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"MILLING AND BAKING QUALITIES OF HARD WHITE WHEAT AS COMPARED TO HARD RED WHEAT"

by

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B.S., Bombay University, 1961

A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Grain Science and Industry

KANSAS STATE UNIVERSITY

Manhattan, Kansas

1976

Approved by

Major Professor

For

My Mother

and

Margaret, Neil, Jeremy and Ruth

and also

The Memory of my Father.

"They furnish shade to others

while standing in the sun themselves."

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INTRODUCTION AND REVIEW OF LITERATURE

Importance Of Wheat As A World Food

In the course of the last few years feeding the people of the world has become a serious problem. Wheat provides more nourishment for the people of the world than any other food source. It therefore has a crucial role to play in the nutritional plans of the world. The wheat grower has thus to grow wheat to satisfy his potential market. He has three types of market to feed, namely:

(1) The first is the affluent countries of the West. This market has abundant sources of food and highly sophisticated quality discerning tastes. In these countries, with the aid of technology, the production of wheat is increasing substantially. Further, per capita consumption of wheat is stationary or showing a slight decline.

(2) The second group is the financially rich countries, such as Japan and the Middle East countries. Cereal eating habits are growing in these countries, but they raise little if any wheat. Thus they have to import the bulk of their wheat requirements.

(3) The third group comprises the developing countries of Asia, Latin America and Africa, where we see alarming increases in population. To satisfy their needs, the current food production within the countries concerned is very inadequate.

TABLE 1. PERCENTAGE IMPORTS OF VARIOUS COUNTRIES

Year / Country	1963-64[1]	1972-73[2]	1975-76
Western Europe	21.38%	12.27%	10.22%
Eastern Europe	6.39%	6.97%	6.57%
USSR	17.69%	22.11%	18.98%
China	9.06%	7.86%	4.38%
Indian Subcontinent	9,06%	6.08%	12.55%
Japan	7.49%	8.16%	8.32%
Others	28.39%	36.64%	38.98%

Further, wheat is steadily replacing the coarse grains such as rice and barley, because it is a more balanced food source. Only recently has there been extensive research and development activity to produce low cost, nutritional, consumer acceptable wheat products. Consequently these countries import and will continue to import substantial quantities of wheat for years to come.

Formerly the rich countries of the West were the principal customers for the wheat exporters. But with the lower per capita consumption combined with an increase in wheat production, their imports have substantially declined. The United Kingdom and the West European countries still import quantities of strong, high protein wheats to blend with their homegrown wheats. They also are mindful of the cost involved and are keen to get long extraction wheats to keep their imports to a minimum.

Presently, we have the developing countries starting to buy by far the larger proportion of wheat traded in the world market. There has been a slight increase in the total world trade; i.e. 67.4 million metric tons was traded in 1972/73 and 68.5 million metric tons in 1975/76. But more importantly there has been a change in the countries' relative proportion of imports. Table 1 shows that the Indian sub-continent and others (Africa, Latin America and the Middle East) now take about 50% of the wheat exported.

The largest wheat exporters of the world, namely the

United States, Canada, Australia and Argentina, have comparatively new markets to feed. In the past, quality demands by buyers were somewhat limited. But now with the demands of the new markets and the changes in requirements of the old markets, there is need for a fresh assessment of the quality factors.

World wheat production in 1975/76 is estimated to be about 349 million metric tons. Of this about 68.5 million metric tons will be available for export (see Table 2). The United States is estimated to be able to export about 35 million metric tons. Its main rivals in an extremely competitive market are Canada, Australia and Argentina.

Wheat Classes

Wheat is a member of the grass family Gramineae. It belongs to the genus Triticum. This genus has 14 species. Of these species three are of commercial importance:

(i) Triticum Compactum i.e., Club Wheat

(ii) Triticum Durum i.e., Durum Wheat

(iii) Triticum Vulgare which provides the wheat used to make breadmaking flour. It may be soft or hard in texture; Winter or Spring classes; and red or white in kernel color. Based on the above in the United States there are seven classes of wheat grown, namely:

1) Hard Red Spring
2) Hard Red Winter
3) Soft Red Winter
4) Durum
5) Red Durum
6) White Wheat (Hard or Soft)
7) Mixed Wheat.

TABLE 2A. WORLD WHEAT PRODUCTION, 1972-73-1975-76(2)*

	72/73	73/74	74/75	75/76
Canada	14.5	16.5	13.3	17.0
Australia	6.4	11.9	11.2	11.0
Argentina	6.9	6.6	5.7	7.7
W. Europe	51.4	50.8	56.5	49.0
E. Europe	30.7	31.5	34.1	29.5
USSR	86.0	109.8	83.8	75.0
China	31.6	30.2	31.2	31.2
Indian Sub-Cont.	33.4	32.7	30.0	33.3
U.S.	42.0	46.4	48.8	58.1
Other	37.0	32.0	35.7	37.2
Total	339.9	368.4	350.3	349.0

*million metric tons

TABLE 2B. WORLD WHEAT TRADE 1972-73 - 1975-76, JULY-JUNE CROP YEAR (2)*

	72/73	73/74	74/75	75/76
EXPORTS				
Canada	15.6	11.7	11.1	13.0
Australia	5.6	5.3	8.2	8.7
Argentina	3.4	1.1	2.2	2.8
USSR	1.3	5.0	4.0	-
U.S.	31.8	31.1	28.0	35.3
Other	9.7	8.0	10.8	8.7
Total	67.4	62.2	64.3	68.5

*million metric tons

Hard Red Winter is predominant. It comprises nearly 60% of the total wheat grown. Soft Red Winter makes up 14% of the crop, Hard Red Spring about 14%, Durum about 3%, and White Wheat about 10%.

Most of the Hard Red Winter grown in the U.S. is grown in the Great Plains. These plains have ideal conditions for growth of wheat. As noted in the book "Wheat Field to Market", good hard wheat with a high protein percentage and strong gluten quality can be grown in Kansas, provided these qualities are bred in the varieties, and proper fertilizers used. Soils in these areas are capable of producing an abundance of wheat with desirable protein content and quality. The climate too, with an annual rainfall of 20-40 inches, a long cool growing season, a warm and dry harvest period, abundant sunshine and an elevation well above sea level, helps to give high yields without a drop in protein content.

Statewide, Kansas is the largest Wheat grower in the United States, producing about 20% of the total U.S. wheat crop, North Dakota grows 14%, and Washington grows about 6%. The Kansas crop is almost entirely Hard Red Wheat. It exports more than half of its crop, the exports being almost entirely Hard Red Wheat. With such a large export market, the buyers' requirement are of great importance to the Kansas wheat grower. In the past a large proportion of the export was to countries like the United Kingdom, Western Europe and Japan where the imported wheats were used to supplement the local wheats in a blend, to produce bread, calling for high protein, bread wheat. Hard Red Wheat which is fairly strong and produces excellent bread both by itself and as a supporting flour, admirably filled the requirements. With the shift in the pattern of international trade, consumer demands have to re-appraised. Consumers decide preferences on the basis of habit, taste, custom and most importantly on economic considerations. These economic considerations are of particular interest to the developing countries of Asia, Africa and Latin America. Here a primary factor taken into consideration is the flour extraction level. It is imperative to be able to increase the flour extraction levels so that the vast numbers of people can be fed within the financial limits of the countries concerned.

Wheat Kernel Structure

The wheat kernel is a dry, one seeded fruit. It has on one surface a crease, which in the commonly grown varieties, extends inwards nearly to the center.

Structurally the wheat consists of a number of parts as can be seen from Fig. 1. The pericarp surrounds the entire seed and acts as a protective covering. The outer pericarp consists of the epidermis and hypodermis layers. The inner pericarp is composed of intermediate cells, cross cells and tube cells, going inwards from the hypodermis.

The pericarp or fruit coat is fused with the seed coat. Together they form the two protective layers around the endosperm and the germ. Finally there is the aleurone layer which is

THIS BOOK CONTAINS NUMEROUS PAGES WITH DIAGRAMS THAT ARE CROOKED COMPARED TO THE REST OF THE INFORMATION ON THE PAGE.

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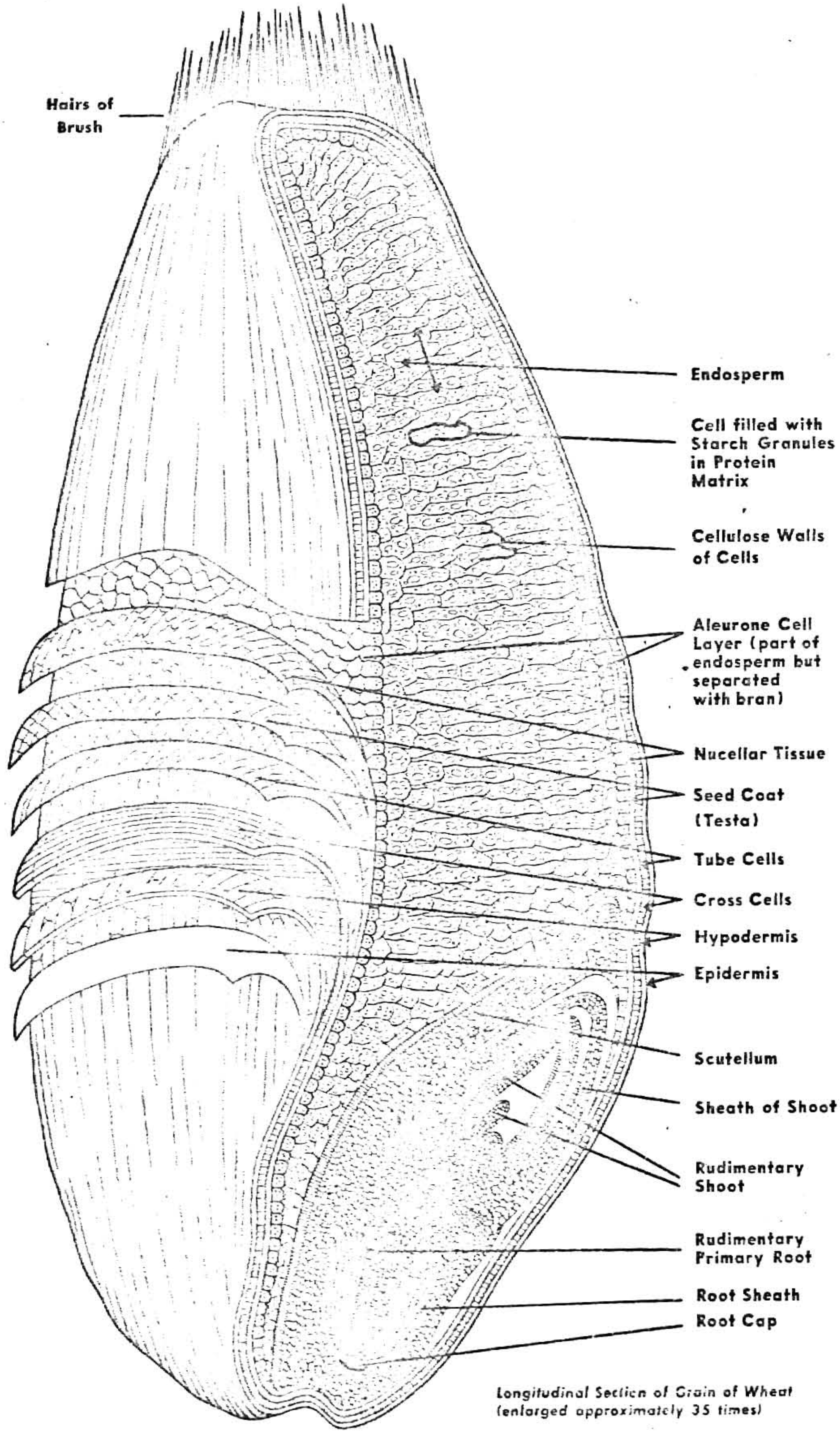
a Kernel of Wheat



Longitudinal Section of Grain of Wheat (enlarged approximately 35 times)

Fig. 1

the outer layer of the endosperm tissue, but usually accompanies the bran in the normal milling process. This aleurone cell layer is composed of cellulose cells with moderately thick cell walls.

Enclosed within these layers is the endosperm which makes up 83% of the kernel. The endosperm cells contain many starch granules embedded in a proteinaceous matrix. It is this starchy endosperm which is the source of flour.

The germ located at the base of the kernel, is structurally a separate entity from the endosperm. It constitutes about 2.5% of the wheat kernel.

Kernel Color-Chemical and Functional Aspects

All the outer structures of the kernel inward to and including, the alureone layer comprise what is called "Bran" by the miller. Bran consists of the pericarp (Inner and Outer), the seed coat and the aleurone layer. From the color standpoint, wheat is classed as either Red or White, depending on the color of bran. The basic red or white is varietal. The seed coat which is part of the bran has three layers: a thick outer cuticle, a central "color layer" and a very thin inner cuticle. This "color layer" is filled with dark colored pigments in red wheat and so is known as the pigment strand. In white wheat this pigment strand contains little or no pigment, depending on variety (6). Myanoto and Everson (7) point out, relatively little is known about the chemical or physiological function of the pigments in the wheat kernel. These chemists investigated the catechin and catechin tannin contents of the pericarp and seed coat in white and red wheats. They found a close positive correlation between the degree of kernel color in wheat and quantity of catechin and catechin tannin present in the seed coat. They found more catechin and catechin tannin in red wheat seed coat than in white wheat seed coat. They also found that catechin and catechin tannin content in the pericarp of both white and red wheat was negligible.

These workers further suggest that catechin is the precursor of catechin tannin which in turn is a precursor of phlobasphene, a reddish brown pigment. It is thus assumed that the higher the content of catechin and catechin tannin, the greater the formation of phlobasphene and hence darker the seed.

As mentioned previously we need a wheat which can give an increased extraction of acceptable quality standards. In the United States a 70% extraction is normal. Wheat contains 82% of the white endosperm of which flour is made. But in the process of milling as we increase flour extraction, there is substantial contamination of the endosperm by adhering bran and germ.

Table 3 shows that bran contamination increases substantially with increase in extraction levels (8). The main drawback in higher extraction is bran contamination. Bran contamination is frowned upon for two basic reasons i.e., nutritional and functional.

(1) Nutritionally opposing claims have been made about the effect of bran addition. A study in England (9) in the early

TABLE 3. BRAN CONTAMINATION AT VARIOUS EXTRACTION LEVELS (8)

Extraction	80%	85%	100%
Bran	1.4%	3.4%	12%
Germ	1.6%	1.9%	2.5%
Endosperm	77%	79.7%	85.5%

part of the century suggested that with increased extraction, the percentage digestibility for energy as well as protein decreased. But a study carried out in 1954 by the British Medical Society concluded that "Taking into account all circumstances there is no ascertainable difference between 85% extraction flour and a lower extraction flour which has been enriched with Vitamin B, and Iron". Thus there seems to be no evidence that within limits, high extraction flour is inferior purely on nutritional grounds.

In a recent article, Dr. R. Passman (10) reports that lack of dietary fibre contributes to incidence of cancer of the colon. He cites an example of Africa where there are fewer cases of cancer probably due to the presence of indigestible fibre in food. There is therefore ground to think that higher extraction flours may even have some beneficial nutritional effects.

(2) Functionally there are two aspects. One is the effect on baking quality. There is no evidence that within small limits, an increase in bran adversely affects bread volume. Research needs to be carried out to find maximum levels of extraction having levels of bran contamination that do not adversely affect baking quality.

More important is the effect of high extraction on color of flour. Historically bread has been judged on its whiteness which depends on flour color. Flour color depends on carotenoid pigments of the endosperm and contamination by bran. Color of well milled flour without excessive bran contamination is purely dependent on the carotenoid pigments which if excessive can be bleached. If the color due to carotenoid pigments is controlled, then further color variability depends on bran contamination. As bran contamination increases, color would be darker. If a particular wheat were milled, the color would deteriorate as bran contamination increased. Bran from different wheats have different "specific discoloring powers". Equal proportions of bran from white and red wheat affect the color of the resultant flour differently. In tests conducted in England (11), the best color values were given by Australian white wheat as compared to red wheat flour. It thus seems that white wheats have very substantial points in its favor in increasing flour extraction. The importance of this factor cannot be over-emphasized. For example it is projected that the import requirements of the Indian sub-continent will be 8.6 million metric tons in 1975/76. If through the use of White wheat, extraction were increased by only 5% without affecting the quality, this would mean an extra half million metric tons of flour. This is a very substantial amount both from the economic viewpoint as well as the angle of the massive world food shortage.

Finally the cultural preferences of the buyer are a substantial factor. There is such a preference for white wheat in many countries. An example is the Indian sub-continent. Here whilst machine-made, mass-produced white bread is gaining acceptance, very large segments of the population live in rural areas. Here wheat is traditionally ground into "atta" - a wheat meal which contains about 95% of the original kernel. This is then baked into "chappattis" - an unleavened type of bread. Substantial consumer resistance has been noted here to the imported hard red wheats when used instead of the "historic" white wheats.

Another example is Bulgur. This is an insect-resistant, pre-cooked, high storage, fortified convenience food. Up to 500 million lbs. of this has been annually exported to the Middle East from the United States. Bulgur can be made from all types of wheat. But white wheats yield a preferable golden yellow color as against the darker brown product given by red wheat (15).

White Wheat Market Potential

From these facts, there does seem to be a "prima facie" case, for the growth of Hard White Wheat, as there is a substantial possible market for this type of wheat.

Of the major international exporters only Australia concentrates on Hard White Wheat. Australia has nearly doubled its production over the last five years (see Table 2). Of the projected 11 million metric tons production in 1975/76 it is expected to export about 80% of its production, i.e., 8.7 million metric tons - almost all Hard White. Australian wheat is well known abroad for its plump kernels. It is also well accepted as it yields a high percentage of flour of good color.

Within the U.S. itself only 12% of the wheat grown in 1975/76 will be white. Of this less than a quarter will be hard white, which is grown mostly in the Pacific North West specifically in the Washington State area. Most of the wheat grown in the Pacific North West is exported to India, Japan and Taiwan (see Table 4). Until 1947 a high percentage of wheat grown in the Pacific North West was red wheat; in 1952 only 20% was red wheat and currently only 3-4% is red wheat. The shift came in the 1950's when it was noted that many of the white varieties yielded more than the red varieties. This was noted even in the driest areas (11).

