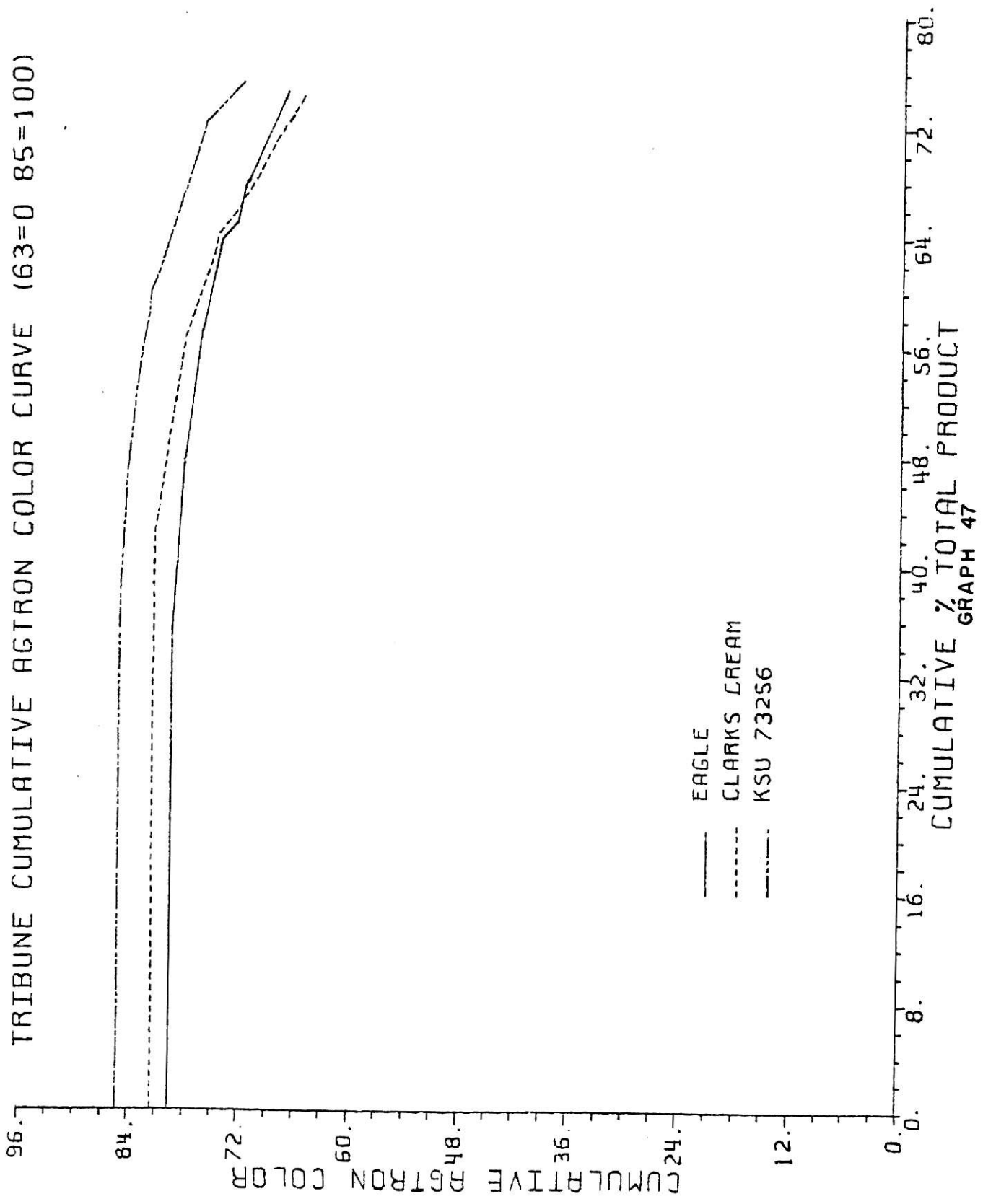


The results of the Ross milling tests for the Tribune location are depicted on graphs 46 through 50. In terms of flour color and extraction level, an obvious advantage exists for the KSU 73256 experimental variety. If a 74% extraction level is chosen as a reference point for the Tribune milling results, the KSU 73256 experimental variety's Agtron color grade is 6.5 units better than the Eagle variety and 8.0 units better than the Clark's Cream variety. It would seem that Clark's Cream and Eagle cumulative color curves do not support the discoloring power curves (See graphs 17 and 27 for Tribune). The discoloring power curves show that the Eagle variety bran had a much greater discoloring power than the Clark's Cream variety. It would be expected that the Clark's Cream variety would produce the brighter flour if the amount of bran contamination was equal. Graphs 48 and 49, which denote the amount of low grade streams (1st BK, 2BK, 3BK, 4 & 5th BK, 1st tails and 5M) present in each flour indicate that 10.7% of the total flour in the Eagle variety is made up of tail end streams and 11.67% of the total flour in the Clark's Cream is made up of tail end streams. This difference explains part of the data on graphs 46 and 47. The final explanation is found if consideration is given to how well a certain flour can carry or sustain bran contamination. The purity and quantity of 1M and 2M flours determines how much bran contamination each of the varieties could sustain without seriously reducing the straight grade flour color. Graphs 48 and 49 show that 46.64% of the Eagle variety's straight grade flour was composed of 1M and 2M while the Clark's Cream variety straight grade flour contained only 42.6% flour from 1M and 2M. Although the Clark's Cream variety initially had superior color grade, it could not sustain the additional bran contamination from the low grade streams.

TRIBUNE CUMULATIVE AGTRON COLOR READINGS (63=0 85=100)

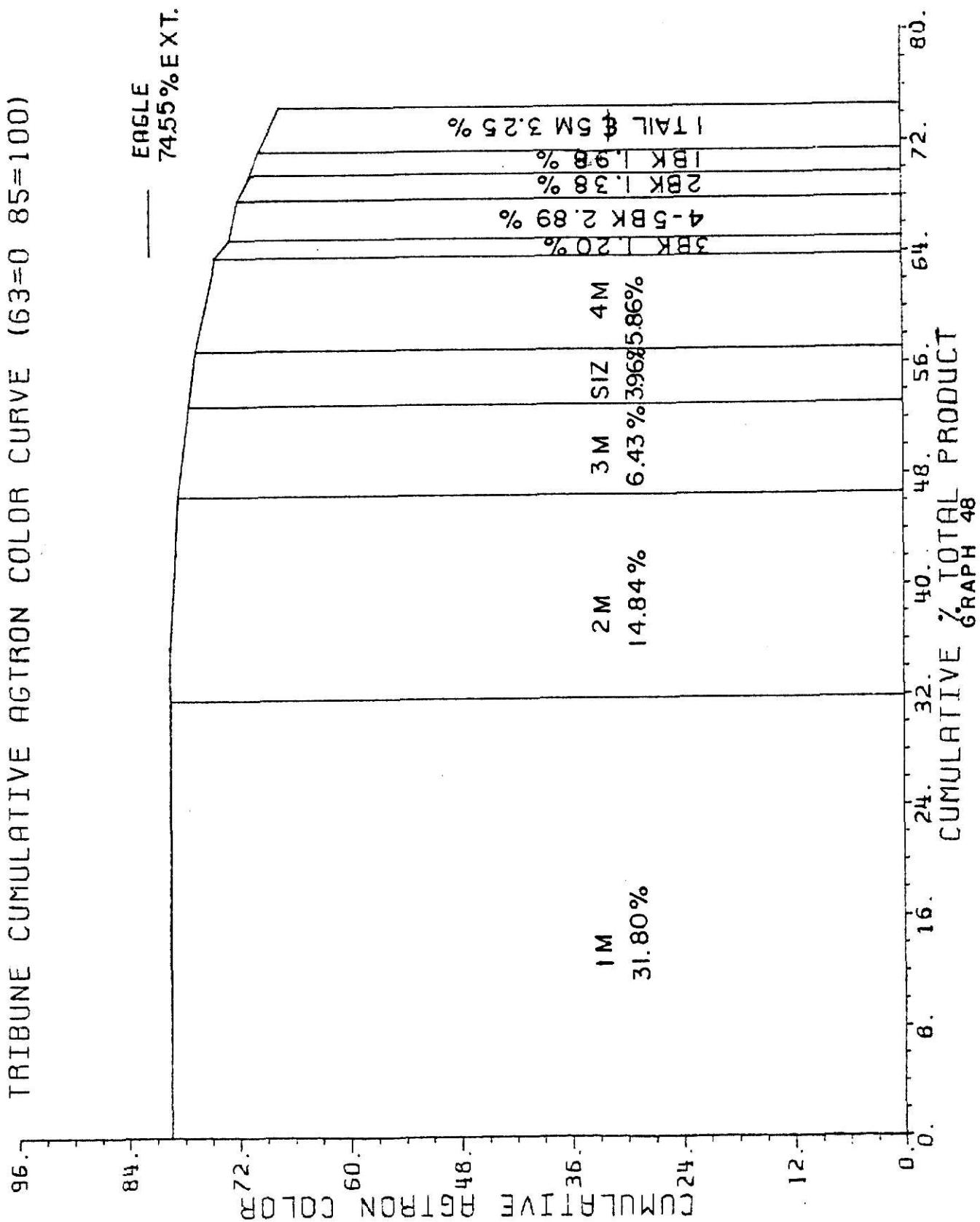


TRIBUNE CUMULATIVE AGTRON COLOR CURVE (63=0 85=100)