But the white wheat grown in the Pacific North West is Soft White or low protein Hard White. This problem of Hard White wheats, like Burt, having low protein values has tended to give Hard White wheats an unfavorable reputation for bread-making. Barmore and Bequette (13) have pointed out the tendency of growing Burt in high yield areas, has created the quality problem of too little protein for bread flour. High protein Burt flours have high sedimentation and viscosity values, strong mixing properties and large loaf volumes typical of the better hard red varieties. Table 5 shows that Hard White Wheat grown correctly can be as good as Hard Red Wheat.

Australian research has shown that to grow a strong high protein wheat the following is needed: a) a fertile soil and sufficiently high levels of available nitrogen , b) optimum seasonal rainfall and incidence at proper times, c) a variety which genetically is capable of giving a combination of optimum yield and protein content.

TABLE 4. WHEAT CLASSES - PRODUCTION AND EXPORTS IN UNITED STATES (37)

Year Beginning July 1	Supply			Disappearance			Ending Stocks June 30
	Beginning Stocks	Production	Total	Domestic Use	Exports	Total	
	Million Bushels						
1975/76							
Hard Winter	186	1,056	1,242	267	735	1,002	240
Red Winter	20	342	362	165	175	340	22
Hard Spring	70	328	399	155	160	315	84
Durum	21	123	145	43	60	103	42
White	30	285	315	55	220	275	40
All Classes	327	2,134	2,463	685	1,350	2,035	428

TABLE 5.a)HARD WHEATS GROWN AT LUND EXPERIMENTAL STATION IN WASHINGTON (38)

	Variety & Class	T.W.	Flour Yield	Flour Ash	Mill Score	Wheat Prot.	Flour Prot.	Flour Color
1972	Burt HWW	61.7	71.7	.40	84.4	14.1	13.1	46.5
1972	Coulee HWW	62.3	72.1	.42	84.5	13.6	12.8	45.8
1973	Burt HWW	62.0	71.2	.48	80.3	14.9	3.9	67.0
1973	Coulee HWW	62.4	71.4	.49	79.9	14.2	15.0	64.0
1973	Wanser HRW	62.3	71.7	.42	84.2	14.0	14.9	68.0
1974	Burt HWW	60.9	72.7	.37	88.2	11.5	9.6	74.8
1974	Coulee HWW	62.8	72.1	.38	86.6	11.2	10.1	81.3
1974	Wanser HRW	62.8	73.0	.36	89.4	12.4	11.0	74.8

b)HARD WHEATS GROWN AT LUND EXPERIMENTAL STATION - LONG TIME AVERAGE (38)

Variety	No. Obs. (n)	Flour Yield	Flour Ash	Mill Score	Flour Protein	Bake Abs.	Mix Time	Loaf Vol.
Wanser (HR)	81	72.9	.38	88.4	11.3	63.6	4.4	842
Burt (HW)	194	72.3	.42	85.1	11.9	65.4	4.5	834
Coulee (HW)	29	72.1	.40	85.7	10.1	64.0	4.6	782

HWW = Hard White Wheat

HRW = Hard Red Wheat

HR = Hard Red

HW = Hard White

It is known that a strong wheat needs besides a strong genetic variety, correct farm practices and optimum soil conditions. We notice in some cases in the Pacific North West, that all strong varieties have not necessarily given strong wheats. This has often been due to soil deficiencies, unfavorable weather and other environmental factors.

Although there is definitely a market for Hard White Wheat in the World market, the U.S. as a major exporter of wheat is not currently in a position to fully satisfy this demand. This neglect could be due to the belief that Hard White Wheat is intrinsically inferior to Hard Red Wheat as a bread making wheat and in its milling properties. There is some basis to conclude that this belief is more a result of "prejudice" rather than a scientifically proven fact. One of the commonly held notions is that Hard White Wheats tend to suffer in protein quantity and kernel hardness when compared to Hard Red Wheat. But one of the most popular White varieties on the International market, Australian Prime Hard, is a very high protein and hard wheat. So it cannot be said that this White Wheat is genetically inferior to Red Wheat in protein.

We have a case for investigation of Hard White quality. Wheat quality is a complex concept. To be acceptable, a variety must satisfy the requirements of the grower, the processor and the consumer.

From the grower's viewpoint, Gillis and Sibbit (15) point out that a variety is acceptable if

" a) it matures properly in its environment and lends itself readily to a typical harvesting process without shattering or having the kernels spontaneously fall from the husk;

b) it threshes easily and remains clean; and

c) it presents a good yield of cleaned wheat."

In parts of the world where it is grown, there is no evidence that Hard White Wheat has problems in meeting any of the above requirements. The three main factors of climate, soil and variety are interdependent and affect variety. When White Wheat from one region compares unfavorably with Hard Red Wheat from another region, one must remember this important influence of environment and other growing conditions.

Another factor to be considered is yield. As previously noted, the reason that the growers in the Pacific North West shifted to White Wheat was the higher yield obtained in comparison to Red Wheat. In Australia, too the yield of Prime Hard compares favorably to that for Hard Red Wheat in Kansas. Thus we see that White Wheat has an equal yield potential if not a better potential than Red Wheat.

The main adverse factor from the grower's point of view is the sprouting problem. On occasion haavy rainfall during or just prior to harvest results in deterioration of the grain , mainly due to germination in the head. In such cases the following happen successively:

a) grain coat dulling,

b) loss of test weight,

c) increase in protein-degrading and starch-degrading enzymes, and

d) actual sprouting (16).

Functionally this sprouting results in marked increases in Alpha Amylase activity and the water soluble portion of the Alpha Amylase. Increased Alpha Amylase activity results in excessive liquefaction of starch during baking, giving a sticky crumb in bread (17).

All wheat is, in varying degrees, susceptible to such deterioration. The extent of weather damage depends, among other things, on the rainfall, temperatures experienced and stage of maturity of the plant. Since Red Wheats are known to have more tolerance to pre-harvest rain damage and White Wheat is more susceptible to the sprouting problem, permeability of the seed coat is also involved (16). It is felt that the protein in the red kernel seed coat is less permeable to water and provides greater dormancy. Myamoto and Iverson (17) theorize that a dehydrogenase is necessary for germination. They postulate that the catechin and catechin tannin in red wheat inactivate this dehydrogenase. As the red colored kernel has a higher level of the tannins it would be less susceptible to sprouting than the white kernel.

The exact causes of sprouting have not yet been ascertained, but it is accepted that this is a "genetic" problem. Geneticists believe it possible to develop a white grain which is as dormant as the red grain by genetic manipulation. The grower's problems are being investigated by agronomists. Assuming that the grower will have no disadvantage in growing white wheat one has to ascertain the Hard White Wheat's milling and baking qualities.

This project was therefore undertaken to make an initial investigation of the milling and baking properties of White wheat vis-a-vis Red Wheat. One part of the plan was to investigate the ability of White Wheat to give a higher extraction flour as compared to Hard Red Wheat using color as a quality factor. As Hard Red Wheat is accepted as a breadmaking wheat, it was used as a standard to which White Wheat was compared.

Of primary importance to the miller is the ability of the wheat to give a high yield of flour with minimum bran contamination. For the international and domestic market, it is imperative to ascertain the ability to give a higher extraction flour without having unacceptable bran contamination levels. Also as many of the foreign buyers still prefer wholemeal a comparative study of whole meal may be of some use.

The bread baker in his evaluation requires a flour with a high water absorption, a medium to a medium-long mixing time requirement with satisfactory tolerance, good dough handling properties and finally the ability to give a full-volume loaf when baked.

Quality Testing Principles

The determination of wheat milling or baking quality is complex. No single test has yet been devised to establish conclusively whether a particular wheat is good or bad. Many individual tests are preformed to measure different parameters. These are then taken together to give a composite picture which can be used to predict overall quality. The relationship between chemical composition, physical and physicochemical properties and the actual milling and baking performance is not exactly defined. Final judgment is always made on the basis of actual experimental milling and baking tests under well defined conditions.

On this basis, wheat quality evaluation is done as follows:

a) Investigation of Physical and Chemical Characteristics of wheat,

b) Experimental Milling Results,

c) Investigations of Rheological and Chemical Characteristics of Flour and Dough. These are indicators of Baking potential.

d) Experimental Baking Tests.

Chemical Wheat Tests

i) Protein Percentage. In evaluating a Hard Wheat for breadmaking we are concerned with the ability of the flour to hold the gas produced by the fermentation process. This ability depends on the protein content and protein quality of the flour. The protein content of the flour is dependent on the protein content of the wheat. Johnson (19) states that the quality of protein in wheat is the best single indicator of flour strength potential. Aitken and Geddes (18) showed as early as 1938 that there is a linear relationship between protein content and loaf volume within a particular variety.

The importance of protein level nutritionally can not be overemphasized. Another important factor is the economic angle, as in many markets including the U.S. and the international market, protein content is used to establish grain prices.

ii) Ash Content. It is related to the amount of bran in wheat and hence has a rough inverse relationship to flour yield. Small or shriveled kernels have more bran than plump kernels on a percentage basis and thus a higher ash percentage. Millers have been known to locate areas of production in which endosperm ash content of wheat is lower and selectively accept such wheat.

iii) Moisture Content. Excessive moisture will result in grain deterioration. Above 13.5% moisture, wheat is unsafe for extended storage in some areas. At the other extreme, around 8-9% it is excessively brittle, and there is the possibility of kernel damage. This can affect the milling properties.

Moisture is also an important economic factor. This is because dry weight is net weight. Comparisons of protein and ash contents of different wheats, are made on dry weight basis.

<u>Physical Wheat Tests</u>

i) Test Weight is the weight per unit volume; that is lbs. per bushel (1.25 cu. ft.). Kernel shape, uniformity of size and shape, and grain density influence the Test Weight. Earlier, Test Weight was considered as a highly accurate index of flour yield potential. But later data show that this is not entirely correct. Based on some tests, above 57 lbs. per bushel, the test weight has relatively little influence on flour yield. Below this, flour yield falls rather sharply, with decreasing test weight suggesting shriveled wheat. Test weight can be taken as a rough indicator of flour yield when used in combination with other factors. But test weight is very important as a grading factor in the U.S.

ii) Thousand Kernel Weight is the weight of 1000 kernels of wheat. It is dependent on kernel size and density. Large, dense kernels have a higher ratio of endosperm to non-endosperm fraction, as compared to smaller less dense kernels. 1000 kernel weight is a fairly good indicator of flour yield potential.

iii) Kernel hardness is an important quality characteristic. Milling behavior and flour suitability for end use depend significantly on grain hardness. Harder wheats have a higher tolerance to conditioning moisture levels, produce granular stock which flows easily, allow good bran clean up and tend to give higher extraction at better color levels. However, the work involved in reducing the harder endosperm to flour results in more starch damage. This in turn results in higher water absorption, which is of importance to the bread baker. This kernel hardness is an important quality factor (20).

iv) Wheat Size Test. Flour yield is substantially dependent on kernel size. A larger kernel has the potential to yield more flour as detailed above. Shuey (21) reported a method to separate wheat kernels into three batches dependent on cross sectional area. Using a mathematical formula giving the larger kernels more weightage in flour yield potential a theoretical yield is obtained. Shuey reported high correlation between theoretical and actual yield. Dattaraj(22) et al. also found the test promising, but they pointed out that moisture values also played a part in this assessment.

Experimental Milling Tests

Each of the above mentioned physical and chemical tests evaluates particular wheat characteristics. They are indicators which when taken together give a rough comparative quality evaluation. To get a fairly reasonable indication of the commercial milling behavior of the wheat we finally have to carry out Laboratory Test milling. This is commonly known as Experimental Milling. The basic aim is the production from a small amount of wheat, of flour equivalent in its properties to that which would be produced by a commercial mill. The milling capabilities are judged by checking such factors as yield, ash contamination and color and their inter-relationship. Effect of increasing extraction on color and other functional characteristics can be checked. Experimental milling gives an indication of the actual physical millability of the wheat under test. Factors such as optimum tempering, roll pressure for optimum yield, bran, shorts etc. can be gauged (23).

Many types of Experimental Mills have been designed. They range from the very simple, which do batch testing, to extremely sophisticated mills like the Miag Multumat which can do continuous milling. In this study, the Buhler Pneumatic Laboratory Mill, an experimental mill of intermediate sophistication, was used. Various mathematical formulas have been devised to get an empirical millability indicator. The reliability of these tests depends on the reproducibility of the results. This depends largely on the operator and the particular experimental mill used. A substantial effort at standarization is required. Properly conducted experimental milling is an effective milling indicator. After the milling process the flour obtained is subjected to the following series of tests.

Chemical Flour Tests

1) Protein Content is important, as many other flour qualities are a function of protein content. Finney and Yamazaki (22) point out that water absorption, mixing requirement, mixing tolerance, dough handling, oxidation requirements, loaf volume and bread crumb are in various degrees proportional to protein content.

2) Moisture Percentage. Three important reasons for the importance of moisture measurements are given by Pyler (25), namely:

a) Economic importance; as a baker who buys high moisture flour is in fact buying water at the price of flour.

b) Stability of flour in storage is inversely related to moisture content.

c) Undetected gain or loss of moisture in storage can effect dough characteristics.

3) Ash Content is an indication of the mineral content of the flour. In the wheat kernel, the bran and aleurone layer contain at least 20 times as much as mineral matter as the endosperm (see Table 6). This large differential helps to check the efficiency of the milling process. When a particular wheat is milled, then the higher the ash content, the more the bran contamination (see Table 7). Hitherto it has been standard practice in the milling industry to take ash figure as a quality determinant. But there are growing objections to the use of ash as a flour grade factor. Sebestyn points out (39) the determination of the ash content of the grain per se reveals practically no relationship to the baking qualities of the flour. It only helps to indicate the rate of extraction for a particular wheat blend. When comparing the milled products from two different wheats, ash content may be misleading. The intrinsic mineral composition and content of wheat depend on the minerals of the soil, and environmental conditions. Consequently, one wheat may have a substantially higher ash figure than another (see Table 8). In such a case the higher ash figure of the resultant flour from one wheat as compared to another is not a reflection necessarily of higher extraction and/or bran contamination, but could be a reflection of higher ash content in the endosperm.

There have been considerable investigations undertaken to

TABLE 6. MINERAL COMPOSITION OF COMMERCIAL FLOUR MILL FRACTIONS AND BREAD, DRY BASIS(40)

	Ash %	K %	P %	Mg %	Ca %	Na ppm	Zn ppm	Fe ppm	Mn ppm	Cu ppm	Mo ppm	Co ppm
Wheat	1.96	0.455	0.380	0.167	0.045	12.8	31.0	37.3	49.0	4.0	0.33	0.024
Farnia	0.43	0.115	0.065	0.021	0.019	5.0	6.6	5.4	4.6	1.6	0.17	0.004
Patent flour	0.48	0.122	0.105	0.027	0.021	5.2	6.4	7.4	6.0	1.5	0.19	0.004
First clear flour	0.86	0.190	0.196	0.065	0.030	7.5	15.3	20.4	9.0	2.7	0.32	0.012
Low grade	1.93	0.434	0.294	0.156	0.045	8.5	44.5	43.6	35.8	5.5	0.39	0.023
Germ	3.98	0.889	0.923	0.268	0.048	23.2	100.8	66.6	137.4	7.4	0.67	0.017
Red dog	4.07	0.903	0.781	0.342	0.110	30.5	105.3	131.4	121.4	14.2	0.70	0.074
Shorts	5.64	1.293	1.307	0.541	0.133	37.2	100.1	145.7	164.7	13.3	0.79	0.099
Bran	7.28	1.671	1.570	0.688	0.128	30.6	99.4	141.3	136.5	15.2	0.83	0.109
Bread	--	0.191	0.183	0.034	1.127	8580.0	9.7	27.3	5.9	2.3	0.32	0.022

TABLE 7A. RELATION OF FLOUR ASH TO BRAN CONTENT (41)

Percentage of ash in flour	Percentage of shorts and bran in flour
0.36	0.75
0.40	1.48
0.46	2.75
0.50	3.29
0.60	5.11
0.80	10.00

TABLE 7B. RELATION OF FLOUR ASH TO EXTRACTION (42)

% Ash	% Flour Extraction
0.44	75
0.49	77.5
0.58	80
1.50	100

TABLE 7C. PERCENTAGE OF MINERAL IN WHEAT GROWN UNDER VARYING CONDITIONS (43)

Treatment	Per Cent
No irrigation water	1.56
35 inches irrigation water	2.28
Spring wheat (average of 7 varieties over 8 years)	1.60
Winter wheat (average of 17 varieties over 8 years)	1.40
Wheat grown in 1934 (dry season)	1.09
Wheat grown in 1923	1.58
No manure, stubble burned	1.52
Green manure	1.71

find alternative ways of detecting bran contamination. The most successful indicator so far has been flour color. As stated earlier main sources of color in flour are the carotenoid pigments and contamination by outer layers of the kernel commonly known as bran. The color due to carotenoid is characteristic of the endosperm. It has a yellowish tint. The color due to the mineral content i.e. ash content is a measure of the contamination of the flour by finely ground branny material. It is the measurement of this color factor that is being considered to replace the Ash figure. This substitution of flour grade measurement by color measurement instead of ash measurement is being used more widely.

Within a given mill mix, the amount of pigments in the endosperm remains the same. As flour extraction increases we expect more bran contamination. Hence to measure the grade, one has to measure the flour color as affected by the relative levels of bran contamination. On this principle the simplest and first method of flour measurement was the Pekar Test. Flour samples to be compared are laid side by side on a wooden stick, a smooth surface is formed, and then wetted by dipping in water. On wetting, the enzyme Tyrosinase reacts with bran protein to develop a brown color. The amount of brown specks being proportional to the bran contamination one gets a comparative indication of flour grade. This is a comparative and relatively subjective method. More recently specific instruments have been devised, which give numerical readouts proportional to the effect of the bran on the flour color. These give objective flour color measurement. The two most well known of such instruments are the Agtron Reflectance Spectrophotometer, widely used in the U.S., and the Kent-Jones Spectrophotometer used in Great Britain, Canada and parts of Europe.

The Agtron Reflectance Spectrophotometer has mercury and neon gas discharge tubes emitting light. This light illuminates the product and its monochromatic reflectance can be measured at one or more of four spectal lines. The reflectance is measured by a photo-electric cell which finally gives a readout indicating the reflectance in the 0-100% range. The lower the bran contamination, the higher the reflectance (26, 27). A number of calibration discs with varying shades of gray to white are provided. With these discs the Agtron readout scale can be calibrated as required. Substantial research has been done on the use of Agtron for Evaluation of Cereal Flours. Some of the principal findings are given below:

a) Gillis in 1963 (28) worked on an early model Agtron. He found that on a Blue Agtron-wavelength 436nm, variation due to carotenoid pigments and bran contamination could not be distinguished separately as this wavelength was sensitive to the yellow carotenoid pigments. But when Gillis shifted to the green mode-wavelength 546 nm, he noticed this mode was relatively insensitive to yellow but sensitive to brown red color range in which bran lies. It was found that this wavelength gave maximum values for bran contamination. Murthy and Dietz (26) also confirmed this finding. It is now accepted that the green mode is the correct spectral line for measurement of flour grade.

b) Patton and Dishaw (29) in 1968 reported that the particle size of flour affected the reflectance readings. Hitherto the reflectance was taken directly on the flour under test. They introduced a new method of forming the sample into a flour-water slurry, so that the influence of particle size was minimized.

c) Murthy and Dietz (26) found that when two samples of different color reflectance readings were blended, the resultant color readings were an arithmetical average. This showed the color readings were additive just like ash.

The Kent-Jones Reflectance Spectrophotometer is another instrument based on similar principles. It is a direct reading instrument, employing a balanced photo-electric circuit. It uses the principle of the reflection of light from a flour-water paste at a wavelength where there is minimum interference from varying yellow taints due to carotenoid pigments, so that dullness of the flour due to bran contamination rather than influence of carotenoid pigments is measured.

Flour color readings taken by the above mentioned methods have a relationship with ash content within the same mill blends. But the color values of two different flours made from different wheats, depend not only on the bran contamination but also on the "specific discoloring power" of each particular bran. Jones (11) reports that his experiments show Australian white bran has a lower discoloring power. Hence it seems possible to get a higher extraction with a White wheat with a comparable color as compared to a Red wheat. Consequently the use of color measurement as a flour grade indicator takes on added significance.

Physico-Chemical Dough Tests

In evaluating dough qualities, we must note that we are testing wheats for breadmaking quality, where two factors are important; gas production and gas retention. To get an optimum loaf, the dough must have the ability to produce sufficient gas to inflate the starch-gluten matrix. To complement this, the gluten in the dough must have the resistance and extensibility for optimum elasticity, which defines the gas retention properties of the dough. The tests used in this study were the following:

1) Gas Production Test. In this test one measures the carbon dioxide produced by a fixed quantity of yeast from a fixed quantity of dough under standarized experimental conditions. The diastatic enzymes in flour hydrolyze the starch into fermentable sugars, which are then fermented by the yeast enzymes into Carbon Dioxide and alcohol. Production of Carbon Dioxide is of critical importance in the fermentation and baking process, and it has to be produced at an optimum rate and amount. In the United States where sugar is added at the mixing

stage in high levels this may not be very critical, but in the United Kingdom, Europe and Asia, where the sugar added is comparatively low, the sugar formed by diastic activity is critical. The gas Pressuremeter test is as Blish (30) points out an indicator of the flour's inherent potential for supporting yeast fermentation.

2) Amylograph Test. The diastatic enzymes Alpha and Beta Amylase together play a crucial part in the sugar production vital to gas production. Normally Beta Amylase is available in sufficient quantities. Alpha Amylase levels tend to vary and need to be measured. Alpha Amylase has the ability to attack gelatinized starch rapidly, but Beta Amylase is inactivated around gelatinizing temperatures. In this test a starch-water slurry is gradually heated. The starch starts to gelatinize around 65°C., when we have an increase in viscosity due to gelatinization. This is countered by the liquefying action of Alpha Amylase on the gelatinized starch, till the enzyme is inactivated around 85°C. A measurement of the final viscosity serves as a measure of the liquefying action of the Alpha-Amylase which is a measure of the Alpha-Amylase activity not its concentration. Enzyme activity is also a function of the substrate, and this test can give an indication of unusual starch damage (Substrate condition). Gelatinization temperature is another parameter measured. There is a connection

between the gelatinization temperature and crumb characteristics and usually high gelatinization temperatures result in poor crumb characteristics. Also as already indicated, white wheat is more susceptible to sprouting, wherein Alpha-Amylase activity is very high. Amylograph evaluation can give an indication of Alpha Amylase activity of normal sound hard white wheat and its comparative values with hard red wheat. These tests give some indication of the gas production potential. The following three tests are indicators of the gas retention properties of the flour, where we measure the "physical properties" of dough. The physical properties in question are viscosity, ductility, elasticity, and plasticity and their interrelation with Water Absorption.

3) The Farinograph consists of a bowl with two mixing paddles rotating in opposite directions. The force required to rotate the mixing blades is proportional to the relative plasticity and mobility of the dough, and is recorded in the form of a curve. Doughs which are stiffer require the application of more force registering as a higher figure in the Farinograph chart and vice versa. Water Absorption, mixing time and mixing stability are two of the most important readings which can be taken off the Farinograph. These give an idea of general quality of flour. Farinograph testing is empirical, and it is a very good machine for comparative work. It

helps to compare the rheological properties of hard white and hard red flours at different stages of the mixing cycle. High water absorption, optimum mixing time and a long stability are looked for in a good bread flour (31).

4) The Extensigraph measures the elastic properties of the dough. It measures the stress to strain ratio, by applying a standard force to a dough at a given rate in a given direction. In this method a dough prepared under standard experimental conditions is placed in a Extensigram arm. A dough hook moving through it at a standard rate stretches it. The stresses set up in the dough by the hook as a result of the dough's resistance to extension are recorded in a graph form, called an Extensigraph, from which we can read off the resistance and extensibility at various points. The units are empirical. Bakers often apply the terms lively and springy to describe a dough with ideal baking properties. Dough with a too high resistance and too little extensibility will be rough and bucky and difficult to machine. Doughs with too little resistance and too much extensibility will be weak and may not machine at all. To be lively and springy, an optimum relationship between resistance and extensibility must exist. The Extensigraph aids in measuring these factors.

5) Mixograph. The mixing of flour and water serves two

purposes. The ingredients blend to form a homogeneous mass, after this the gluten proteins develop into a continuous phase. These two actions together when optimally carried out give a smooth elasticity, plasticity and viscosity. The result is a dough with optimum gas retention properties. The Mixograph measures the crucial point of optimum elasticity, plasticity and viscosity and its relationship to mixing time. The Mixograph consists of a cylinder into which the flour and water are put. Four pins, moved by a motor, mix the flour and water into a dough and meet a resistance depending on flour characteristics. This resistance is recorded graphically. From a perusal of this graph, an experienced operator can get (a) Water Absorption, (b) Optimum Mixing Time and, (c) Mixing Tolerance. These measurements help in comparing overall mixing characteristics of bread flour.

Experimental Baking Tests

Most of the tests described so far are empirical in nature. They give measurements of mixing characteristics, water absorption, dough elasticity etc., which are indicators of baking potential. But they have certain limitations. One is that the test procedures significantly change the material properties of the dough, and it is difficult to make more than empirical interpretations in basic physical terms (32). Further the final actual potential which depends on the interaction of the various properties cannot be specifically measured. This can ultimately be judged by the Baking test. In the Baking test, the flour is worked into a dough under specified experimental conditions. We can then see how the flour behaves under actual baking conditions.

The Baking test is not a simple procedure, but requires a significant degree of skill and expertise and adherence to procedural details for meaningful results. There are two methods of test baking. In the European method, adjustments are made in formulation and methodology to bring out the full potential of each flour. In the American A.A.C.C. method, conditions are standardized as far as possible so as to eliminate the effect of the human element.

In this series of tests, the American (A.A.C.C.) method was used.

Using these methods an initial investigation was carried out to investigate the quality of white wheat as compared to red wheat. Special importance was given in this project to the Experimental Milling aspect, to find out if in fact it was possible to increase extraction with a color advantage for white wheat as compared to red wheat. These flours were then checked to ascertain their comparative bread-making characteristics.

MATERIALS AND METHODS

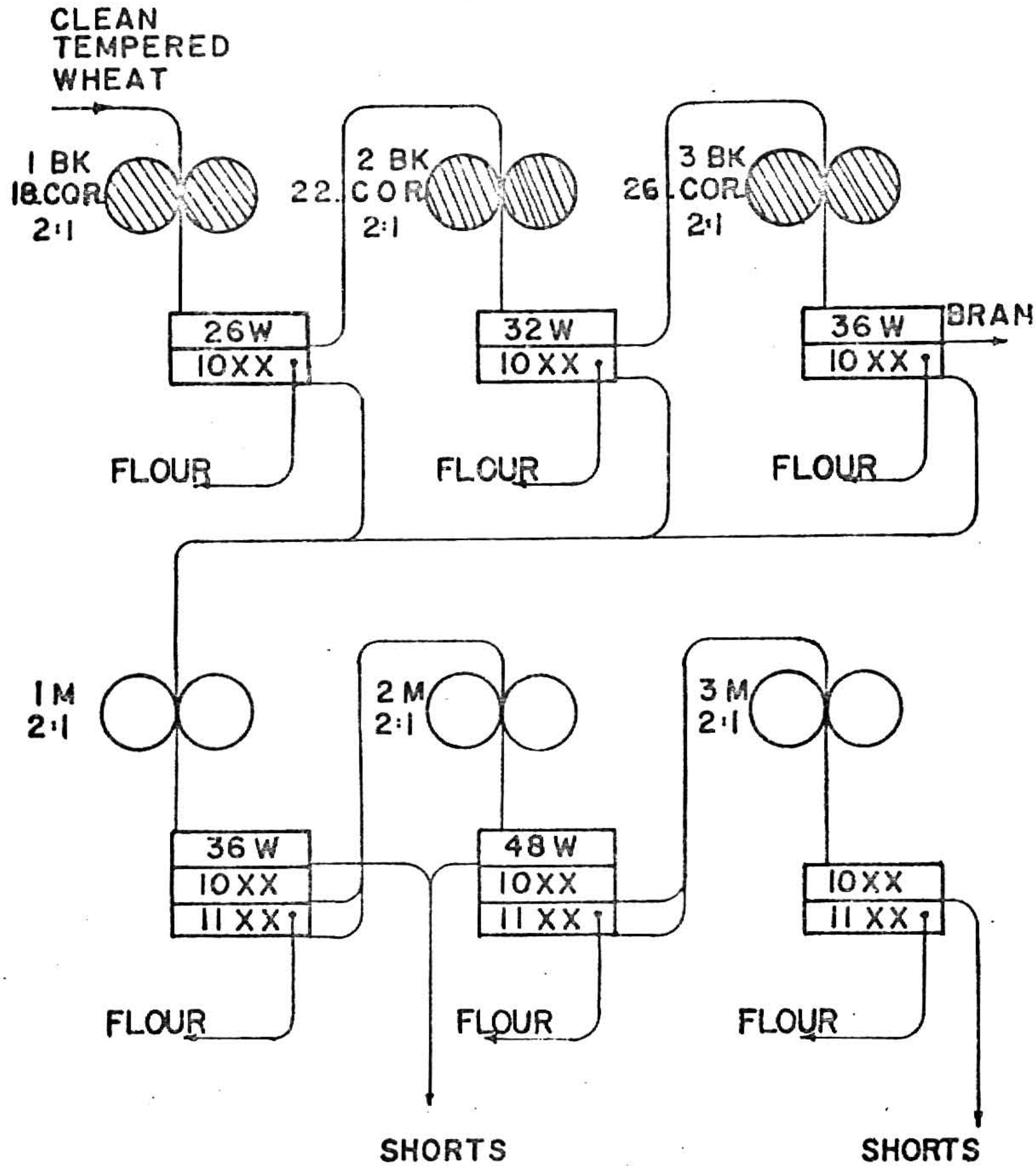
Wheats

Wheats were selected from Kansas and Washington. Very little White Wheat is grown in Kansas and obtaining it was very difficult. Two samples were obtained from Newton, Kansas; Clark's Cream (Hard White) and Golden Chief (Hard Red). Samples from the 1973 and 1974 crops were obtained. The problem with this particular White wheat was that the kernel was not as white as expected. However the 1973 sample was the better and the milling tests were done on this sample.

Washington wheats obtained through the USDA Agricultural Research Station at Pullman, Washington, were grown at the Lund Experimental Station in Washington. The wheats obtained were Coulee (Hard White), Burt (Hard White), and Wanser (Hard Red). Small samples of 1972, 1973, 1974 were obtained and a larger sample of the 1975 crop. The problem with these samples was that the wheat qualities in terms of protein quantity and hardness varied from year to year. Coulee varied even within the same year in terms of hardness. The color was constant, and the White Wheats - Coulee and Burt - were in terms of color ideal. They were used to check the relationship between extraction and color for white and red wheats.

Flours

Wheat was milled on the Buhler Experimental Mill. The flow of the mill is shown in Fig. 2. This consists of three



FLOW SHEET FOR BUHLER EXPERIMENTAL MILL

Fig. 2

breaks and three reduction rolls with sifters. The rolls have a differential of 2:1 with the fast roll running at 540 r.p.m. The break rolls were corrugated and had the following corrugations:

First Break - 18 corrugations per inch

Second Break - 22 corrugations per inch

Third Break - 26 corrugations per inch.

Each flour stream flowed into separate containers as did the bran and the shorts. All these were collected individually and weighed. Their percentages were calculated and used in all further calculations. The straight grade was formed by mixing all the streams in the proportion in which they were milled (33).

Prior to milling, wheats were tempered to the requisite moisture and for tempering the initial moisture of the wheat was ascertained on the Tag-Happenstal Meter. Then the water to be added to this sample was calculated by the formula:

$$(100-M_1)W_1 = (100-M_2)W_2$$

where

M_1 = Moisture percentage of original sample.

M_2 = Moisture percentage required.

W_1 = Total weight of original sample.

W_2 = Total weight of tempered sample.

The requisite amount of water was added to the sample, and it was then mixed in a Laboratory Tempering Unit for 10 minutes. It was then allowed to stand for 24 hours before milling.

For setting the Buhler Mill, it was first operated empty for 30 minutes to allow the rolls to attain normal grinding temperature. After this the lock nuts on all four knobs were loosened and the rolls set at 0.10 mm distance. After the rolls were set, the nuts were tightened. The pointers were then set at 10 on all four knobs, and the roll spacings were changed to the following settings:

Break Rolls		Reduction Rolls	
Left	Right	Left	Right
7	3	5	2

This was the basic setting used and finer adjustments were made as required and are described in individual tests. All millings were repeated three times to ensure reproducibility. When this was consistently and successively achieved, the readings of the last test were used for further calculations.

A detailed account of the Buhler operation is given in the Cereal Miller's Handbook (34) which was used as a basis for operations.

WHEAT TESTS

Wheat Protein, Moisture and Ash

Protein was estimated by the Kjeldahl nitrogen method, using the factor 5.6. Moisture was determined by heating the samples in a convection oven for one hour at 130°C. Ground wheat was ashed to constant weight at 550-600°C. These estimations were done according to standard AACC methods (35).

Physical Tests

1) Test Weight per Winchester bushel was determined on approved apparatus by the method described in the USDA circular 21.

2) 1000 Kernel Weight was determined by counting the number of kernels in 40 gms. of wheat by an electronic seed counter after all foreign matter and broken kernels were removed. 1000 Kernel Weight was calculated by the formula:

$$\text{1000 Kernel Weight} = \frac{40 \times 1000}{\text{No. of kernels in 40 gms.}}$$

3) Kernel Hardness or Pearling Value was obtained by using 20 gms. of wheat free of foreigh material and broken kernels. The wheat sample was retained for one minute in an operating Strong Scott Laboratory Barley Pearler equipped with a No. 30 grit stone and a 10 mesh screen. Pearling value is the percentage of original sample remaining on a 2 mesh screen after the sample is removed from the pearler.

4) Wheat Size Test was made using 200 gms. of wheat placed on the top sieve of a stack of 3 Tyler standard sieves (Nos. 7, 9, and 12). The stack is placed on a Ro-Tap sifter and sifted for 60 seconds. The percentage of wheat remaining on each sieve was determined by weight. The percentages were multiplied by 78, 73, and 67 respectively and summed up to obtain theoretical flour yield (21).

Flour Tests

1) Flour Moisture, Ash and Protein were determined by standard methods described in the Cereal Laboratory Methods (AACC) (35).

2) Flour Color, Color evaluation was done with the Agtron Spectrophotometer and the Kent-Jones Spectrophotometer.

The Agtron Spectrophotometer used in this experiment has four spectral lines; blue-436nm, green-546nm, red-640nm, and yellow-360nm. Various researchers including Shuey (27), Patton and Dishaw (29), and Murthy and Dietz (26) have clearly shown that the effect of bran and other low grade materials is most effectively measured in the green mode which is unaffected by the creamy or yellow color of flour arising from the bleachable carotenoid pigments (28). All measurements were therefore made in the green mode-546nm.

Before use the machine was heated for a minimum of 24 hours. The Agtron meter scale was calibrated with two discs - 65 and 90 - at 0% and 100% reflectance respectively. The discs are in varying shades of gray, the whiteness increasing with the number of the disc.

The flour samples were made into slurries consisting of 20 gms. of flour and 25 ml. of distilled water. Slurry was mixed for 2 minutes by hand using a glass stirrer with a rubber policeman, after which the slurry was checked to see that there were no lumps or air holes in the light reflecting surface at the bottom. The slurry was then set aside for 5 minutes and then the Agtron reading was taken. The meter scale callibration was checked before each reading. All readings were taken in duplicate and repeated if the difference was more than ±0.75.

The Kent-Jones and Martin Spectrophotometer was operated to the manufacturer's instructions. Briefly this method involved warming up the machine for 30 minutes. The machine was calibrated with a Standard Working Reference Surface. The sample was prepared in the form of a slurry consisting of 30 gms. of flour and 50 ml. of distilled water. This was mixed in a beaker to form a smooth paste. It was ensured that the reading was taken within 90 seconds of the start of the mixing operation. All readings were duplicated.

3) Gas Production Test - Method was the AACC Method 22-11 as given in the AACC Methods (35).

4) Amylograph Test - Method used was the AACC method 22-10 as given in the AACC Methods (35).

5) Farinograph Test - Method used was the AACC Method 54-21 as given in the AACC Methods (35).

6) Extensigraph Test - Method used was the AACC Method 54-10 as given in the AACC Methods (35).