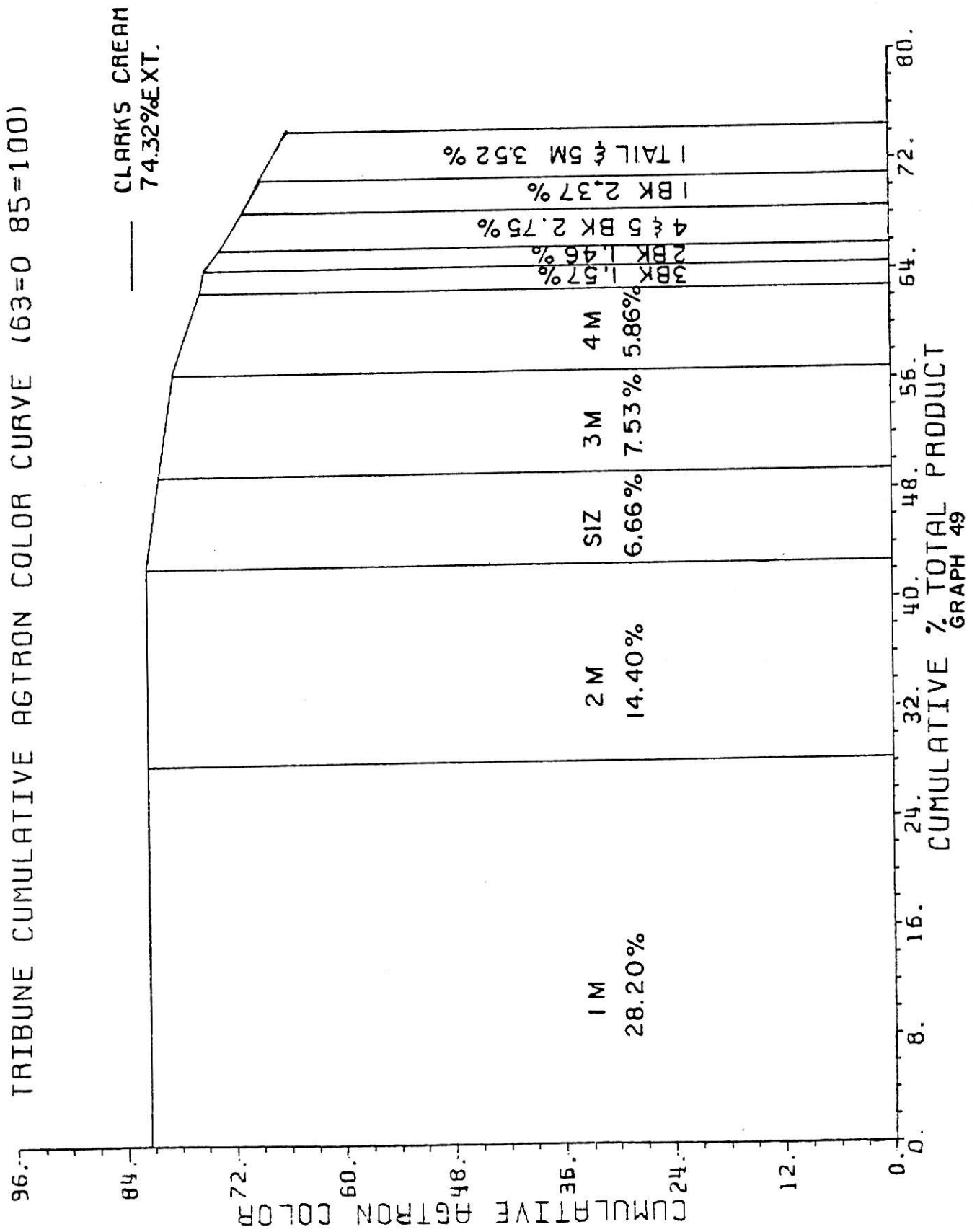


TRIBUNE CUMULATIVE AGTRON COLOR CURVE (63=0 85=100)

— EAGLE
7455%EXT.

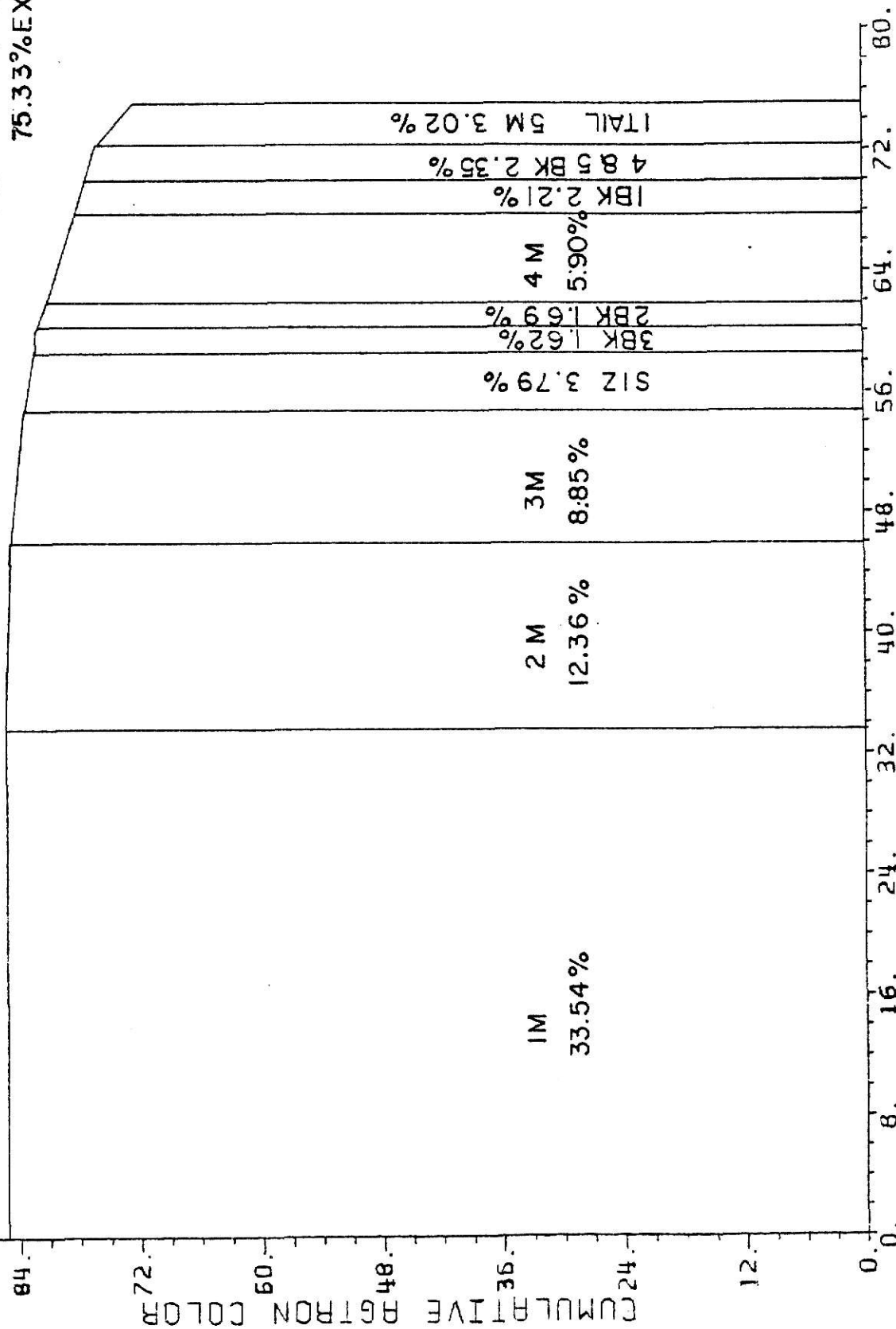


TRIBUNE CUMULATIVE AGTRON COLOR CURVE (63=0 85=100)



TRIBUNE CUMULATIVE AGTRON COLOR CURVE (63=0 85=100)

— KSU 73256
75.33%EXT.