7) Mixograph Test - Method used was the AACC Method 54-40 as given in the AACC Methods.

8) Baking Test - 100 gms. of flour were mixed in a 3 pin Mixer similar to that used in the Mixograph test - but of larger capacity. The recipe used was:

Flour-----------100 gms.	Sucrose------------5 gms.
Salt------------1 gm.	Fresh Yeast--------2 gms.
Ascorbic Acid---100 p.p.m.*	Malt---------------0.5 gm.
Potassium Bromate---10 p.p.m.*	

*p.p.m.--Parts per million of flour

Water was added according to the indications of the Mixograph Test. Mixing time was also decided by the Mixograph test. After mixing, the dough was allowed to ferment in a Fermentation cabinet (National Mfg. Co-Lincoln, Nebraska) for 105 minutes at 85 F and at 80% Relative Humidity. At the end of this period the punching operation was carried out. For this the rolls were set at 3/16 in. Then the dough was allowed to ferment for a further 50 minutes. Then it was punched for a second time with the rolls at 3/16 in. Again the dough was allowed to ferment in the cabinet for a further period of 25 minutes. The dough was finally punched with the rolls at 5/16 in. Then the dough was passed through the drum molder and put into a greased pan. This was then proofed in the Fermentation cabinet for 55 minutes. Finally it was baked for 24 minutes at 425°F. After baking, the weight and volume were checked. The volume was ascertained by the rape seed displacement method.

RESULTS AND DISCUSSIONS

Wheat

Physical Tests

Table 8 shows little difference in Test Weight, 1000 Kernel Weight and Kernel Hardness between the White and Red wheats in the Kansas Series. There were slightly higher values in the Hard White wheats. It was noted that the Hard White wheats were marginally harder and this suggested need for closer grinding for white wheat. This can theoretically result in more starch damage and higher water absorption. These factors within limits are considered advantageous in bread making flours. But the most noticeable factor is the wheat size test, where we note that the Hard White Wheat has a distinctly larger proportion of plumper kernels. This is an advantage in favor of Hard White Wheat as it suggests higher theoretical yield and can result in a higher practical yield with proper milling procedures.

The Washington series showed no difference in Test Weight, 1000 Kernel Weight or Kernel Hardness. But here too, we note, except in one case, the White Wheat has on the average the larger kernel and consequently a higher theoretical yield.

The Washington samples have a decrease of kernel hardness from 1972 to 1976 showing the effect of environment and growing conditions on wheat quality. Generally the Washington wheats (Red and White) are softer than the Kansas wheats. But within themselves the Kansas and Washington varieties are comparable in most respects. There is no evidence to suggest that white

TABLE 8. WHEAT PHYSICAL TESTS

Sample	Test Weight	1000 Kernel Weight	Kernel Hardness	Wheat Size Test			Theo. Yield
				+7W	+9W	-9W	
Cream Wheat-1973 Kansas Hard Wheat	62.1 lbs.	35.18 gms.	78	175	21	4	77.26%
Golden Chief-1973, Kansas Hard Red	60.7 lbs.	29.2 gms.	74	130	67	3	76.16%
Cream Wheat-1974 Kansas Hard White	60.7 lbs.	24.75 gms.	79	110	85	5	75.6%
Golden Chief-1974, Kansas Hard Red	60.8 lbs.	23.30 gms.	79	73	122	5	74.67%
Burt-1972 Washington Hard White	62.2 lbs.	35.46 gms.	49	170	29.5	0.5	77.22%
Coulee-1972 Washington Hard White	62.5 lbs.	32.26 gms.	57	140	59.5	0.5	76.49%
Burt-1973 Washington Hard White	61.8 lbs.	29.76 gms.	60.5	163	37	-	77.07%
Coulee-1973 Washington Hard White	62.3 lbs.	36.04 gms.	64	160	39	1	76.95%

TABLE 8 (continued)

Sample	Test Weight	1000 Kernel Weight	Kernel Hardness	Wheat Size Test			Theo. Yield
				+7W	+9W	-9W	
Wanser-1973 Washington Hard Red	62.4 lbs.	32.71 gms.	61.75	134	65	1	76.32%
Burt-1974 Washington Hard White	60.5 lbs.	40.16	60.5	188	12	--	77.7%
Coulee-1974 Washington Hard White	62.5 lbs.	36.10	62.5	175	24.5	0.5	77.36%
Wanser-1974 Washington Hard Red	62.5 lbs.	36.50	62.5	171	28	1	77.24%
Burt-1975 Washington Hard White	60.9 lbs.	24.6	56.3	186	13	1	77.57%
Coulee-1975 Washington Hard White	60.9 lbs.	40.9	55.3	172	27.5	0.5	77.29%
Wanser-1975 Washington Hard Red	62.8 lbs.	33.45	57	163	36.5	0.5	77.06%

TABLE 8 (continued)

Sample	Test Weight	1000 Kernel Weight	Kernel Hardness	Wheat Size Test +7W	Wheat Size Test +9W	Wheat Size Test -9W	Theo. Yield
Burt-1976 Washington Hard' White	60.4 lbs	31.95 gms.	48	171	27	2	77.22%
Coulee-1976 Washington Hard White	60.9 lbs.	37.31 gms.	48.6	129	69	2	76.17%
Wanser-1976 Washington Hard Red	60.4 lbs.	30.24 gms.	48.75	163	34	3	76.89%
Cream Kansas H.W. (Average)	61.4 lbs.	29.97 gms.	78.5	142.5	53	4.5	76.43%
Golden Chief Kansas H.R. (Average)	60.75 lbs	26.2 gms.	76.5	101.5	94.5	4	75.42%
Burt Wash. H.W. (Average)	60.9 lbs.	34.12 gms.	56.33	177	22.25	0.75	77.31%
Coulee Wash. H.W. (Average)	61.65 lbs	35.09 gms.	57.60	159	40	1	76.94%
Wanser Wash. H.R. (Average)	62.03 lbs	33.23 gms.	57.50	157.8	40.9	13	76.88%

wheat is inferior to red wheat, in fact wheat size and kernel hardness are in favor of white wheat on the basis of these limited numbers of samples.

Chemical Tests

In the Kansas series the Protein values for Hard White is higher in both samples. In the Washington series there is no difference between the Hard White and the Hard Red. Protein is am important indicator of baking potential, we note no substantial difference in baking potential between white and red varieties based on protein content.

Ash values in Kansas and Washington series are practically the same. As there is a rough relationship between ash content and bran content these results show no difference in bran content between the two varieties. This coupled with the fact that white wheat has a plumper kernel, suggests there could be more endosperm percentage in white wheat.

Moisture contents are comparable. There is a slightly higher value generally for white varieties in the Kansas and Washington series.

Main factor noted was that difference in Moisture, Protein and Ash where noticeable is environmental (between Kansas and Washington wheats) and not varietal (between White and Red varieties). These results suggest no major difference in milling potential of the two varieties.

TABLE 9. WHEAT CHEMICAL TESTS: MOISTURE-PROTEIN-ASH

Samples	Moisture	Ash 14%/N.B.	Protein 14%N.B.
Cream-Kansas White, 1973	10.9%	1.45%	12.85%
Golden Chief-Kansas Red, 1973	10.8%	1.45%	12.63%
Cream-Kansas White, 1974	10.4%	1.73%	11.33%
Golden Chief-Kansas Red, 1974	10.2%	1.72%	10.92%
Burt-Washington White, 1972	8.2%	1.22%	13.68%
Coulee-Washington Red, 1972	8.1%	1.22%	13.48%
Burt-Washington White, 1973	8.3%	1.59%	14.72%
Coulee-Washington White, 1973	8.4%	1.69%	14.74%
Wanser-Washington Red, 1973	8.1%	1.50%	14.6%
Burt-Washington White, 1974	9.0%	1.73%	10.49%
Coulee-Washington White, 1974	8.9%	1.23%	10.57%
Wanser-Washington Red, 1974	8.8%	1.23%	10.5%
Burt-Washington White, 1975	9.2%	1.32%	8.91%
Coulee-Washington White, 1975	9.3%	1.13%	8.92%
Wanser-Washington Red, 1975	9.0%	1.32%	8.97%
Burt-Washington White, 1976	7.7%	1.21%	8.57%
Coulee-Washington White, 1976	8.2%	1.22%	8.72%
Wanser-Washington Red, 1976	8.0%	1.22%	8.88%

TABLE 9 (continued)

Samples	Moisture	Ash 14%M.B.	Protein 14% M.B.
Cream-Kansas White, Average	10.65%	1.59%	12.09%
Golden Chief-Kansas Red, Average	10.5%	1.585%	11.78%
Burt-Washington White, Average	8.55%	1.34%	10.67%
Coulee-Washington White, Average	8.70%	1.32%	10.74%
Wanser-Washington Red, Average	8.48%	1.32%	10.74%

Experimental Milling

As discussed in the Introductory section, the basic purpose of milling is initially to separate the bran and germ from the endosperm and then to grind the endosperm into fine particles to give the required flour. In an ideal separation, the flour should not be contaminated by bran. This is an impossibility. There is inevitably some contamination of flour by bran powdered to flour fineness which is undesirable. The ability of wheat to give a maximum yield of flour with minimum contamination by bran is a reflection of its milling values. The milling value depends on two variables; the mill used and the method of its operation; and secondly, the intrinsic milling characteristics of the wheat.

The Buhler mill used in this project, and its operations have been described in the Materials and Methods section. If the mill is operated correctly, its results are reasonably constant. An important part of evaluation is bran detection and estimation which can be done by either ash estimation or color determination. In view of the decision to use color as a quality determinant, the first part of the experimental investigation was to confirm the feasibility of using Agtron (Green Mode) and the Kent-Jones "color figures" as measures of ash.

Relationship Of Ash To Kent-Jones Color And Green Agtron Color

Two wheats, a Hard White and a Hard Red, were milled on the Buhler. Four streams were collected separately on each

TABLE 10. RELATIONSHIP OF ASH TO KENT-JONES COLOR AND AGTRON COLOR

Coulee--White Wheat			Wanser--Red Wheat		
Ash	Agtron Color	Kent-Jones Color	Ash	Agtron Color	Kent-Jones Color
.332	77	0.3	.384	72	1.05
.371	73.5	0.8	.395	69	1.4
.463	69.5	1.3	.433	64.5	2.25
.561	60	2.3	.489	56	2.85

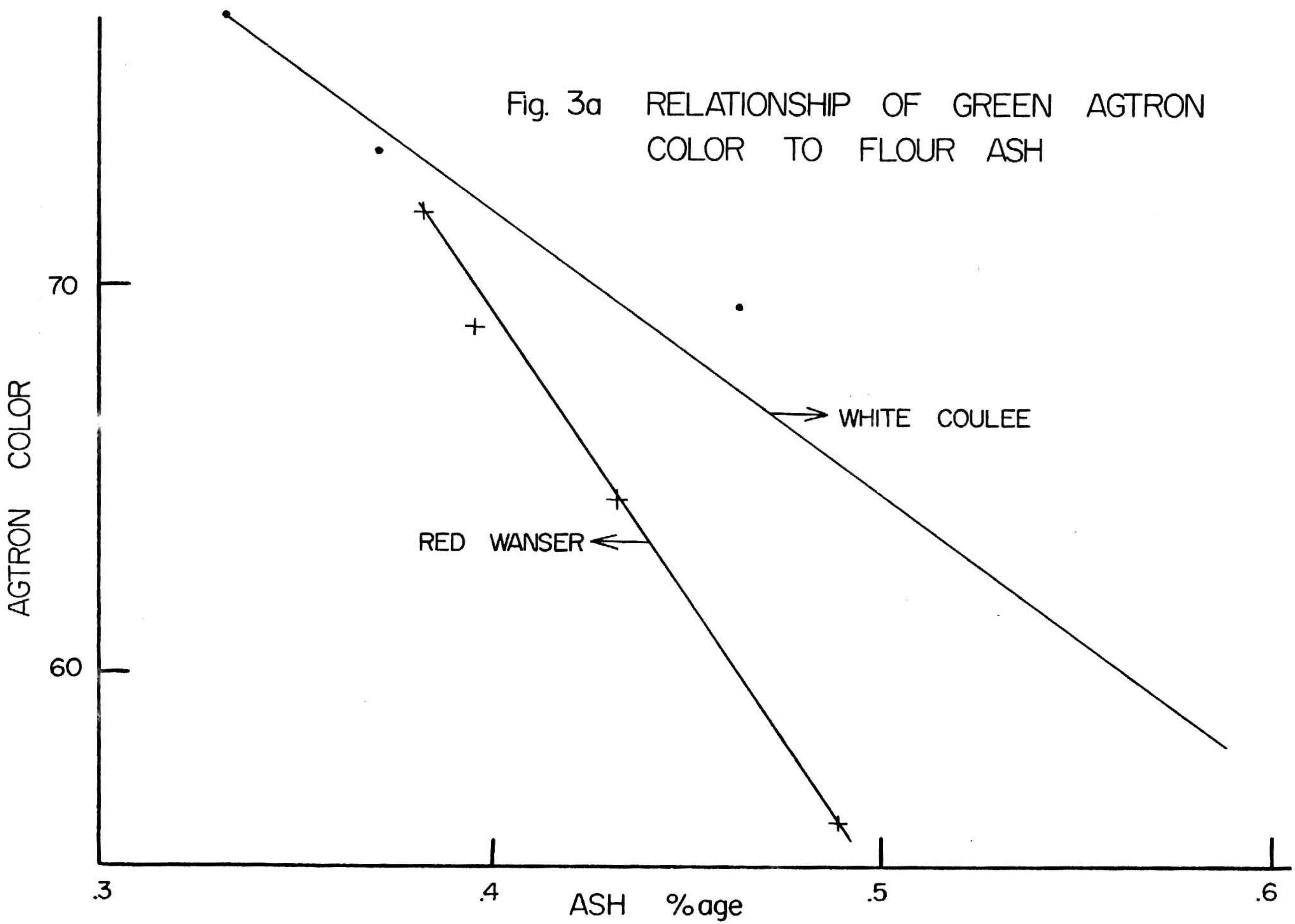


Fig. 3a RELATIONSHIP OF GREEN AGTRON COLOR TO FLOUR ASH

3b RELATIONSHIP OF KENT-JONES COLOR TO FLOUR ASH

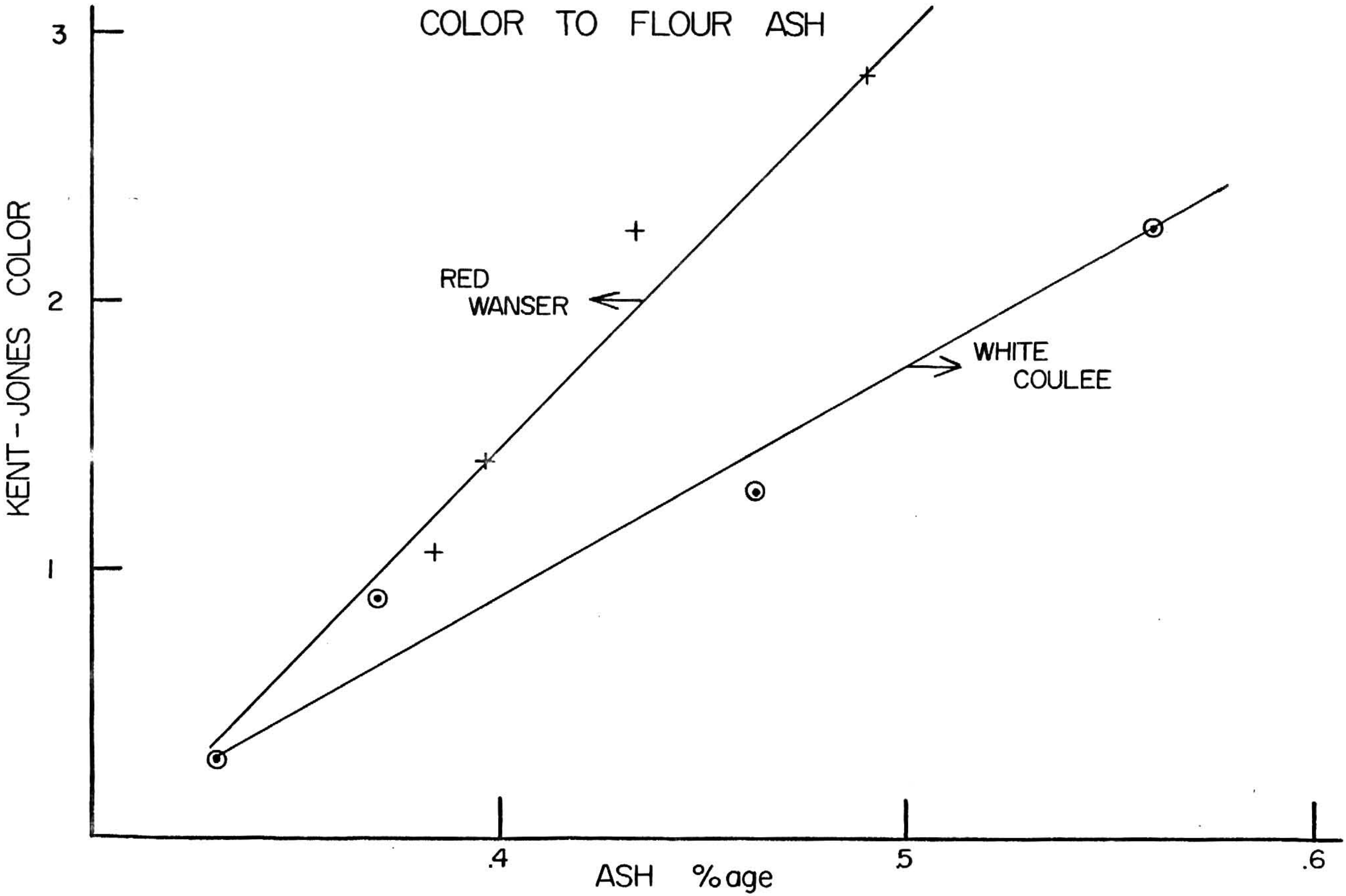
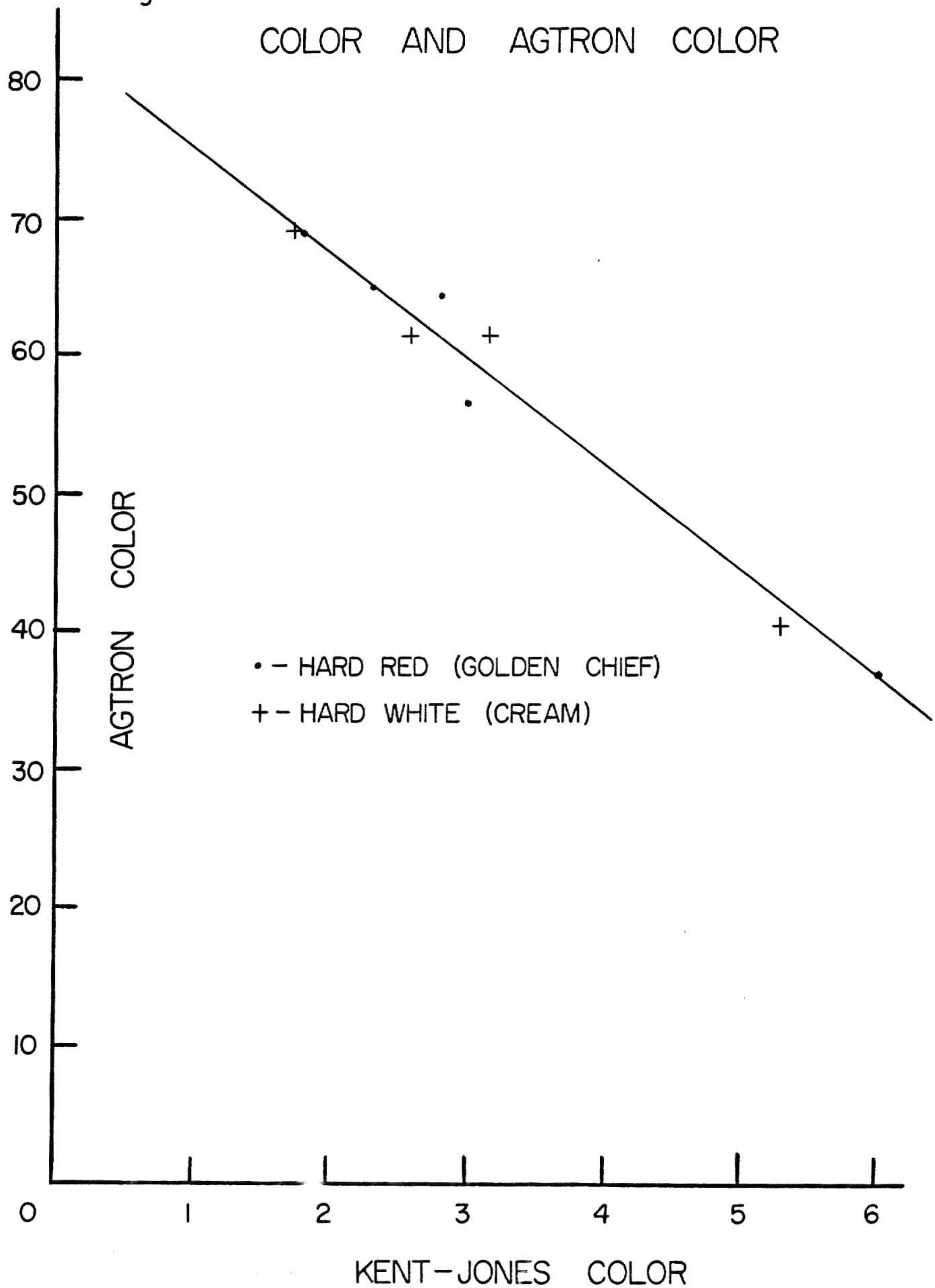