CUMULATIVE % TOTAL PRODUCT
GRAPH 50

It should be noted that the Ross milling experiments produced approximately the same color versus extraction relationships obtained in the Buhler milling experiments. In the Buhler results for the Powhattan location, the Clark's Cream variety produced the best color versus extraction relationship. The same relationship existed in the Ross milling experiments except the Clark's Cream variety's superior color versus extraction relationship was much more pronounced. The Tribune location had somewhat different results. The Buhler experiments produced three straight grade flours of very similar extraction and color grade. When the three varieties were milled on the Ross system, the KSU 73256 variety produced a remarkably better cumulative color curve. The Eagle and Clark's Cream varieties color versus extraction relationships were once again similar as in the Buhler experiments.

The significance of the Ross milling experiments was that in both locations a Hard White Wheat produced the same amount of flour as a Hard Red Wheat (Eagle) but at a significantly better color grade. There could be a definite economic advantage to milling these Hard White Wheats from these two locations. Obviously it is very difficult to segregate wheat by location on a commercial scale. In an attempt to produce more realistic wheat samples, a composite sample consisting of 3000 grams from each of the ten locations was blended together. The Multomat Mill was used for the composite milling tests because of its capacity and continuous mill flow as versus a batch system like the Ross Mill.

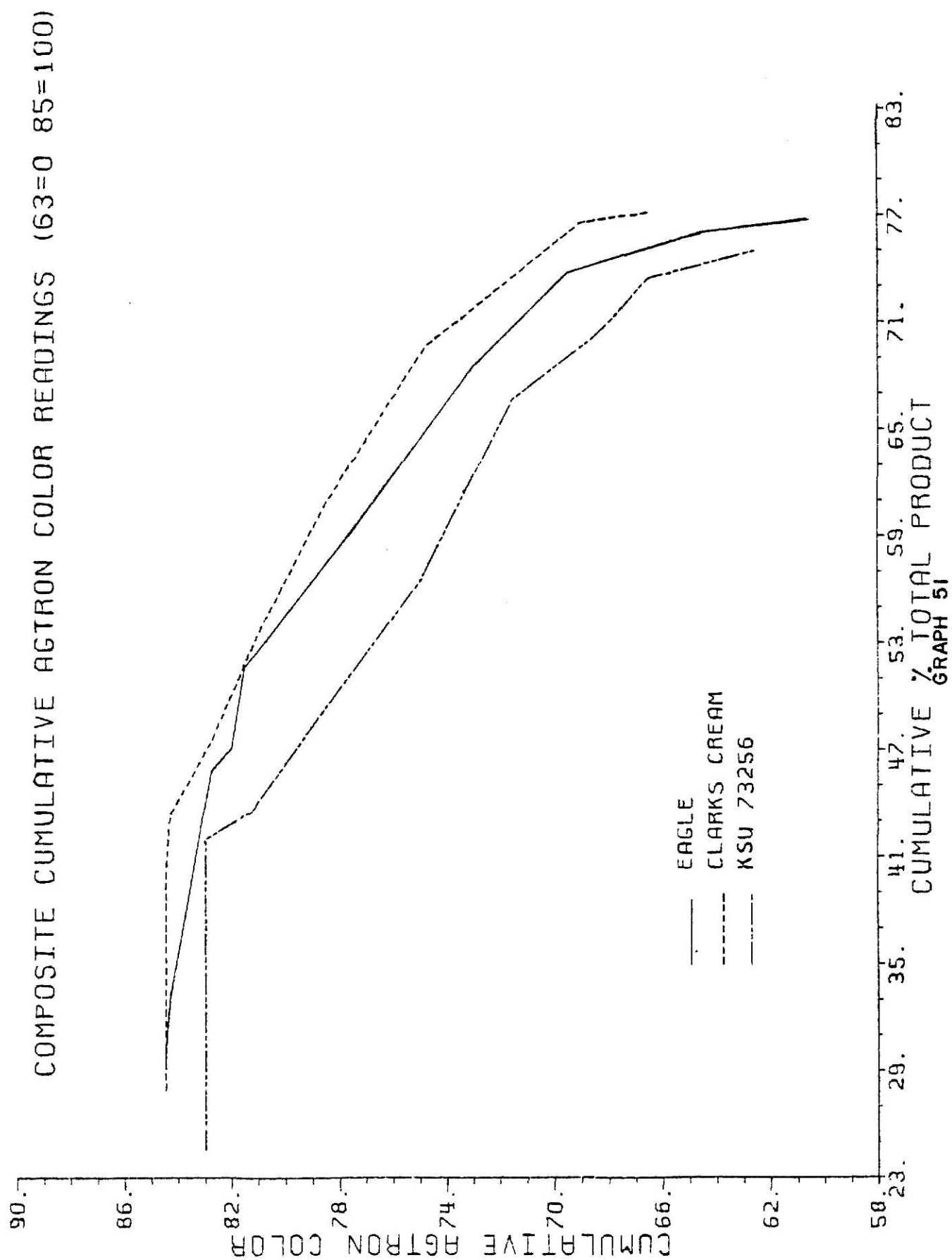
Multomat Experimental Milling

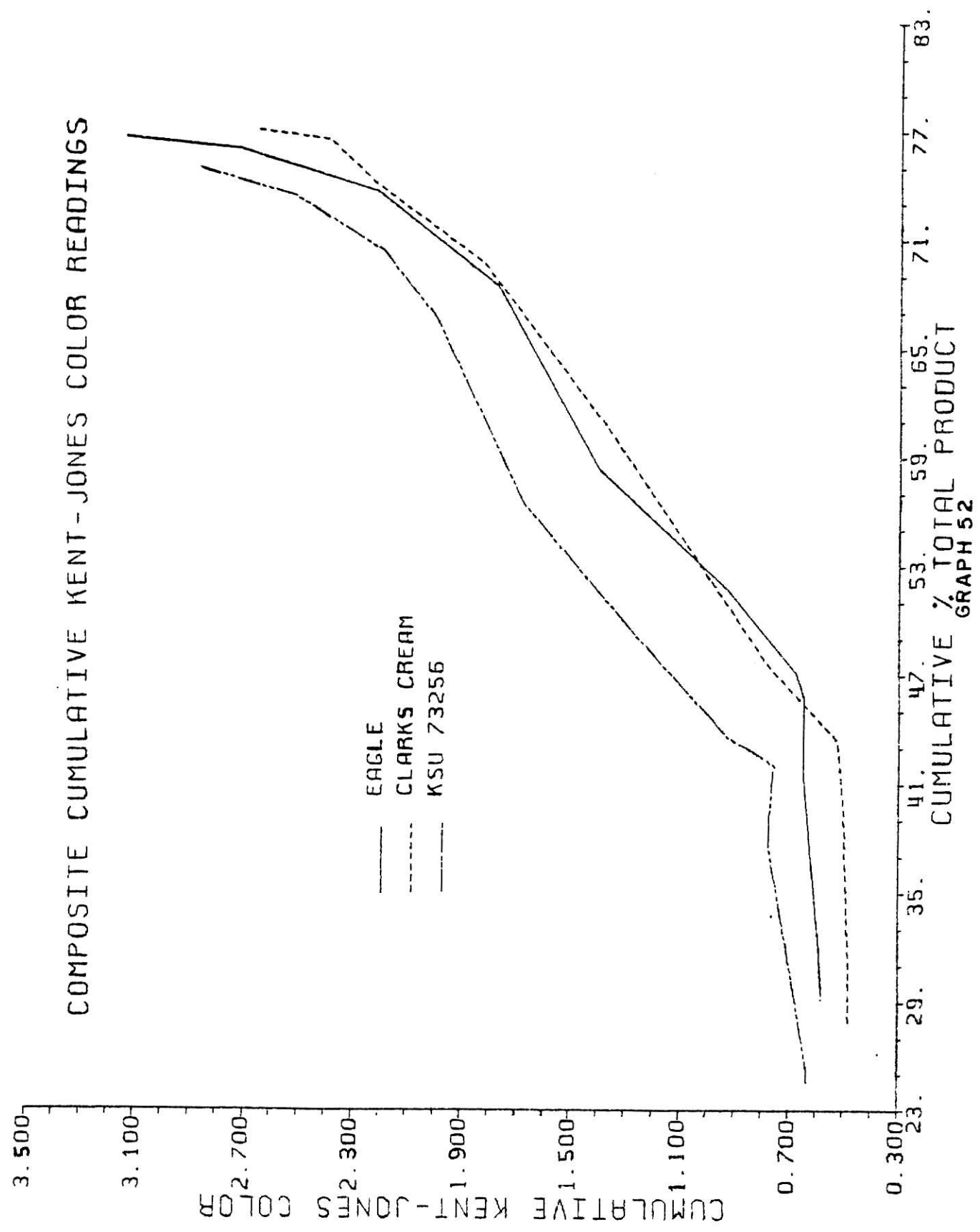
The Multomat Experimental Mill was the final milling system used to evaluate the milling qualities of the three varieties. A composite sample consisting of all ten locations was blended together to be milled

on the Multomat. Standard feed rates, tempering moistures and break releases were used for all three varieties. Color (Kent-Jones and Agtron), protein, moisture and ash values were taken for each individual flour stream and cumulative color, protein and ash curves were produced (Graphs 51-58).