TABLE 11. RELATIONSHIP BETWEEN KENT-JONES AND GREEN AGTRON COLOR

Red Wheat-Golden Chief		White Wheat-Clark's Cream	
Kent-Jones Color	Green Agtron Color	Kent-Jones Color	Green Agtron Color
1.8	69	1.7	68
2.3	65	2.65	62.5
2.8	64.5	3.15	59
3.0	56.5	5.3	41
6.2	37		

Fig. 4 RELATIONSHIP BETWEEN KENT-JONES COLOR AND AGTRON COLOR



milling. These were analyzed for ash, Green Agtron color, and Kent-Jones color. Results are tabulated in Table 10, and plotted on Figure 3A and 3B. These showed that Ash has a straight line relationship with both Kent-Jones and Agtron Color figures.

Each Ash to Color straight line relationship was valid for a particular wheat only. It was noted that the color of the red wheat flour tended to be darker at an equivalent ash level when compared with the white wheat flour. This confirmed the conclusion of C.R. Jones (11) that brans from different wheats have different discoloring power (11) and that the White Wheat discolored less.

<u>Relationship Between Kent-Jones and Green Agtron Color</u>

Two wheats - one Red and one White - were milled under identical conditions. Streams were collected separately and their color checked on Kent-Jones and on the Green Agtron respectively. The results are tabulated on Table 11, and plotted on Fig. 4. This showed a straight line relationship between the Kent-Jones color and the Agtron color. We note that the relationship is valid irrespective of the bran color and that as the bran contamination increases, the Agtron color and the Kent-Jones color are affected proportionately irrespective of the color of the wheat.

<u>Additive Effect On Agtron and Kent-Jones Color</u>

Agtron--Two streams were taken, having the following Green Agtron color:

Stream A----76 Stream B---67.5

They were blended in various proportions as shown in Table 12.

Kent-Jones--Two streams were taken having the following Kent-Jones color:

Stream A---2.4 Stream B---2.0

They were blended in various proportions as shown in Table 13. Results tabulated on Tables 12 and 13 show that both Kent-Jones and Agtron colors are additive. To confirm this a sample of wheat was milled on the Buhler. All six streams were collected and weighed; as were the bran and shorts. All streams were checked for ash, green Agtron color and Kent-Jones color, and then mixed together to make a straight grade. The Ash, Green Agtron, and Kent-Jones Color of the straight grade were checked. The results obtained as Tabulated in Table 14 confirmed that ash, Kent-Jones color and Agtron color are cumulative. This confirms the usefulness of color as a quality factor.

On this basis the Experimental Milling Tests were set. Hitherto the millability was judged by the ability of the wheat to give the highest possible extraction with the least bran contamination as judged by the ash figure. The new quality standard used was to judge the millability of the wheat to give the highest possible extraction with the least bran contamination as judged by the color figure. The objective of these tests was to see how white wheat compared with red wheat in obtaining an optimum extraction which combined maximum flour yield with optimum flour color.

TABLE 12. ADDITIVE EFFECT OF GREEN AGTRON COLOR

Stream A = 76 Stream B = 67.5

Stream A	Stream B	Weighted Average i.e. Expected Color	Actual Color
50%	50%	71.75%	71
66%	33%	72.5%	72.5%
33%	66%	69.75%	69.75%

TABLE 13. ADDITIVE EFFECT OF KENT-JONES COLOR

Stream A = 2.4 Stream B = 2.0

Stream A	Stream B	Weighted Average i.e. Expected Color	Actual Color
50%	50%	2.2	2.25
66%	33%	2.26	2.3
33%	66%	2.13%	2.1

TABLE 14. ADDITIVE EFFECT OF ASH, KENT-JONES COLOR AND GREEN AGTRON COLOR

Stream	%age of Total Products	Ash 14% M.B.	Green Agtron Color	Kent-Jones Color
1 Bk.	10.24	.406	61	2.55
2 Bk.	4.59	.451	64	2.35
3 Bk.	1.04	.679	50	3.1
1 M	29.27	.395	72.5	1.1
2 M	21.72	.415	69	1.15
3 M	5.80	.583	57.5	2.9
Weighted Average	-	.425	67.21	1.72
St. Grade Actual	72.66	.430	67.0	1.65

Experimental Milling Test No. 1

Two Kansas wheats - one a Hard Red and the other a Hard White sample - were tempered and the mill was set as detailed in Materials and Methods. The control sample was then milled, and minor adjustments were made on the roll distances after visual inspection of the bran and shorts to give an extraction of 68-70% on the Control sample. Then the samples under test were milled with these settings.

All streams were collected separately, and checked for Moisture, Ash, Protein and Green Agtron Color and then joined together to form a straight grade which was checked for Moisture, Ash, Protein, Green Agtron and Kent-Jones color. All milling results are tabulated in Table 15. This showed rather suprisingly that the Hard Red had a better color profile which was further confirmed by the Cumulative Ash and Color calculation and the Cumulative Ash and Color Graph (Table 16 and Fig. 5 respectively).

Figure 5 shows that the Hard Red has a lower ash figure up to about 65% extraction above which it tends to rise faster than White Wheat. More surprisingly the Hard Red had a much better color than the Hard White.

The break-up of the mill stream showed the percentage of the break flour for the Hard White was 10.39% as against 8.76% for the Hard Red. The Cumulative Color of the Hard White Break Flour was 57.3 as against 60.6 for the Hard Red Break Flour. Hence it did seem that the mill settings used for the tests were

TABLE 15. RESULTS OF EXPERIMENTAL MILLING TEST NO.1

	Hard White-Kansas Clark's Cream				Hard Red-Kansas Golden Chief			
Sample Weight	2000gms.				2000gms.			
Milling Moisture	16%				15.92%			
	% of Total Products	Ash 14%M.B.	Green Agtron Color	Kent-Jones Color	% of Total Product	Ash 14%M.B.	Green Agtron Color	Kent-Jones Color
1st Break	2.24%	0.49	53.0		1.51%	0.51	56.0	
2nd Break	5.45%	0.43	62.0		4.64%	0.42	63.0	
3rd Break	2.70%	0.50	51.5		2.61%	0.49	59.0	
Break Flour	10.39%	-	-		8.76%	-	-	
1st Reduction	21.40%	0.39	69.0		18.83%	0.39	69.5	
2nd Reduction	28.32%	0.36	69.0		30.0%	0.35	72.0	
3rd Reduction	9.58%	0.47	51.0		11.53%	0.50	57.5	
Reduction Flour	59.3%	-	-		60.35%	-	-	
Straight Grade	69.69%	0.40	64.0	2.3	69.12%	0.42	67.0	2.1
Bran %age	19.77%				20.71%			
Shorts %age	10.55%				10.17%			
Production Loss	1.87%				4.15%			
Flour Moisture	13.8%				13.8%			
Flour Ash, 14%M.B.	.40%				.42%			
Flour Protein, 14%M.B.	11.77%				11.47%			
Average Particle Size, Fisher	20.75%				19.50%			

TABLE 16. EXPERIMENTAL MILLING NO. 1 - CUMULATIVE ASH AND COLOR

	KANSAS HARD WHITE-CLARK'S CREAM									
	Ash						Agtron Color			
Flour	% of Total Product Q	Cum.% of Total Prod. S of Q	%Ash 14% M.B. A	%of Total Prod. x % Ash QxA	Cum. QxA	Cum.%of Ash= Cum.QxA / sfQ	Color C	%of Total Prod. x Color QxC	Cum. Color s of Qxc	Cum.% of Color s of Qxc / s of Q
2R	28.32	28.32	.36	10.2	10.2	.36	69	1954	1954	69
1R	21.40	49.72	.39	8.35	18.55	.373	69	1476.6	3430.6	69
2B	5.45	55.17	.43	2.34	20.89	.374	62	337.9	3768.5	68.31
3R	9.58	64.75	.47	4.5	25.39	.392	51	488.6	4251.7	65.66
1B	2.24	66.99	.49	1.1	26.49	.395	53	118.7	4375.8	65.33
3B	2.70	69.69	.50	1.35	27.84	.399	51.5	139.1	4514.9	64.79
	KANSAS HARD RED-GOLDEN CHIEF									
2R	30	30	.35	10.5	10.5	.35	72	2160	2160	72
1R	18.83	48.83	.39	7.34	17.84	.365	69.5	1308.7	3408.7	71.04
2B	4.64	53.47	.42	1.95	19.79	.370	63	2923	3761	70.34
3B	2.61	56.08	.49	1.28	21.07	.376	59	154	3915	69.81
3R	11.53	67.61	.50	5.77	26.84	.397	57.5	163	4578	67.71
1B	1.51	69.12	.51	0.77	27.61	.399	53	8005	4658.05	67.35

Fig. 5a CUMULATIVE AGTRON COLOR CURVE FOR EXPERIMENTAL MILLING TEST NO: I

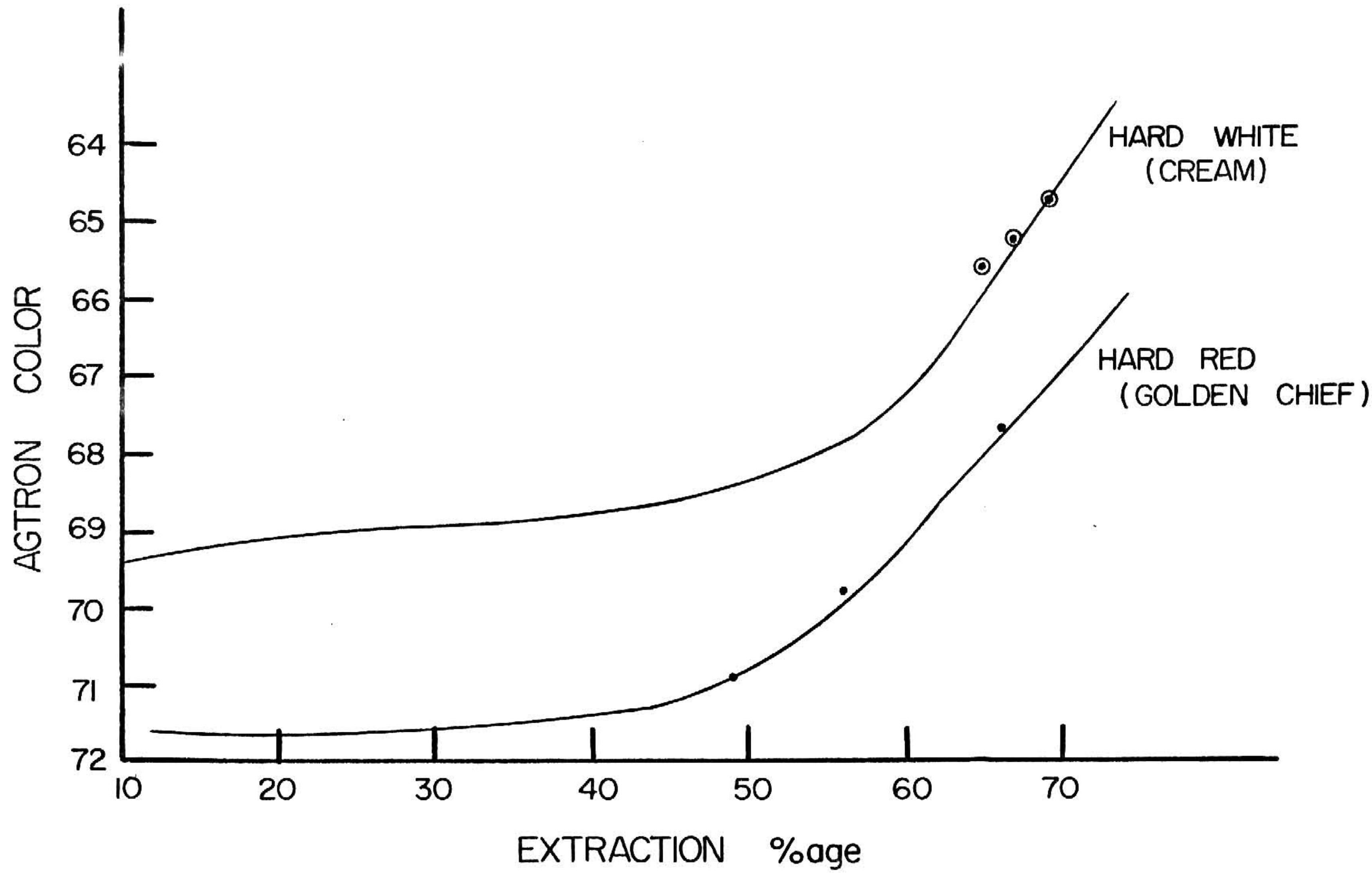
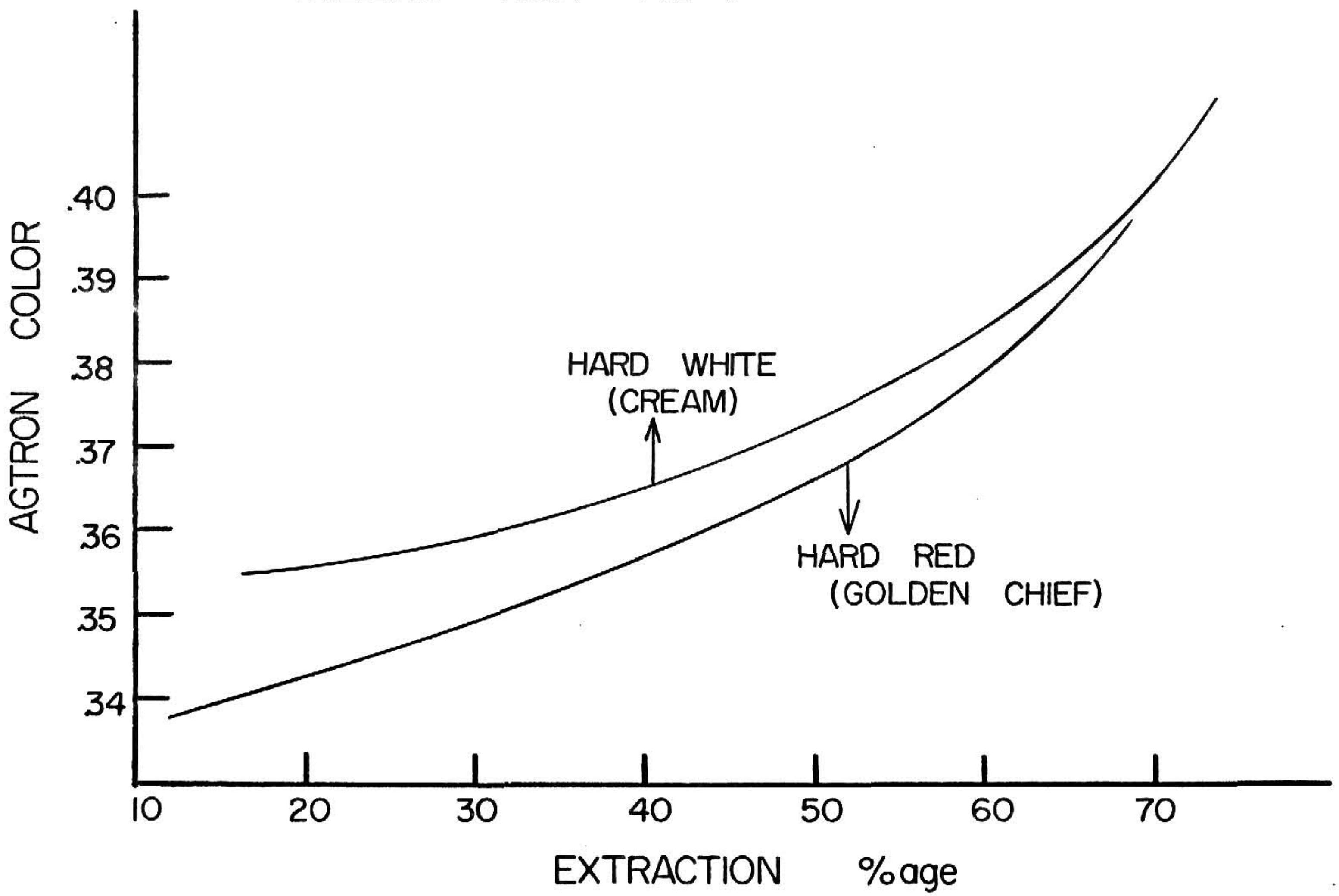


Fig. 5b CUMULATIVE ASH CURVE FOR EXPERIMENTAL MILLING TEST NO: I



causing the plumper White kernel to break more than required on the break rolls, resulting in more bran contamination in the break flour than was expected.