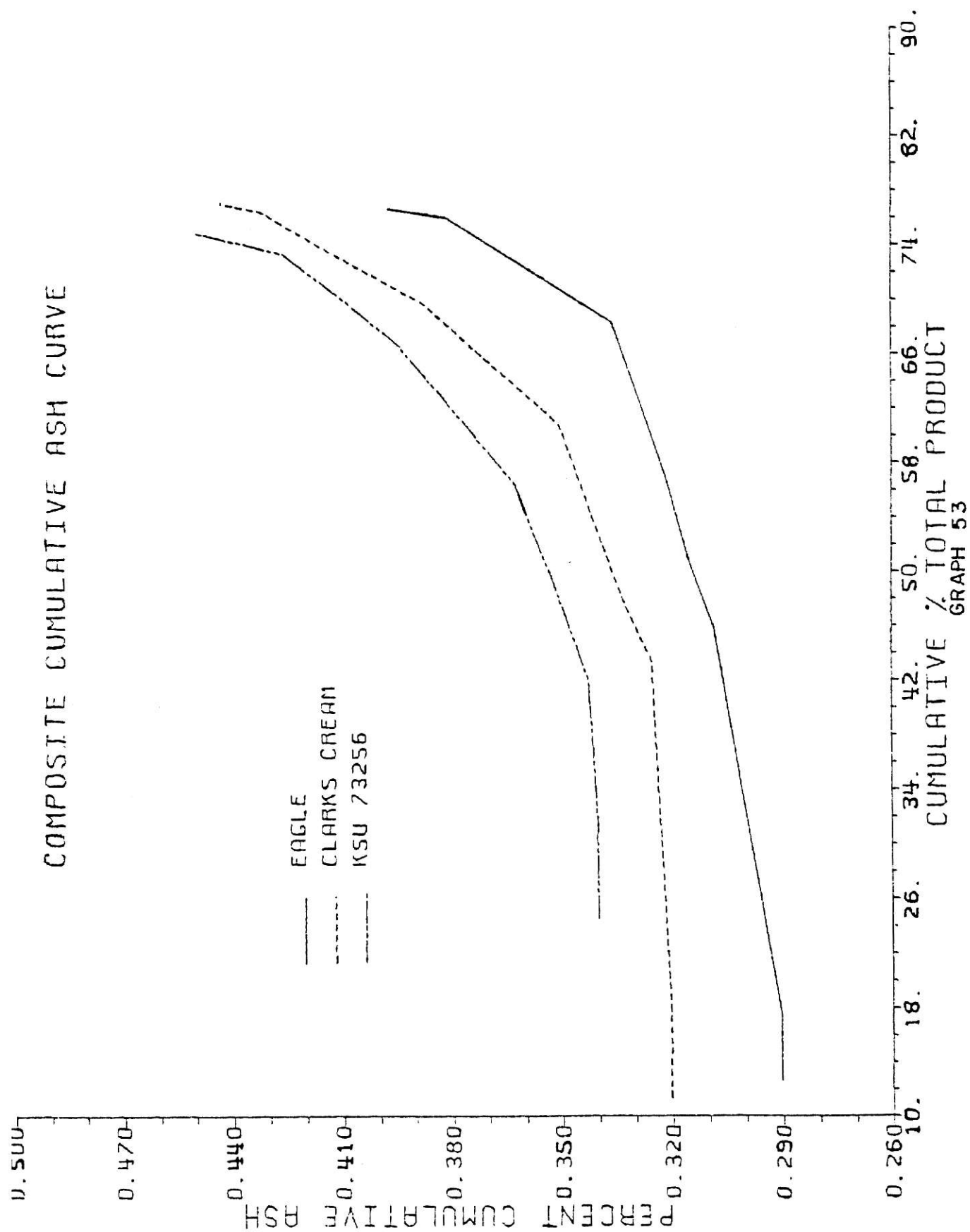
The cumulative Agtron and Kent-Jones color curves found on graphs 51 and 52 depict the pertinent results. In both cases, the Clark's Cream variety produced more flour at a better color value. Flour is bought and sold in the United Kingdom by Kent-Jones color. A Kent-Jones color grade of 2.5 is accepted as a standard. Using a 2.5 Kent-Jones color grade as a reference point, the Clark's Cream variety produced 3.5% more flour than the KSU 73256 experimental variety and 2% more flour than the Eagle variety. The Agtron Cumulative Color Curve produced almost identical results. If an Agtron Color grade of 61 is used as a reference point, the Clark's Cream variety produced 3% more flour than the KSU 73256 experimental variety and 2% more flour than the Eagle variety.

The cumulative ash curve (Graph 53) indicates that the Eagle variety produced the lowest ash flour. The Clark's Cream variety was in between the Eagle and the KSU 73256 experimental variety. The cumulative ash results can be explained by referring to the whole kernel ash values determined earlier, as part of the Chemical Wheat Tests. The Eagle variety had an average whole kernel ash value of 1.59% as compared to 1.63% for Clark's Cream and 1.55% for KSU 73256. All of these values are very similar and do not explain the difference in the cumulative ash curve. An explanation can be found if reference is made to the endosperm ash values of each variety. Graph 53 indicates that the Eagle variety's endosperm ash was about .290 while the Clark's Cream variety had a value of about



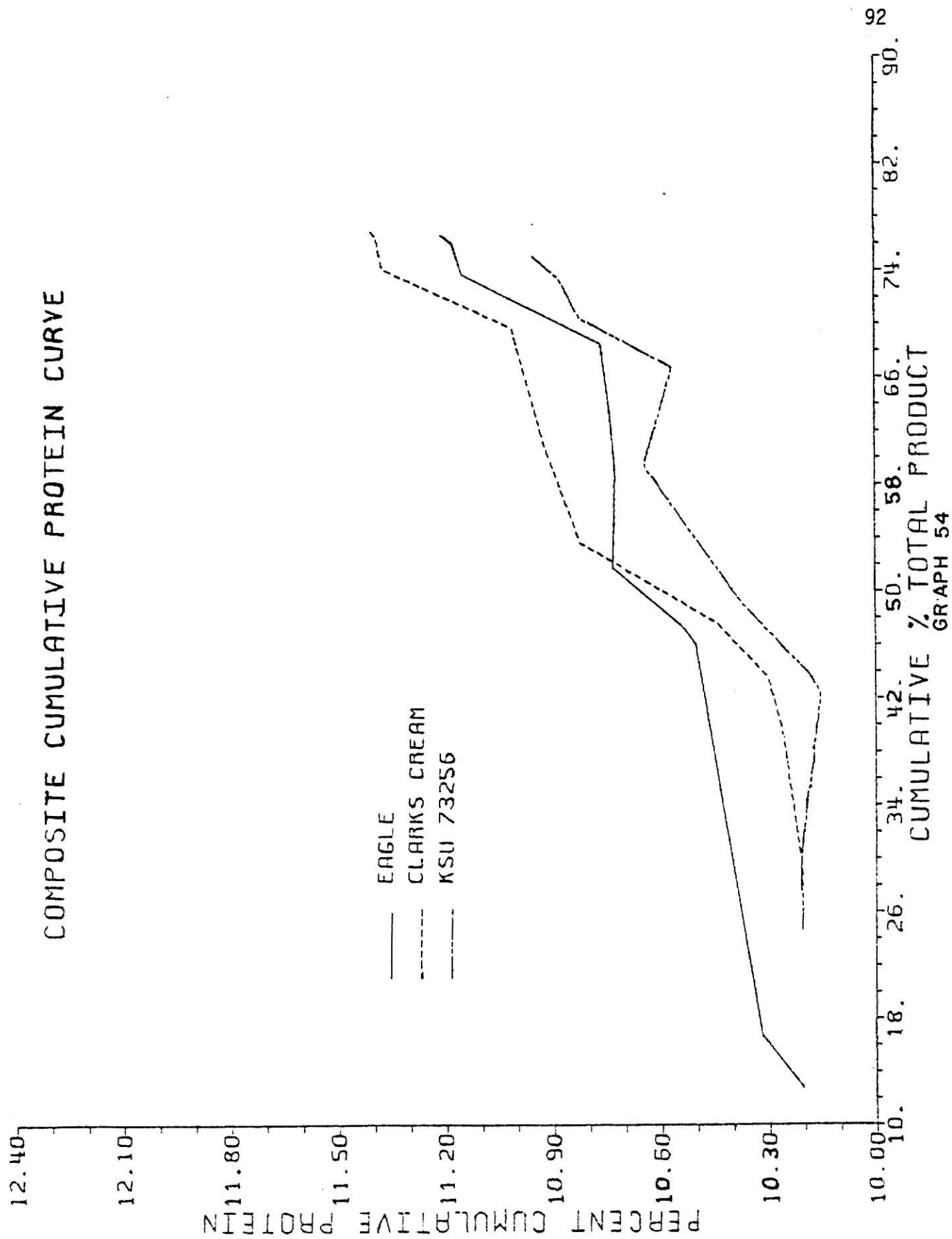


COMPOSITE CUMULATIVE ASH CURVE

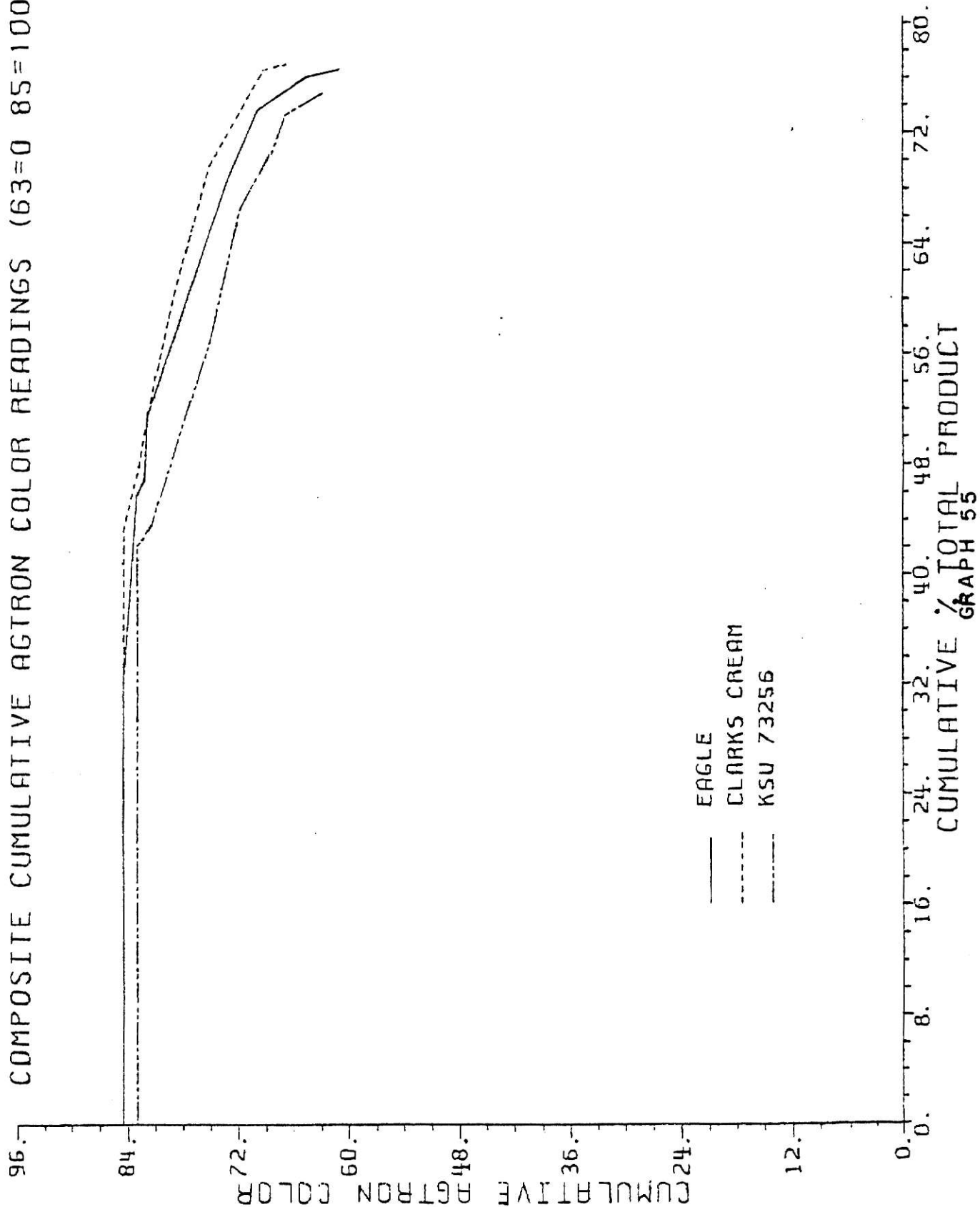


CUMULATIVE % TOTAL PRODUCT
GRAPH 53

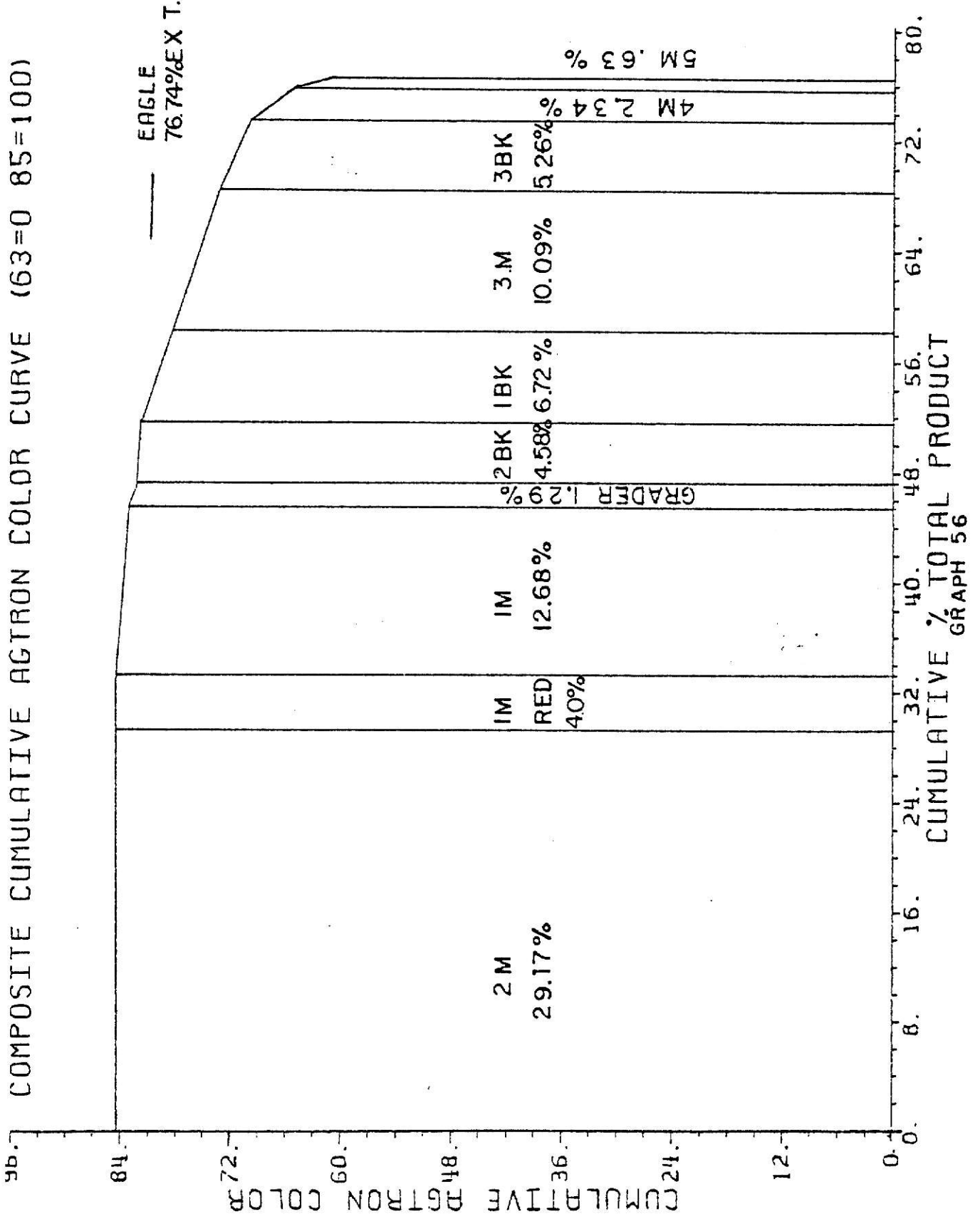
COMPOSITE CUMULATIVE PROTEIN CURVE

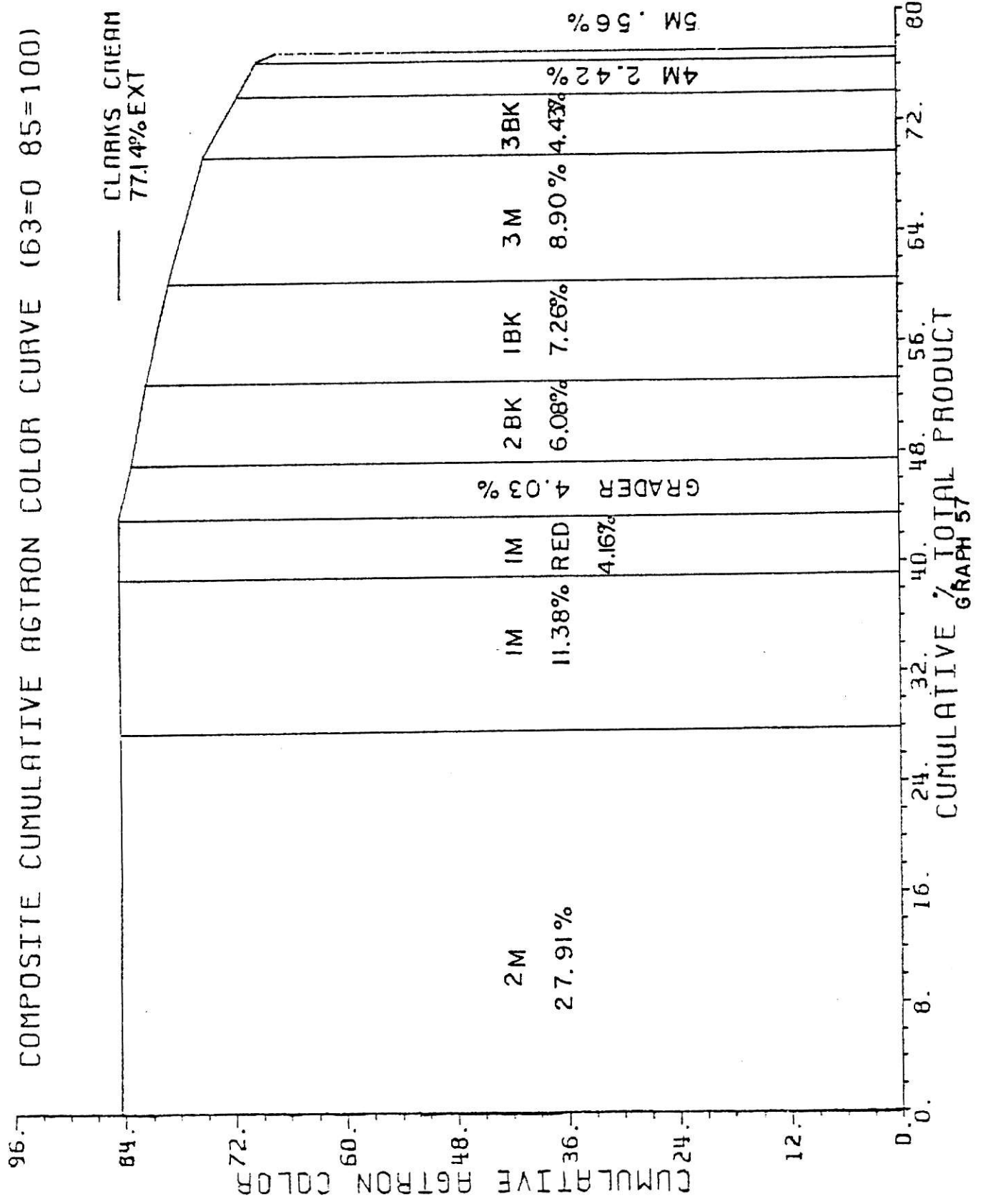


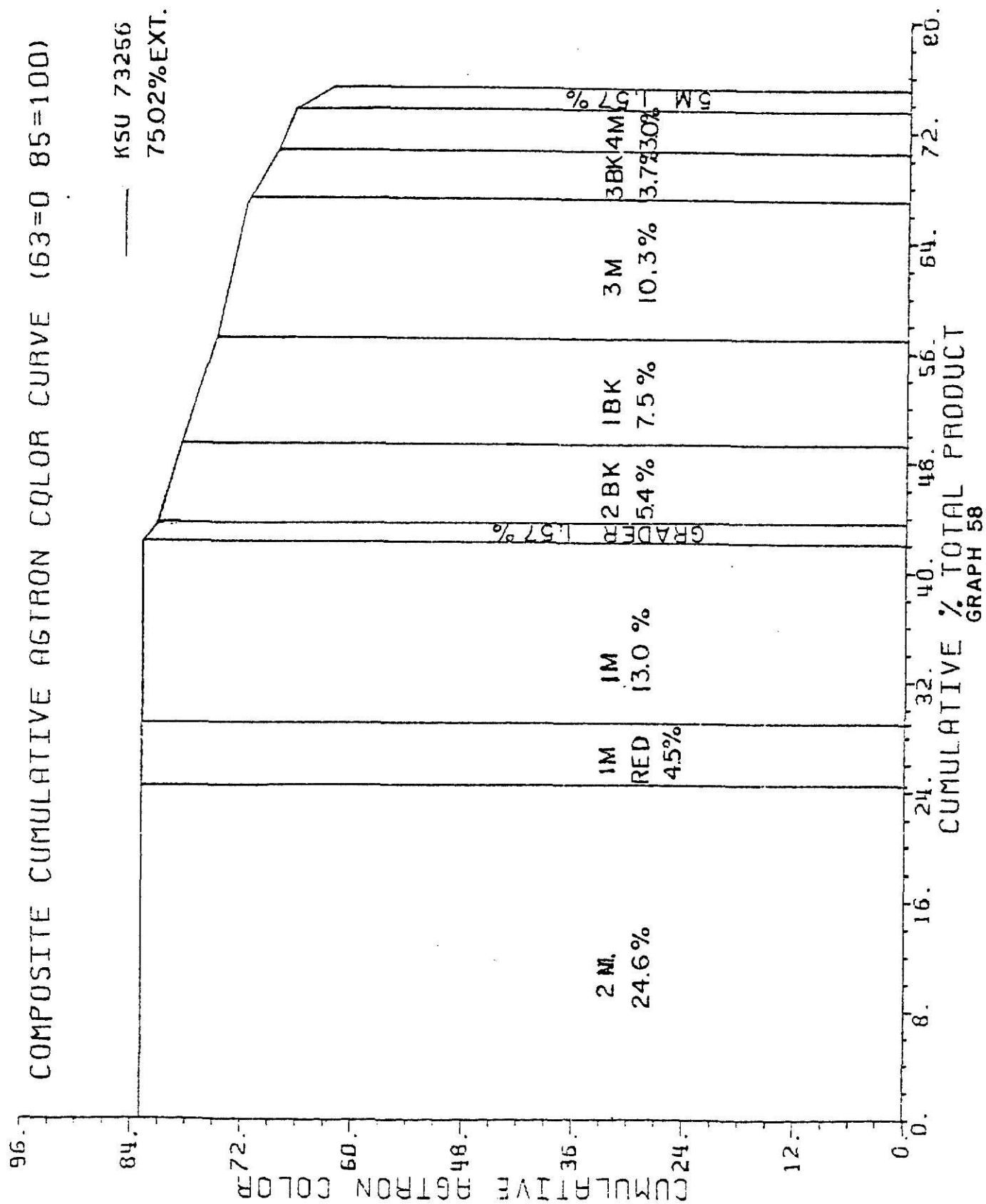
COMPOSITE CUMULATIVE ACTRON COLOR READINGS (63=0 85=100)



COMPOSITE CUMULATIVE AGTRON COLOR CURVE (63=0 85=100)







.320 and the KSU 73256 variety had a value of .340. Clearly the Eagle variety had the lowest endosperm ash and thus produced the lowest ash flour. It is also possible that both the Clark's Cream and KSU 73256 varieties had additional bran contamination.

The Multomat results yielded quantitative evidence that an economic advantage existed for the Clark's Cream variety. A two percent addition in flour production without the loss of color quality could have great economic ramifications. Developing nations would be very interested because they could import less wheat. There would be monetary savings not only in the amount of wheat required for purchase but also in the shipping of less wheat. The domestic ramifications of such a wheat would basically be controlled by the prices of feed and flour. If the price of flour was greater than feed, then a monetary incentive for additional flour production would exist.

Baking Tests

Four of the original ten locations (Ottawa, Hays, Hesston, SWK) were chosen to be tested for baking quality. The Buhler experimental straight grade flours from these four locations were selected because their protein levels were within a 11-13.5% range. A variety of tests were performed on each flour in an attempt to ascertain the water absorption, mixing time, mixing tolerance and the flour's ability to produce high volume bread of good grain and texture.