As in test baking so in Experimental Milling there are two methods for milling for comparative tests. One is to use the same setting for all the wheats. The other is to work on optimal settings for each wheat. In the first test the mill was set on the basis of the performance of the control wheat which was a Kansas Hard Red variety (not Golden Chief). This gave an optimal setting for the Golden Chief (a Kansas Hard Red) and was detrimental to optimal milling of the plumper White kernel. Consequently it was decided to run the next test at an optimal setting for each wheat.

Experimental Milling Test No. 2

In this series samples of Hard Red and Hard White, both Kansas varieties, were taken and tempered as per the standard method. The Buhler mill was set with the Control Wheat as described earlier and the Golden Chief (Hard Red) sample was run. For the Clark's Cream (Hard White) sample, the mill was slightly re-adjusted. The break rolls were opened slightly to help the plumper White Wheat kernel through without production of excessive flour and the reduction rolls were slightly closed to help granulate the slightly harder White wheats.

Individual streams were collected, checked and straight grade made as described in Milling Test No. 1 and the results are tabulated in Table 17. To get a color profile of the two wheats the Cumulative Ash and Color for the two wheats were worked out and these are shown in Table 18 and Figures 6A and 6B.

We note that while the ash content of the Hard White is marginally higher, the color is almost equivalent to the Hard Red. Specifically as the extraction increases, and thus as bran concentration increases, the color of White Wheat flour is better than that of Red Wheat Flour. This is evident from about 67% extraction. This indicates that the white bran has a lower discoloring power.

Table 17 shows that the Hard White break flour was 9.16% and the Hard Red Break flour was 7.9%. The difference is about 1.17% as against 1.63% in Test No. 1. Cumulative color of the Hard White Break Flour is 60.6 for a break extraction of 9.16% and this compares very favorably with the Hard Red break flour whose cumulative color was 60.8 for a break extraction of only 7.99%. This also confirms the lower discoloring power of white bran. The tightening of the reduction rolls helped in increasing the Hard White reduction flour which was 59.55%, and almost equal to the Hard Red reduction flour percentage of 59.8%. To confirm the ability of White wheat to give a better color at high extraction, a study in long extraction was carried out. For this study, shorts were sieved through a 11xx sieve for two minutes. The "thrus" were taken as shorts flour. The overs were ground and pin-milled and sieved again through a 11xx sieve.

The "thrus" were taken as pin-milled shorts flour, and were then added to the respective straight grade in the proportions in which they were found. For each sample the extraction was calculated and color checked. The results are tabulated in Table 19, and plotted on a graph on Fig. 7A showing that the white flour gave nearly 1.8% higher extraction at a Agtron color of 60. In another test the respective brans were taken and ground and pin-milled. They were then sieved through a 11xx sieve and the "thrus" were taken as bran flour. A stream of flour was taken and the two bran flours (Red and White) added to it in various proportions and color checked. The results are given in Table 20, and plotted on Fig. 7B. In both additions of shorts and bran we see the discoloring effect of Hard White is less than that of Hard Red. But the difference between the two samples is not so marked as expected. To check the reason for this the color of the respective bran flours was checked. As the bran flours were too dark to give a reading on the Agtron scale. They were checked on the Kent-Jones color meter. The averages of the readings obtained were as follows:

Kansas Hard White--Clark's Cream----18.0

Kansas Hard Red----Golden Chief-----18.6 (This reading was extrapolated as the reading was off the scale).

These results showed that the Hard White bran is whiter, but the difference is less than the normal difference between Red and White wheats. As no other sample of Hard White was available in Kansas this was accepted. Even this Hard White

TABLE 17. RESULTS OF EXPERIMENTAL MILLING TEST NO. 2

	Hard White-Kansas Clark's Cream				Hard Red-Kansas Golden Chief			
Sample Weight	4000gms.				4000gms.			
Milling Moisture	16.07%				16.1%			
	% of Total Product	Ash 14%M.B.	Green Agtron Color	Kent-Jones Color	% of Total Product	Ash 14%M.B.	Green Agtron Color	Kent-Jones Color
1st Break	2.63%	0.50	56.5		1.78%	0.52	55.75%	
2nd Break	4.48%	0.44	64.0		4.06%	0.44	64	
3rd Break	2.05%	0.47	58.5		2.15%	0.47	59.25	
Break Flour	9.16%	-	-		7.99%	-	-	
1st Reduction	39.83%	0.35	74.0		41.14%	0.33	75	
2nd Reduction	15.09%	0.38	66.0		13.45%	0.38	66	
3rd Reduction	4.63%	0.54	55.75		5.21%	0.54	52	
Reduction Flour	59.55%	-	-		59.8%	-	-	
Straight Grade	68.7%	0.39	70.0	1.1	67.78	0.38	70	1.15
Bran %age	24.04%				25.39%			
Shorts %age	7.26%				6.83%			
Production Loss	2.25%				4.48%			
Flour Moisture	13.7%				13.8%			
Flour Ash, 14%M.B.	0.39%				0.38%			
Flour Protein, 14%M.B.	11.36%				11.57%			
Average Particle Size, Fisher	20				19.5			

TABLE 18. CUMULATIVE ASH AND COLOR

	Ash			KANSAS HARD WHITE-CLARK'S CREAM				Color		
Flour	% of Total Product Q	Cum.% of Total Prod. S of Q	%Ash 14% M.B. A	%of Total Prod. x % Ash QxA	Cum. QxA	Cum.% of Ash= Cum.QxA / sfQ	Color C	%of Total Prod. x Color QxC	Cum.Color s of Qxc	Cum.% of Color s of Qxc / s of Q
1R	39.88%	39.83%	.35	13.941	13.941	0.35	74	2947.42	2947.42	74
2R	15.09%	54.92%	.38	5.734	19.675	0.358	66	995.94	3943.36	71.81
2B	4.48%	59.40%	.44	1.971	21.646	0.364	64	286.72	4230.08	71.21
3B	2.05%	61.45%	.47	.964	22.610	0.368	585	119.93	4350.01	70.79
1B	2.63%	64.08%	.50	1.315	23.925	0.373	565	118.60	4498.61	70.20
3R	4.63%	68.71%	.54	2.500	26.425	0.385	55.75	258.12	4756.73	69.33
				KANSAS HARD RED-GOLDEN CHIEF						
	Ash						Agtron Color			
1R	41.14%	41.14%	.332	13.658	13.658	.332	75	3085.5	3085.5	75
2R	13.45%	54.59%	.376	5.057	18.715	.343	66	887.7	3973.2	72.78
2B	4.06%	58.65%	.439	1.782	20.497	.350	64	259.84	4233.04	72.17
3B	2.15%	60.80%	.466	1.002	21.499	.353	59.25	127.39	4360.43	71.72
1B	1.78%	62.58%	.516	.918	22.417	.358	55.75	99.24	4459.67	71.26
3R	5.21%	67.79%	.543	2.829	25.246	.373	52	270.92	4730.59	69.78

Fig. 6a CUMULATIVE AGTRON COLOR CURVE FOR EXPERIMENTAL MILLING TEST NO: 2

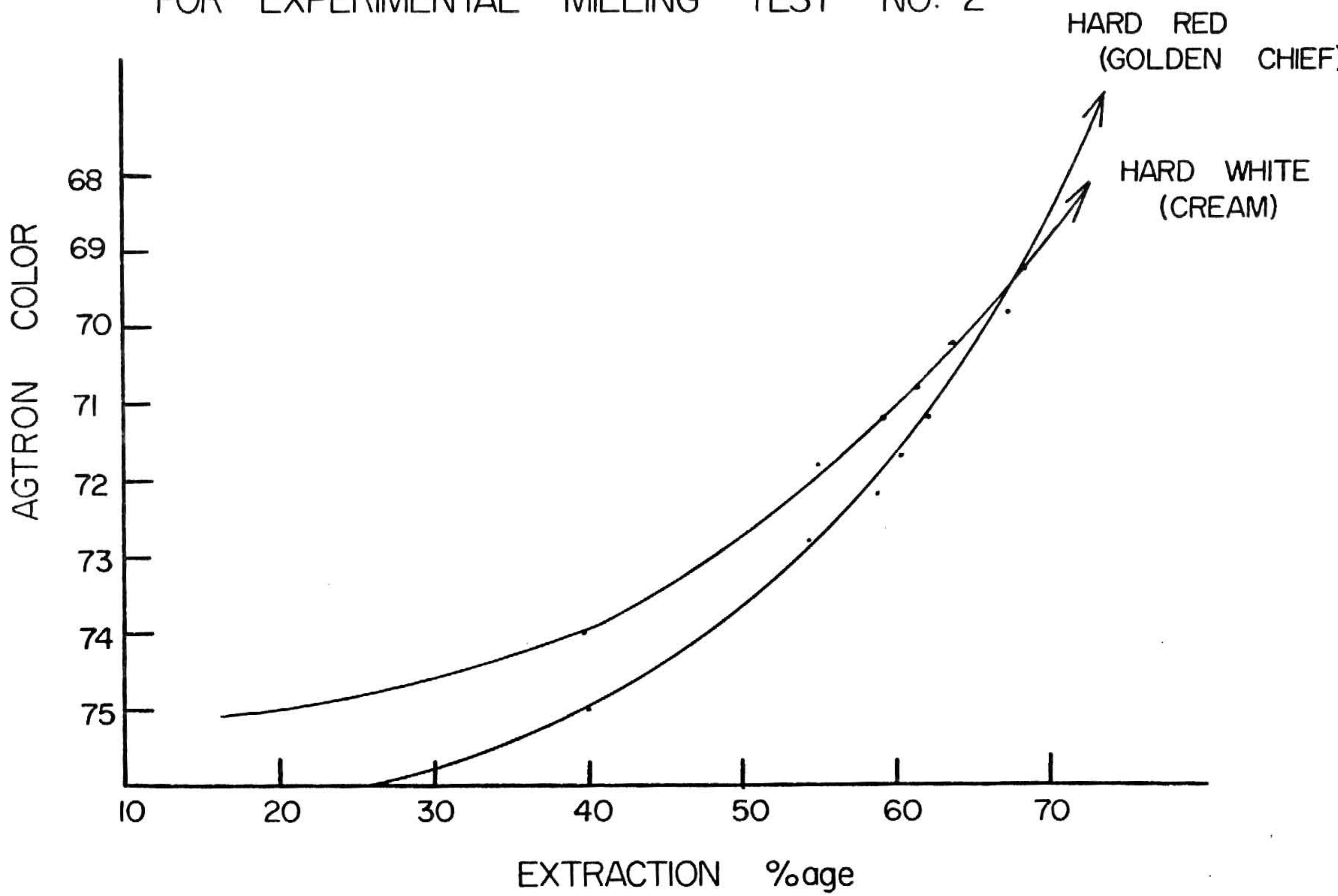


Fig. 6b CUMULATIVE ASH CURVE FOR EXPERIMENTAL MILLING TEST NO: 2

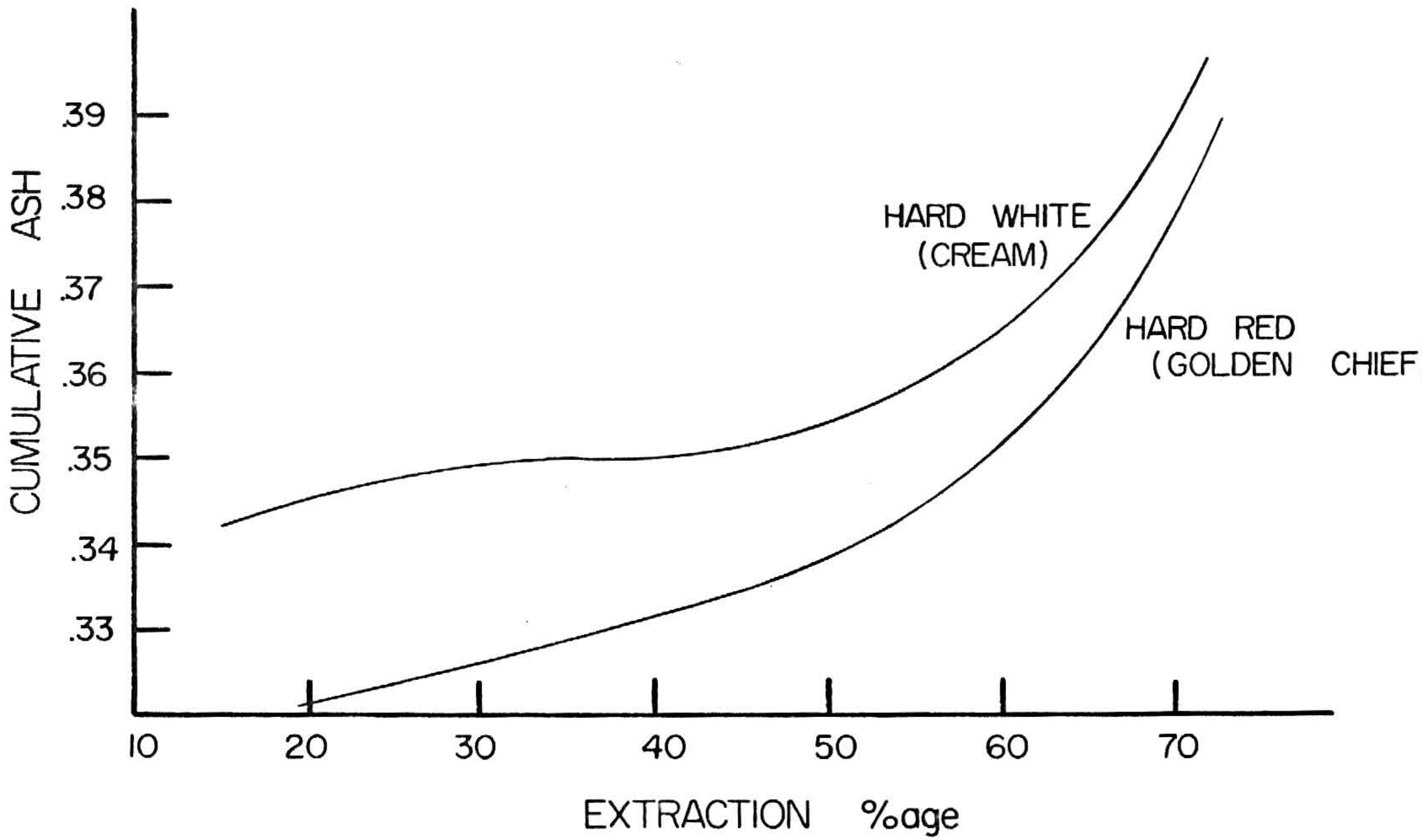


TABLE 19. COMPARATIVE EFFECT ON COLOR OF INCREASED EXTRACTION (KANSAS HARD WHITE vs. KANSAS HARD RED)

KANSAS HARD WHITE--CREAM		KANSAS HARD RED--GOLDEN CHIEF	
Extraction	Color	Extraction	Color
68.7%	70	67.78%	70
71.25%	64.5	70.8%	64
73.9%	60	72.1%	60

Fig. 7a. EFFECT OF SHORTS ADDITION ON AGTRON COLOR
EXPERIMENTAL MILLING TEST NO: 2
(KANSAS HARD RED vs. KANSAS HARD WHITE)