The mixographs for all twelve flour samples are located on graph 59. According to the mixographs, the Ottawa, Hays and Hesston locations produced flours with short to medium mixing times (3-5 minutes). All three varieties from the SWK location had medium to long mixing times (5-7 minutes). The SWK location also produced the flour samples with the

MIXOGRAPHS**GRAPH 59**

LOAF VOLUME / % FLOUR PROTEIN FOR ⁹⁹ OTTAWA, HAYS, HESSTON, AND SWK LOCATIONS

<u>LOCATION</u>	<u>VARIETY</u>	<u>FLOUR PROTEIN 14% MB</u>	<u>LOAF VOLUME vs % FLOUR PROTEIN CC / % PROTEIN</u>
<u>OTTAWA</u>	<u>EAGLE</u>	<u>11.9%</u>	<u>73.3</u>
<u>OTTAWA</u>	<u>CLARKS CREAM</u>	<u>11.9%</u>	<u>63.3</u>
<u>OTTAWA</u>	<u>KSU 73256</u>	<u>11.5%</u>	<u>78.3</u>
<u>HAYS</u>	<u>EAGLE</u>	<u>12.5%</u>	<u>74.2</u>
<u>HAYS</u>	<u>CLARKS CREAM</u>	<u>12.8%</u>	<u>63.5</u>
<u>HAYS</u>	<u>KSU 73256</u>	<u>12.2%</u>	<u>77.7</u>
<u>HESSTON</u>	<u>EAGLE</u>	<u>12.5%</u>	<u>74.6</u>
<u>HESSTON</u>	<u>CLARKS CREAM</u>	<u>12.4%</u>	<u>70.0</u>
<u>HESSTON</u>	<u>KSU 73256</u>	<u>12.6%</u>	<u>74.0</u>
<u>SWK</u>	<u>EAGLE</u>	<u>12.7%</u>	<u>76.6</u>
<u>SWK</u>	<u>CLARKS CREAM</u>	<u>13.6%</u>	<u>72.0</u>
<u>SWK</u>	<u>KSU 73256</u>	<u>13.4%</u>	<u>80.0</u>

TABLE 3

highest protein content. It would require additional mixing time to develop a flour dough with unusually high protein content such as the flour samples from the SWK locations.

The baking procedures described in Materials and Methods were used to test bake all twelve flour samples. Each flour produced bread of acceptable grain and texture. The Clark's Cream variety bread was quite low in volume and this did detract somewhat from the grain and texture of the crumb. Bread volume comparisons were made by computing the break volume/percent flour protein ratio. Those ratios, along with the respective flour proteins are presented on Table 3. As can be seen from the loaf volume/percent flour protein table, the KSU 73256 experimental variety was by far the superior variety for loaf volume production. In all four locations, the KSU 73256 variety had a superior loaf volume/percent flour protein ratio. The Eagle variety also produced excellent loaf volume/percent flour protein ratios at all four locations. The Clark's Cream variety had the poorest loaf volume/percent flour protein ratio for all four locations. The lack of loaf volume for the Clark's Cream variety indicates that it would not be well suited for commercial yeast leavened bread production. Both the Eagle and Clark's Cream varieties had good mixing tolerance. If all aspects of bread baking quality were taken into account the KSU 73256 and Eagle varieties would be considered to be well suited for commercial bread production and the Clark's Cream variety would not.

Additive Effect of Kent-Jones and Agtron Color Grade

Three individual flour streams from the Multomat experimental mill tests were selected for checking the additive effect of Kent-Jones and Agtron color grade values. The flour streams were selected according to their individual color grades. Two similar color grade flours were blended

together in equal amounts as were two diverse color grade flours. Table 4 shows the color grade values for the individual flour streams and the flour stream combinations (actual and predicted). The predicted value is the color grade that would be obtained if Agtron and Kent-Jones color grades were completely additive. Each color grade was taken in duplicate and averaged together to obtain one value.

As indicated in the chart, the predicted color grade values for the flour combination of similar color grade flours are very close to the actual values. This data lends support to the concept that Agtron and Kent-Jones color guides are additive when the flour streams being combined are not too diverse in color grade. The flour streams that showed an additive color effect were from 20 to 30 Agtron units apart. When the flour streams being combined were 40 Agtron units apart, the predicted Agtron color grade was 5 units better than the actual flour combination color grade. The same type of relationship was obtained in the Kent-Jones color grade tests. With combinations of flours that differed by 2.0 to 3.0 Kent-Jones units, a definite additive effect was observed. When the flour combinations differed by 4.0 to 5.0 Kent-Jones units, the predicted Kent-Jones color grade was from .40 to .50 Kent-Jones units better than the actual flour combination color grade.

Both the Agtron and Kent-Jones color data indicated that if one of the flour streams in the flour combination have a low grade color value, the predicted color value for the flour combination will be better than the actual flour color value. An additive effect was present for both Kent-Jones and Agtron color when the flours being combined were similar in color grade. In the future, flour combinations composed of two low grade flours need to be tested.

ADDITIVE EFFECT OF KENT-JONES ¹⁰² AND AGTRON COLOR GRADES

EAGLE

FLOUR STREAM	AGTRON VALUE	FLOUR COMBINATION COLOR GRADE	FLOUR STREAM	KENT- JONES VALUE	FLOUR COMBINATION COLOR GRADE
1 M	81.0	ACTUAL 1M + 3M 64.0	1 M	.9	ACTUAL 1M + 3M 2.3
		PREDICTED 1M+3M 64.7			PREDICTED 1M+3M 2.7
2 BK	61.0	ACTUAL 1M + 2BK 70.0	2 BK	3.1	ACTUAL 1M + 2BK 1.9
3 M	48.5	PREDICTED 1M+2BK 71.0	3 M	4.5	PREDICTED 1M+2BK 2.0

CLARKS CREAM

FLOUR STREAM	AGTRON VALUE	FLOUR COMBINATION COLOR GRADE	FLOUR STREAM	KENT- JONES VALUE	FLOUR COMBINATION COLOR GRADE
2 M	81.2	ACTUAL 2M + 3M 65.5	2M	.8	ACTUAL 2M + 3M 2.4
		PREDICTED 2M+3M 67.0			PREDICTED 2M+3M 2.3
3 M	52.7	ACTUAL 2M + 3BK 54.5	3 M	3.9	ACTUAL 2M + 3BK 3.7
3BK	38.5	PREDICTED 2M+3BK 59.8	3 BK	5.7	PREDICTED 2M + 3BK 3.2

KSU 73256

FLOUR STREAM	AGTRON VALUE	FLOUR COMBINATION COLOR GRADE	FLOUR STREAM	KENT- JONES VALUE	FLOUR COMBINATION COLOR GRADE
1 M	81.7	ACTUAL 1M + 3M 66.5	1 M	1.0	ACTUAL 1M + 3M 2.5
		PREDICTED 1M+3M 66.4			PREDICTED 1M+3M 2.5
3 M	51.0	ACTUAL 1M + 3BK 52.5	3 M	4.1	ACTUAL 1M + 3BK 4.0
3 BK	32.7	PREDICTED 1M+3BK 57.2	3BK	6.3	PREDICTED 1M + 3BK 3.6

Agtron and Kent-Jones Color Grade Change Over Time

An investigation into the change of Agtron and Kent-Jones color grades over time came about by accident. Initially, the flour streams from the Multomat experimental mill tests were tested for Agtron and Kent-Jones color grades. These values were substituted for ash values in the cumulative ash curve table. The table values obtained for straight grade flours were compared to some actual samples of straight grade flour that had been weighed, blended and tested for Agtron and Kent-Jones color grade. The artificially produced straight grade values from the tables were from 4 to 5 Agtron units and .3 to .4 Kent-Jones units better than the actual straight grade flour colors. This degree of difference was unacceptable and it was decided to use the method described in Methods and Materials for the production of the actual cumulative color curves. The Multomat flour streams for the three varieties had been stored at room temperature for the three weeks necessary to conclude the initial color tests. Once it was determined that the table method was not going to produce acceptable cumulative color curves, the flours were stored in a cold room for nine weeks.

Upon initiation of the second phase of the effort to produce cumulative color curves for the Multomat experimental mill flours, each individual stream was once again checked for Agtron color grade. A few of the pertinent flour streams from each variety were also checked for Kent-Jones color grade. The color grade values from the initial tests, the after storage color tests and a third set of color grade values obtained on a different model Agtron reflectance (M-400 Model) meter are presented in Table 5.

As can be seen from the table values, most of the flour streams

MIAG MULTOMAT FLOUR COLOR GRADES FOR VARIOUS TIMES AND METERS

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FLOUR STREAM	INITIAL AGTRON M-500 MODEL COLOR GRADE	INITIAL KENT- JONES COLOR GRADE	12WEEK AGTRON M-500 MODEL COLOR GRADE	12 WEEK AGTRON M-400 MODEL COLOR GRADE	12 WEEK KENT-JONES COLOR GRADE
EAGLE					
1 BK	57.5	3.6	57.5	—	—
2 BK	61.0	3.1	62.5	—	—
GRADER	64.2	2.9	65.7	—	—
1 M	81.0	.9	83.5	—	.6
2 M	81.5	1.0	84.7	—	.6
3 M	48.5	4.5	50.0	—	—
1M REDUST	81.5	.9	83.0	—	.6
3BK 4M 5M	5.0	12.4	5.5	—	—
SI GRADE	59.7	3.0	60.5	—	3.1
CLARKS CREAM					
1 BK	61.0	3.1	62.5	63.0	—
2BK	64.5	2.8	65.7	65.7	—
GRADER	66.5	2.5	69.5	68.5	—
1 M	81.7	1.0	84.5	84.5	.6
2 M	81.7	.8	84.2	84.2	.4
3 M	51.0	4.1	52.0	52.5	—
1MREDUST	81.5	1.1	84.5	84.5	.6
3BK 4M 5M	23.0	9.2	22.5	23.0	—
SI GRADE	64.5	2.5	66.5	66.0	2.6
KSU 73256					
1 BK	52.7	4.1	55.0	55.5	—
2BK	57.7	3.5	59.5	59.2	—
GRADER	60.7	3.1	63.2	63.0	—
1 M	77.0	1.1	81.2	81.0	.7
2 M	81.2	.8	83.0	82.7	.6
3 M	52.7	3.9	55.0	56.0	—
1MREDUST	79.0	.9	82.5	82.0	.7
3BK 4M 5M	19.5	8.3	20.7	21.0	—
SI GRADE	60.5	2.9	62.5	62.0	2.9

improved in color grade over time. The streams with the least amount of bran contamination (1M, 2M, 1M Redust) showed the most improvement. Both the Agtron Reflectance meter (Green Mode) and the Kent-Jones color grader indicated marked improvement in color grade values over time. It is not surprising that both meters would yield similar results because they are both using a light source with very similar wavelengths. The Agtron, in the green mode, has a wavelength of 546 nm. and the Kent-Jones color grader has a permanent wavelength of 530 nm. What is surprising is the the green mode Agtron Reflectance value would be affected by time. The only change in the flour that could have taken place would be in the form of an oxidation reaction. Several researchers have documented that bleaching, an oxidation reaction, does not effect the green wavelength of the Agtron color meter (Gillis, 1963; Kent-Jones et al, 1950; Patton and Dishaw, 1968; Skarsaune and Shuey, 1975). Because of this fact, the Agtron values obtained after the storage period were checked for accuracy on a model M-400 Agtron Reflectance meter. The values obtained on the M-400 model Agtron were almost identical to the color grade values obtained on the after storage flours using the M-500 model Agtron. These results do not agree with existing research and further investigation into the effect of time on green Agtron and Kent-Jones color grade is definitely warranted.

CONCLUSIONS

The ultimate purpose of this study was to compare Hard Red Wheat to Hard White Wheat. Comparisons were made in an effort to answer certain questions or ascertain specific wheat quality characteristics that concern processors and consumers. The three basic quality characteristics emphasized were flour color, flour extraction and baking quality.

Initially, it was determined that Hard Red Wheat had a greater discoloring power than Hard White Wheat. In all ten locations tested, the Hard Red Wheat had a greater discoloring power than either of the two Hard White Wheats. Once the discoloring power assumptions were verified, a flour color versus extraction level relationship was sought in an effort to prove that additional flour extraction, without the loss of color quality, could be obtained using Hard White Wheat. The Ross and Multomat experimental milling systems were utilized in an effort to produce just such a relationship. In both cases, (Hard White Wheat produced a 2% addition in flour extraction at a common commercially accepted color grade.) From experimental baking results, it was determined that one of the White Wheats was well suited for commercial baking, while another was not. The Hard Red Wheat seemed well suited for commercial baking.

Several areas of new research that would be quite pertinent to the expanded production of White Wheat deal with the diverse utilization of the main product, flour and the basic by product, bran. In this specific research, the individual flour samples were only tested for their yeast leavened bread capabilities. The new expanding export market demands that wheats being considered primarily for export purposes must be tested to determine their ability to produce not only yeast leavened bread, but noodles and pasta and possibly chapatti. In the case of all of these

commodities, a demand for whiter products has already been demonstrated. If White Wheat can fulfill these demands, its marketability would be greatly enhanced.

White Wheat bran demands a premium in this country and abroad. In the United States, White Wheat bran is primarily used to produce breakfast cereals. Little if any work has been done on analyzing bran samples and their effects on different products. Bread samples could be baked with different amounts of bran added and crumb color evaluations determined by using the technique developed by Pomeranz. Pasta production seems to be another likely area that White Wheat could meet certain product requirements. In many cases, White Wheat is amber in appearance like durum, depending upon the vitreousness of the kernel. If White Wheat were tested and found suitable for pasta production, the many problems associated with buying and shipping several different types of wheats could be eliminated.

In the final analysis, a wheat variety will be determined adequate or inadequate depending upon the purpose for which it is purchased. Developing nations, in need of long extraction wheats, would be very interested in the White Wheat variety which yielded the 2% additional extraction without the loss of color quality. A country such as Japan, the United States' largest grain importer, is not that concerned with yeast leavened bread products but is more concerned with flour color, which controls the color of their noodles. U.S. wheat producers desperately need to recognize that wheat export markets are changing, and with them, wheat quality characteristics. White Wheat's ability to give a higher yield of flour than Red Wheat at a comparable flour color standard has not gone unrecognized by world wheat importers and many of them now actively seek it. The increased growth of Hard White Wheat in the United States will not be achieved without overcoming certain obstacles and prepossessions. The

prepossession that White Wheat is only of the soft variety and therefore not suitable for bread production can only be overcome by additional published research. It is true that White Wheat is more susceptible to sprouting than Red Wheat. The exact causes of sprouting have not yet been ascertained but it is accepted that it is a genetic problem. This problem could possibly be eliminated through additional research using genetic manipulation. Geneticists need to continue to develop new experimental Hard White Wheats until all aspects of Hard White Wheat production and utilization are positive. Such a White Wheat could do nothing but strengthen this country's competitive advantage in the world wheat export market.

RECOMMENDATIONS

Several questions were raised by the initial studies in the general flour color investigation. A review of the literature indicated strong support for the additive effect of Kent-Jones and Agtron color grade (Murthy and Dietz, 1974). But the additive effect indicated by this research had to be qualified. The additive effect was only present when the flours being combined were of similar color grade. Continued research in this area is definitely warranted. Several combinations of different flour grades should be tested in an effort to determine if an additive color effect exists for all flour combinations or only for a few of these combinations.

Another area of the general flour color investigation which requires additional research is in the effect of time on Agtron (green mode) color grade. Several researchers have reported that the green Agtron is not affected by bleaching. Oxidation is the only change that could be taking place in the flour over a certain period of time. Yasunaga and Uemura, on the other hand, were convinced that carotenoid pigments of flour had an effect on flour color even after bleaching. A time study needs to be initiated in an effort to document the change of flour color over a series of time periods. Flour samples should be stored at room temperature and at cold storage conditions.

A final area that deserves additional consideration concerns the production of a cumulative color curve through the use of a table as is accomplished for the cumulative ash curve. The cumulative ash curve table was utilized in an attempt to produce a cumulative color curve by replacing the flour ash value with its color grade value. This effort did not prove to be acceptable. A table similar to the ash curve table needs to be de-

veloped so that cumulative color curves could be produced easily. In plotting the effect of bran contamination on color and ash, color used a second degree equation and ash utilized a first degree equation. It is possible that a second degree form of the flour color grade is what is necessary for the production of a table produced cumulative color curve.

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"A Milling and Baking Comparison of Hard White Wheat
Versus Hard Red Wheat With Flour Color
and Extraction Level as Primary Quality Factors"

by

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A milling and baking comparison of Hard White Wheat versus Hard Red Wheat was performed using two Hard White Wheat varieties (Clark's Cream, KSU 73256) and one Hard Red Wheat variety (Eagle). The three wheat varieties were grown during the 1976 crop year at ten different Kansas Experimental Stations. Comparisons were made in an effort to answer certain questions or ascertain specific wheat quality characteristics that concern processors and consumers. The three basic quality characteristics emphasized were flour color, flour extraction and baking quality.

Initially, the effect of White Wheat bran flour and Red Wheat bran flour on flour ash and Agtron and Kent-Jones flour color were determined by adding incremental amounts of bran flour to some existing Buhler straight grade flours. The flour ash and color grades were plotted against the percent of bran flour added and linear relationships were obtained for ash (ash = percent bran) and quadratic relationships were obtained for color grade (color = percent bran + percent bran²). High correlations and R² values were obtained for each variety at each location. Results of this work established that Hard Red Wheat bran had a greater flour discoloring effect than Hard White Wheat bran.

Once the discoloring power assumptions of Hard Red Wheat bran were verified, a flour color versus extraction level relationship was needed. This relationship could prove that additional flour extraction, without the loss of flour color quality, could be obtained using Hard White Wheat. The Ross and Multomat experimental milling systems were utilized in an effort to produce this relationship. In both cases, cumulative flour color versus extraction level graphs indicated that a 2% addition in flour extraction, at a common commercially accepted flour color grade, was obtainable using Hard White Wheat as opposed to Hard Red Wheat.

The baking results indicated that the Hard Red Wheat and one of the Hard White Wheats were well suited for commercial baking, while the other White Wheat tested could not be recommended for commercial use.