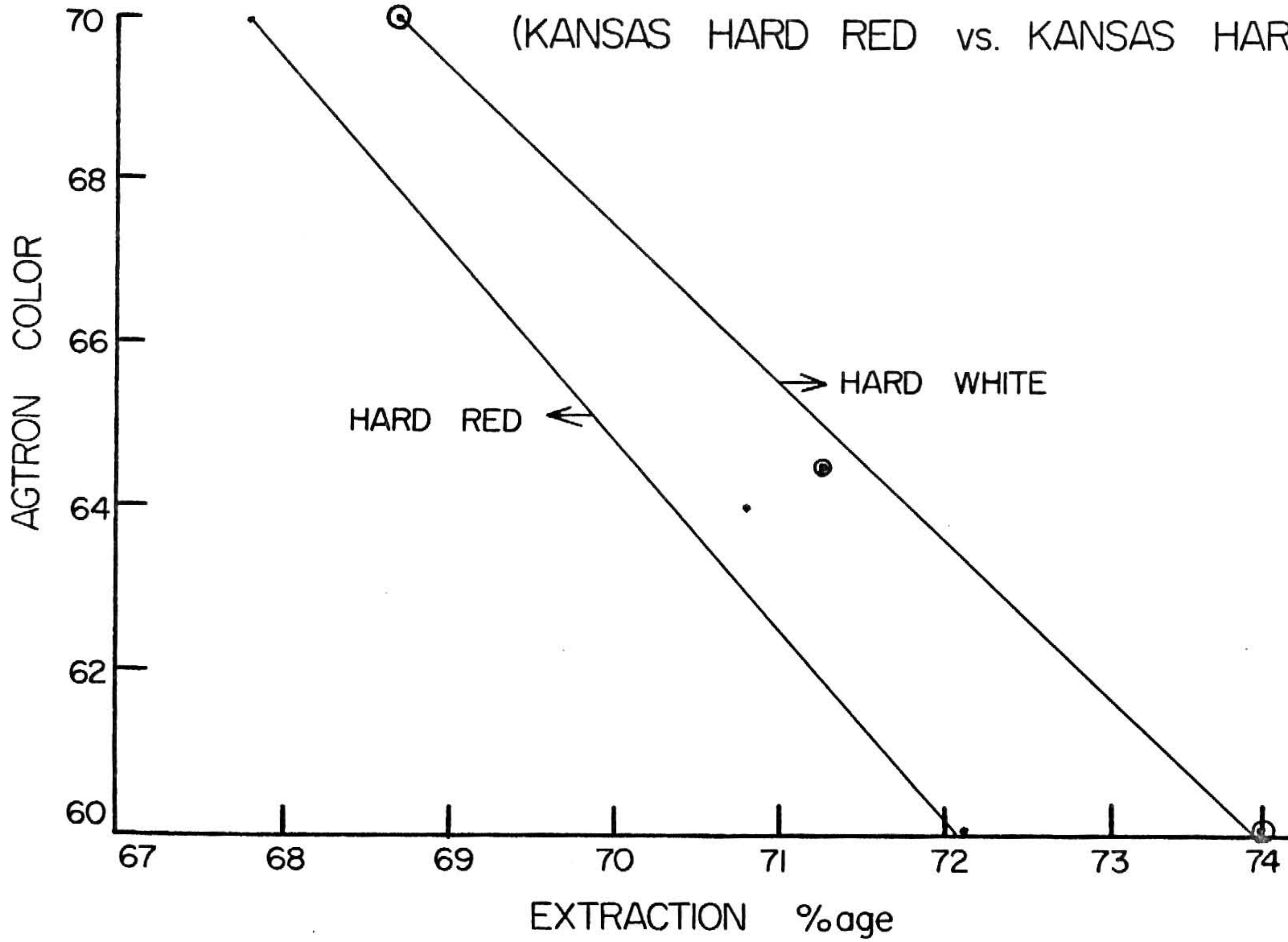
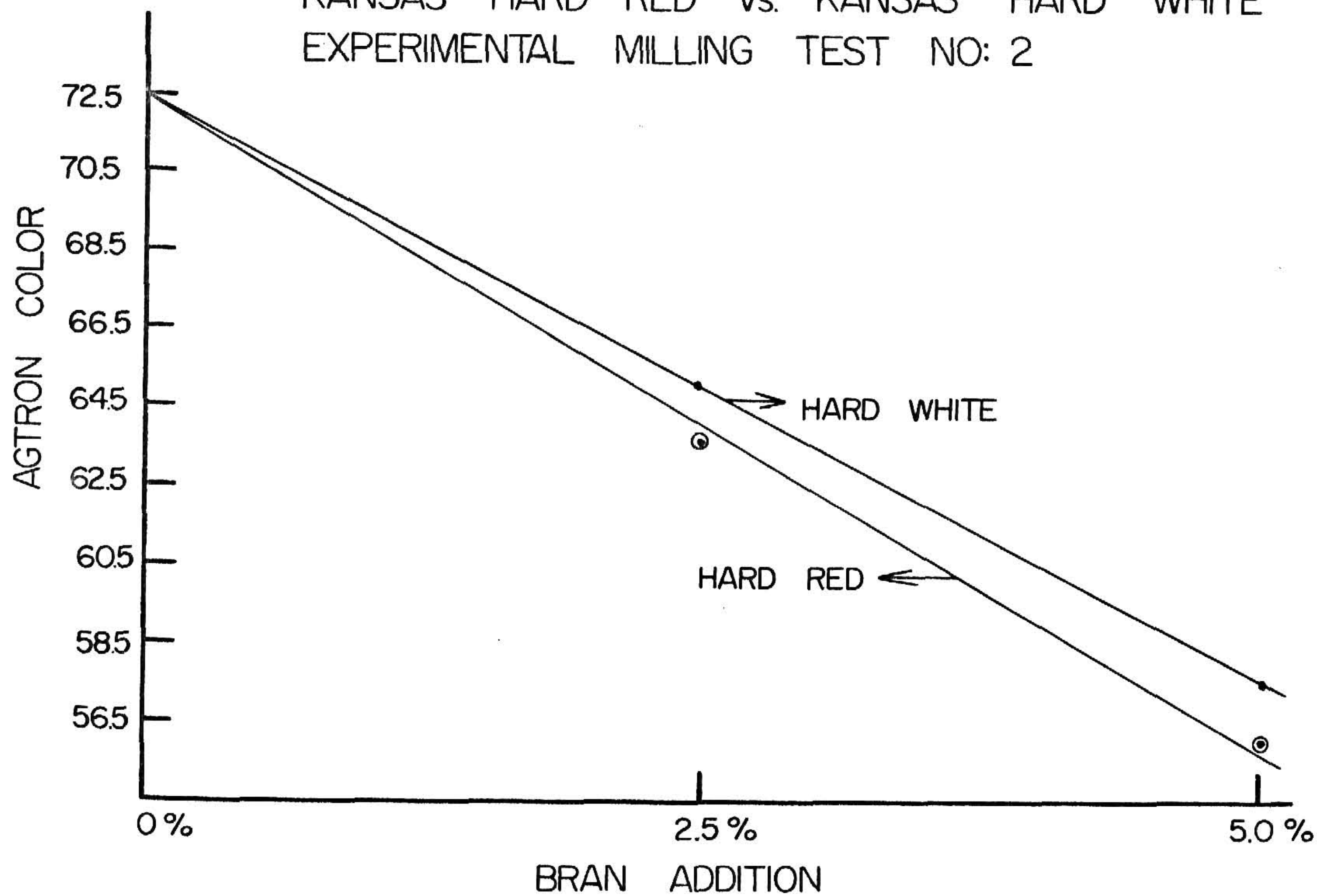


TABLE 20. EFFECT OF BRAN ADDITION ON COLOR (KANSAS HARD RED vs. KANSAS HARD WHITE)

Stream%	Bran%	Hard Red Bran Agtron Color	Hard White Bran Agtron Color
100	-	70	70
97.5	2.5%	63	65
95	5.0%	56.75	58.75

Fig. 7b EFFECT OF BRAN ADDITION ON AGTRON COLOR KANSAS HARD RED vs. KANSAS HARD WHITE EXPERIMENTAL MILLING TEST NO: 2



gave a longer extraction than the Hard Red at a comparable color.

Experimental Milling Test No. 3

This set of tests were done to see the effect of moisture on the extraction-color relationship, especially at the high extraction levels.

Three sets of samples (Hard Red and Hard White) were tempered to 15%, 15.8% and 17% respectively. A fourth was tempered to 14% and then half an hour before milling, another 1% moisture was added to give a total of 15% moisture at milling.

The wheats were milled as previously indicated. The mill was set with the control wheat for the Hard Red wheat optimally. For the Hard White, the break rolls were opened slightly and the reduction rolls were closed very slightly for reasons mentioned above.

In each milling, all the streams were mixed together to give a straight grade flour, which checked for moisture, protein ash and color. The shorts were sieved through a 11xx sieve for two minutes and were added to the respective straight grades. This gave a high extraction long straight grade. The color on each of these was checked and results obtained are tabulated in Table 21 and Figures 8A, 8B, 8C, and 8D which shows that:

a) at all moisture levels the Hard White flours have a better color profile as compared to the Hard Red Flours.
b) We note that for Hard White, the 15% moisture level gives the best results amongst the various moisture

TABLE 21. COMPARATIVE MILLING RESULTS AT DIFFERENT MOISTURES - KANSAS VARIETIES (EXPERIMENTAL MILLING TEST NO. 3)

	Hard White Cream	Hard Red G. Chief	Hard White Cream	Hard Red G. Chief	Hard White Cream	Hard Red G. Chief	Hard White Cream	Hard Red G. Chief
Sample Weight	1220 gm.	1360 gm.	1173 gms.	1341 gms.	1323 gms.	1275 gms.	1246 gms.	1368 gms.
Milling Moisture	17.0%	17.0%	15.7%	15.8%	15%	15%	14%+1%=15%	14%+1%=15%
Break Flour	13.05%	11.18%	13.12%	11.46%	12.97%	11.88%	13.37%	11.29%
Reduction Flour	60.35%	61.68%	61.16%	62.72%	61.62%	63.32%	60.99%	63.62%
Bran	18.18%	19.15%	16.89%	17.66%	15.68%	16.42%	15.41%	17.01%
Shorts	8.42%	7.63%	8.84%	8.16%	9.73%	8.37%	10.25%	8.09%
Production Loss	2.6%	4.6%	2.56%	4.7%	1.74%	3.5%	2.09%	4.17%
Straight Grade	73.4%	72.86%	74.28%	74.18%	74.59%	75.2%	74.34%	74.09%
St. Grade Agtron/ K.J.	63.5/2.7	63/2.75	62.5/2.9	62.5/2.9	63.5/2.6	59/3.15	63.5/2.7	62.5/2.9
Long Straight Grade	75.67%	74.94%	76.89%	76.30%	77.07%	77.5%	76.55%	76.74%

TABLE 21 (continued)

	Hard White Cream	Hard Red G. Chief	Hard White Cream	Hard Red G. Chief	Hard White Cream	Hard Red G. Chief	Hard White Cream	Hard Red G. Chief
Long Straight Grade Agtron/ K.J.	59	60	58.5	58	59	55.5	60	57
Flour Moisture	12.9%	13.0%	12.5%	12.8%	12.3%	12.4%	11.9%	12.4%
Flour Ash 14%M.B.	.435	-	.432	.444	.441	.462	.449	.471
Flour Prot. 14%M.B.	11.85%	11.85%	12%	12.1%	12.15%	12.15%	12.3%	11.95%

Fig. 8a. EFFECT OF INCREASED EXTRACTION ON AGTRON COLOR AT 15% MOISTURE – (KANSAS HARD RED vs. KANSAS HARD WHITE) – EXPERIMENTAL MILLING TEST NO: 3

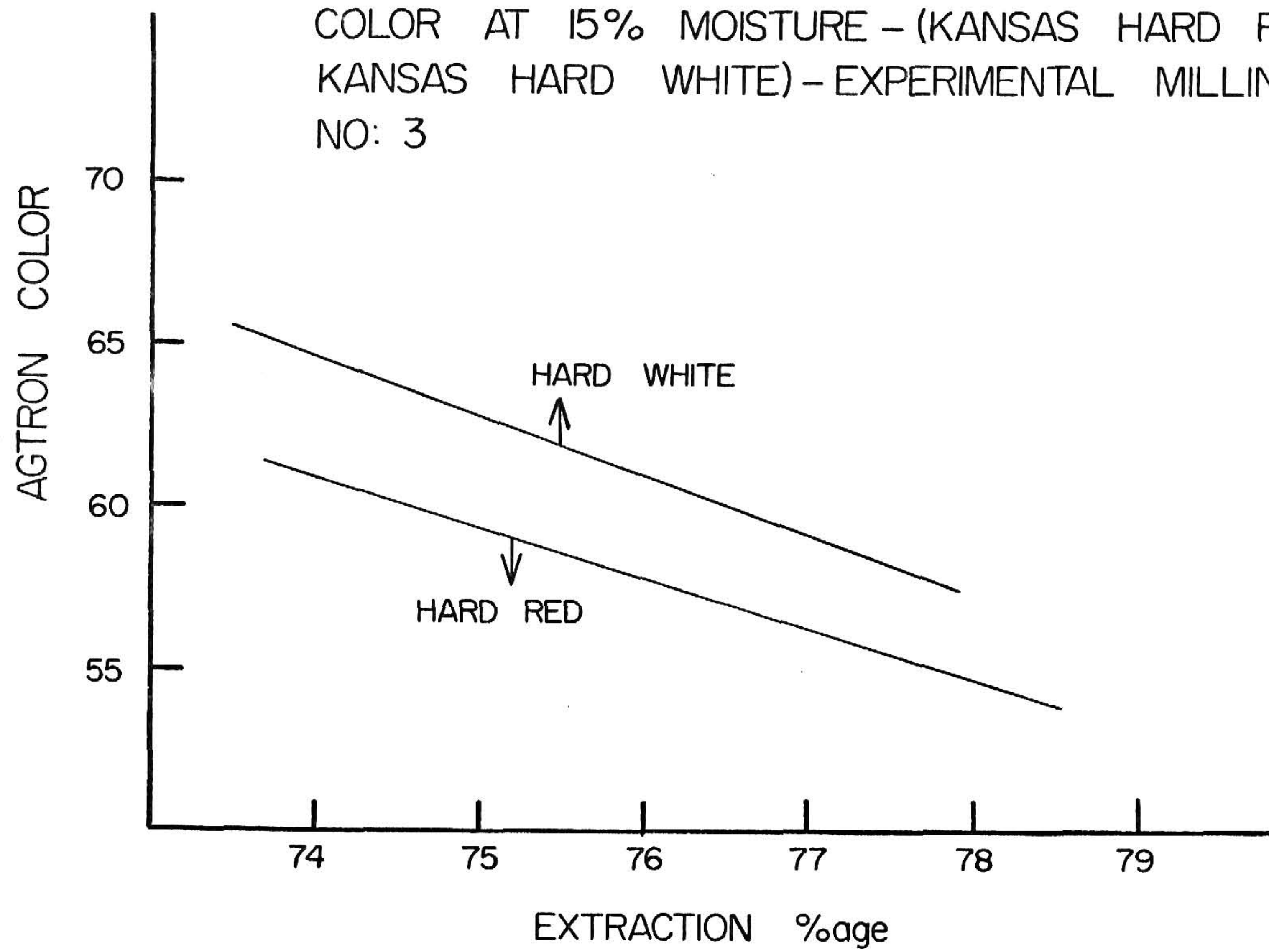


Fig. 8b. EFFECT OF INCREASED EXTRACTION ON AGTRON COLOR AT 16% MOISTURE – (KANSAS HARD RED vs. KANSAS HARD WHITE) – EXPERIMENTAL MILLING TEST NO: 3

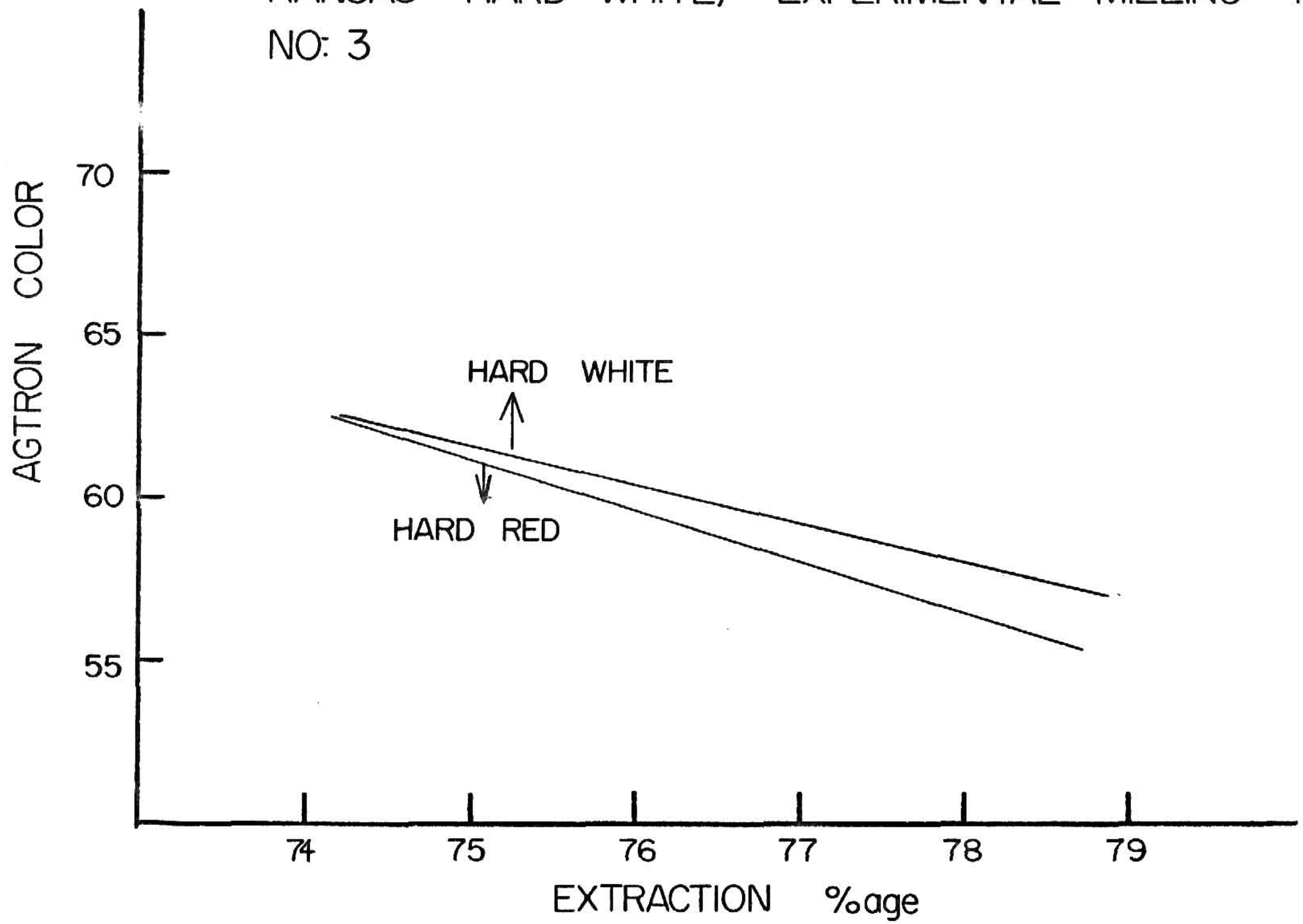


Fig. 8c EFFECT OF INCREASED EXTRACTION ON AGTRON COLOR AT 17% MOISTURE (KANSAS HARD RED vs. KANSAS HARD WHITE)

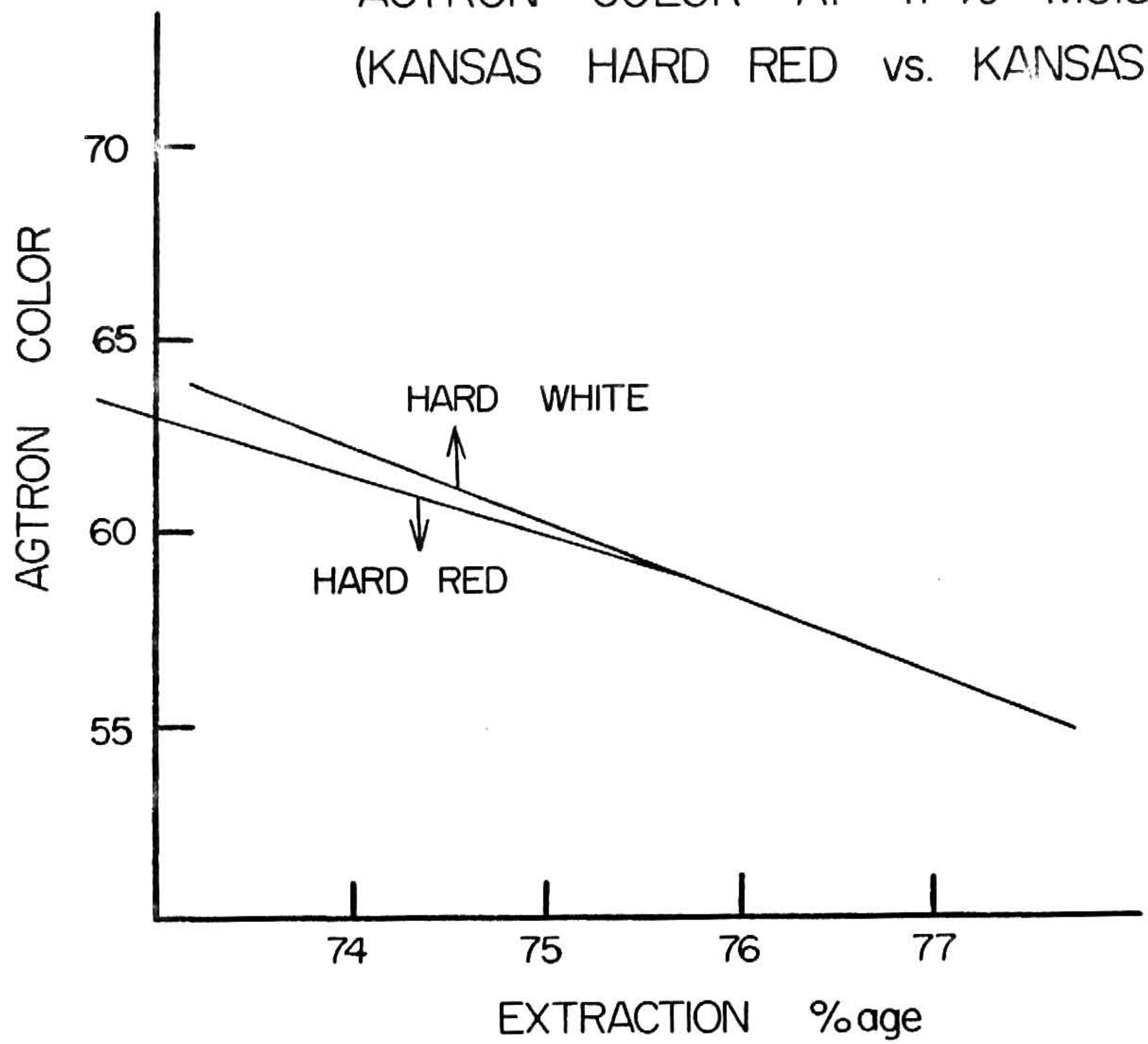
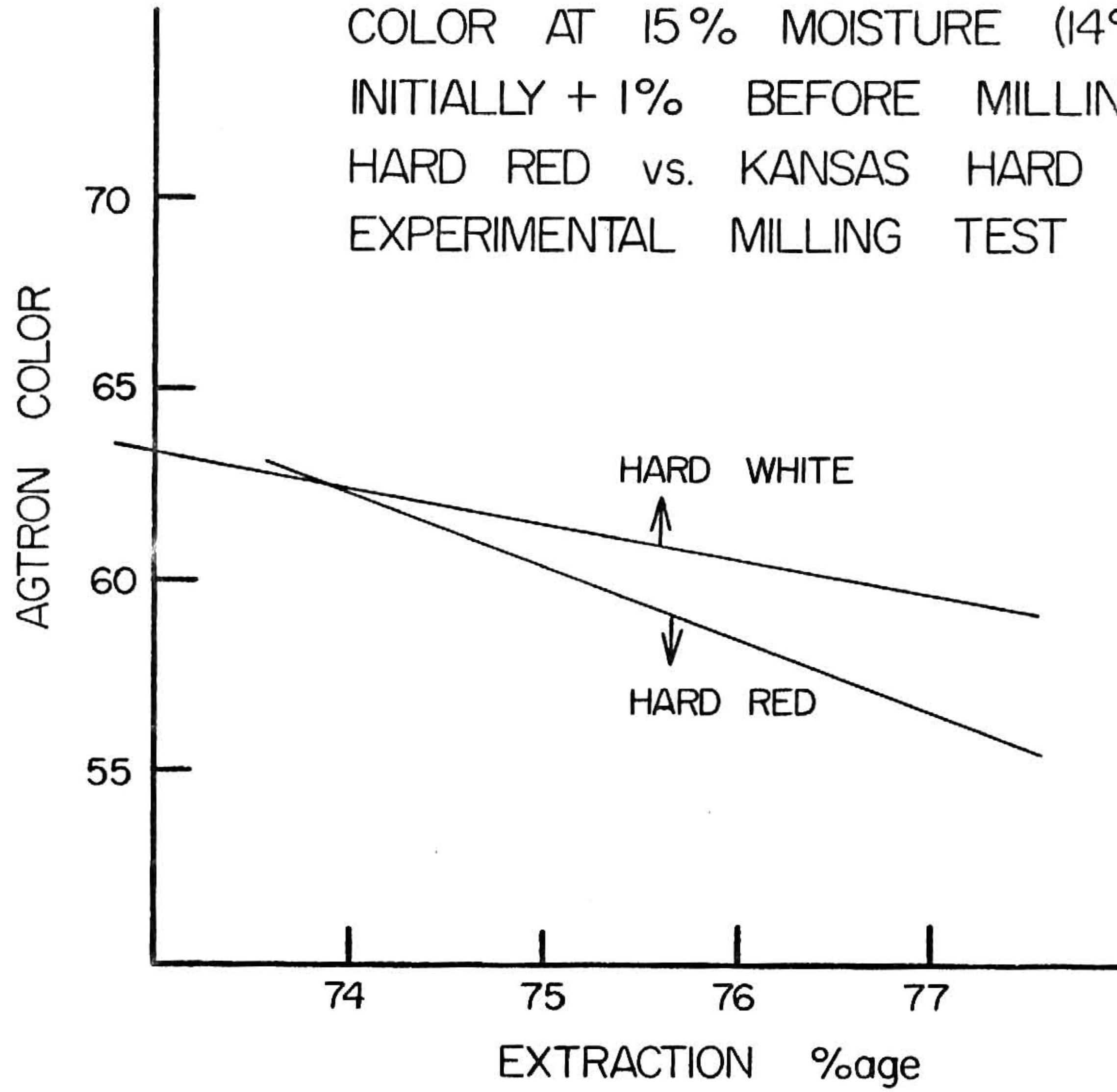


Fig. 8d EFFECT OF INCREASED EXTRACTION ON AGTRON COLOR AT 15% MOISTURE (14% MOISTURE INITIALLY + 1% BEFORE MILLING) KANSAS HARD RED vs. KANSAS HARD WHITE EXPERIMENTAL MILLING TEST NO: 3



samples and at this moisture we see the color profile of Hard White is substantially better than the Hard Red. This is also confirmed by the lowest break flour obtained for Hard White at 15% moisture.

For Hard Red, 16% and 17% gave fairly good results with 16% appearing to give best results for Hard Red.

c) Another notable feature is that the lot tempered to 14% and then retempered to 15%, 30 minutes before milling, gave good results for Hard White. This may be a suitable area for future investigation. This test confirmed the ability of Hard White wheat to give a better color profile than Hard Red wheat. On the basis of this series, the next test was done where the Hard White was tempered to 15% and the Hard Red to 16%, the optimal moistures for each on the basis of Experimental Milling Test No. 3.

Experimental Milling Test No. 4

As detailed in Experimental Milling No. 3 the moistures for each variety were optimal. The Buhler mill settings were optimal for each variety as described in previous experiments.

Each stream was collected individually and checked for moisture, ash, protein, Agtron color and Kent-Jones color and then the streams were joined together to form a straight grade, which was then checked for moisture, ash, color, etc, as above. Results obtained are tabulated in Table 22. On the basis of these figures, Cumulative Ash, Cumulative Agtron Color, and

Cumulative Kent-Jones Color were calculated and plotted on a graph (see Table 23 and Figure 9A, 9B, and 10).

These results show that the White wheat has a better color profile. The Cumulative color Graph shows that from around 50% extraction the Hard White gives a better color profile both on the Kent-Jones and the Agtron (Fig. 9B and 9A respectively). This is in contrast to the Cumulative Ash (Fig. 10) where we note that we have a lower ash figure for Hard Red till about 72% extraction. This indicates that in getting a higher extraction for Hard White, we are getting some more bran into the flour at the "break stage". But the White bran still keeps the color better than the Red bran due to its lower specific discoloring power.

The critical break flours were higher in Hard White by about 1.2% (an acceptable level). More importantly the Cumulative Color of the Hard White break flour was 2.64 on the Kent-Jones and 62.5 on the Green Agtron. This is superior to the 2.88 (Kent-Jones) and 60.56 (Green Agtron) which the Hard Red break flour had.

The reduction flours for the two varieties were similar, with Hard White again showing a slightly better cumulative color. But the First Reduction flour of the Hard White had a lower color as compared to the Hard Red. This was due to the fact that the reduction rolls were kept closer for Hard White to offset its greater hardness. But overall this test confirmed the ability of white wheat to give the extraction at an acceptable color

TABLE 22. RESULTS OF EXPERIMENTAL MILL TEST NO. 4.

	Hard White-Kansas Clark's Cream				Hard Red-Kansas Golden Chief			
Sample Weight	3990 gms.				3906 gms.			
Milling Moisture	15%				16%			
	% of Total Products	Ash 14%M.B.	Green Agtron Color	Kent-Jones Color	% of Total Products	Ash 14%M.B.	Green Agtron Color	Kent-Jones Color
1st Break	7.2	0.25	65.0	2.35	5.56	0.45	63	2.55
2nd Break	5.07	0.44	65.0	2.30	5.29	0.44	64	2.5
3rd Break	1.6	0.74	43.5	5.0	1.81	0.78	43	5.0
Break Flour	13.07	-	-	-	12.66	-	-	-
1st Reduction	39.65	0.40	68.0	1.7	40.32	0.38	69	1.65
2nd Reduction	14.05	0.46	63.0	2.6	14.99	0.51	56.5	3.4
3rd Reduction	5.20	0.72	47.5	4.6	3.40	0.79	35	5.9
Reduction Flour	58.86	-	-	-	58.71	-	-	-
Straight Grade	72.73	0.45	62.5	2.3	71.37	0.48	62	2.4
Bran %age		16.94%				16.58%		
Shorts %age		10.34%				10.05%		
Production Loss		1.1%				4.34%		
Flour Moisture		13.6%				14.0%		
Flour Ash, 14%M.B.		.45%				.48%		
Flour Protein, 14%M.B.		12.1%				11.8%		
Average Particle Size Fisher		22				20		

TABLE 23A. CUMULATIVE ASH

	% of Total Product	Cum. % of Total Product S of Q	% Ash 14%M.B. A	% of Total Prod.x % Ash QxA	Cu. QxA	Cum. % of Ash =Cum.QxA / SfQ
KANSAS HARD WHITE - CLARK'S CREAM						
1R	39.65	39.65	.4	15.86	5.86	.4
2B	5.07	44.72	.44	2.22	18.08	.404
2R	14.05	58.77	.45	3.24	24.4	.415
1B	7.2	65.97	.45	6.32	27.64	.419
3R	5.2	71.17	.71	3.69	31.34	.44
3B	1.6	72.77	.73	1.17	32.5	.477
KANSAS HARD RED - GOLDEN CHIEF						
1R	40.32	40.32	.38	15.32	15.32	.38
2B	5.29	45.61	.44	2.33	17.65	.387
1B	5.56	51.17	.45	2.50	20.15	.394
2R	14.99	66.16	.51	7.65	27.80	.420
3B	1.81	67.97	.78	1.41	29.21	.43
3R	3.4	71.37	.79	2.69	31.90	.447

TABLE 23B. CUMULATIVE COLOR

	Agtron Color				Kent-Jones Color			
	Color C	% of Total Prod. x Colors Q x C	Cum. Color S of Q x C	Cum.% of Color S of Q x C / S of Q	Color C	% of Total Prod. x Color Q x C	Cum. Color S of QxC	Cum. % Color S of Q / sfQ
KANSAS HARD WHITE - CLARK'S CREAM								
1R	68	2696.2	2696.2	68	1.7	67.41	67.41	1.7
2B	65	329.55	3025.75	67.68	2.3	11.66	79.07	1.77
2R	65	468	3493.75	67.29	2.35	16.92	95.99	1.85
1B	63	885.15	4378.9	66.88	2.6	36.53	132.52	2.01
3R	47.5	247	4625.9	64.98	4.6	23.92	156.44	2.2
3B	63.5	69.6	4695.6	64.50	5.0	8.00	164.44	2.26
KANSAS HARD RED - GOLDEN CHIEF								
1R	69	2782.08	2782.08	69	1.65	66.53	66.53	1.65
2B	64	338.56	3120.64	68.42	2.5	13.23	79.76	1.75
1B	63	350.28	3470.92	67.83	2.55	14.18	93.94	1.84
2R	56.5	846.94	4317.86	65.26	3.4	50.97	144.91	2.19
3B	43	77.83	4395.69	64.67	5.0	9.05	153.96	2.27
3R	35	119	4514.69	63	5.9	20.06	174.02	2.43

Fig. 9a CUMULATIVE AGTRON COLOR CURVE
EXPERIMENTAL MILLING TEST NO: 4

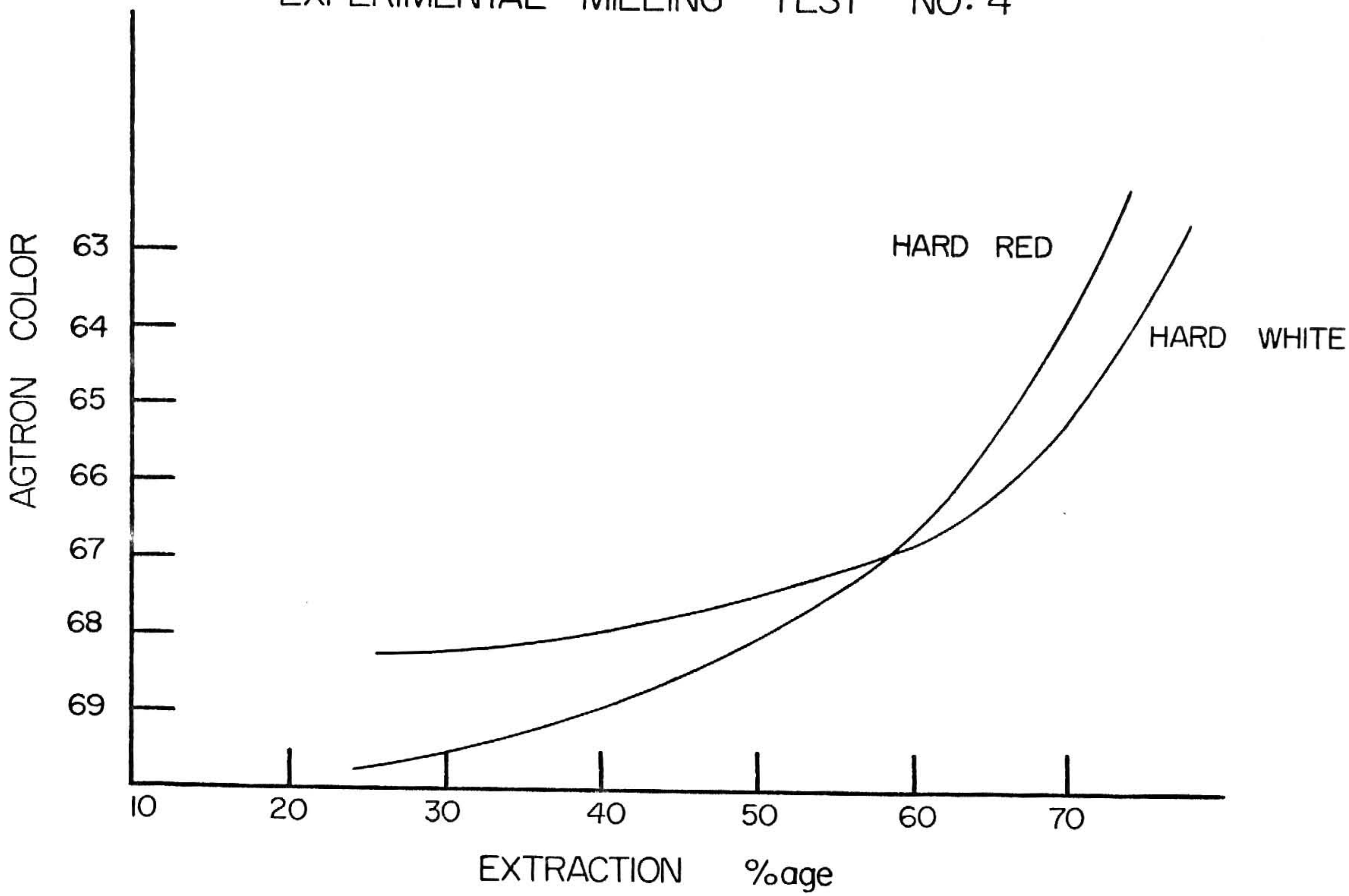


Fig. 9b CUMULATIVE KENT-JONES COLOR CURVE
EXPERIMENTAL MILLING TEST NO: 4

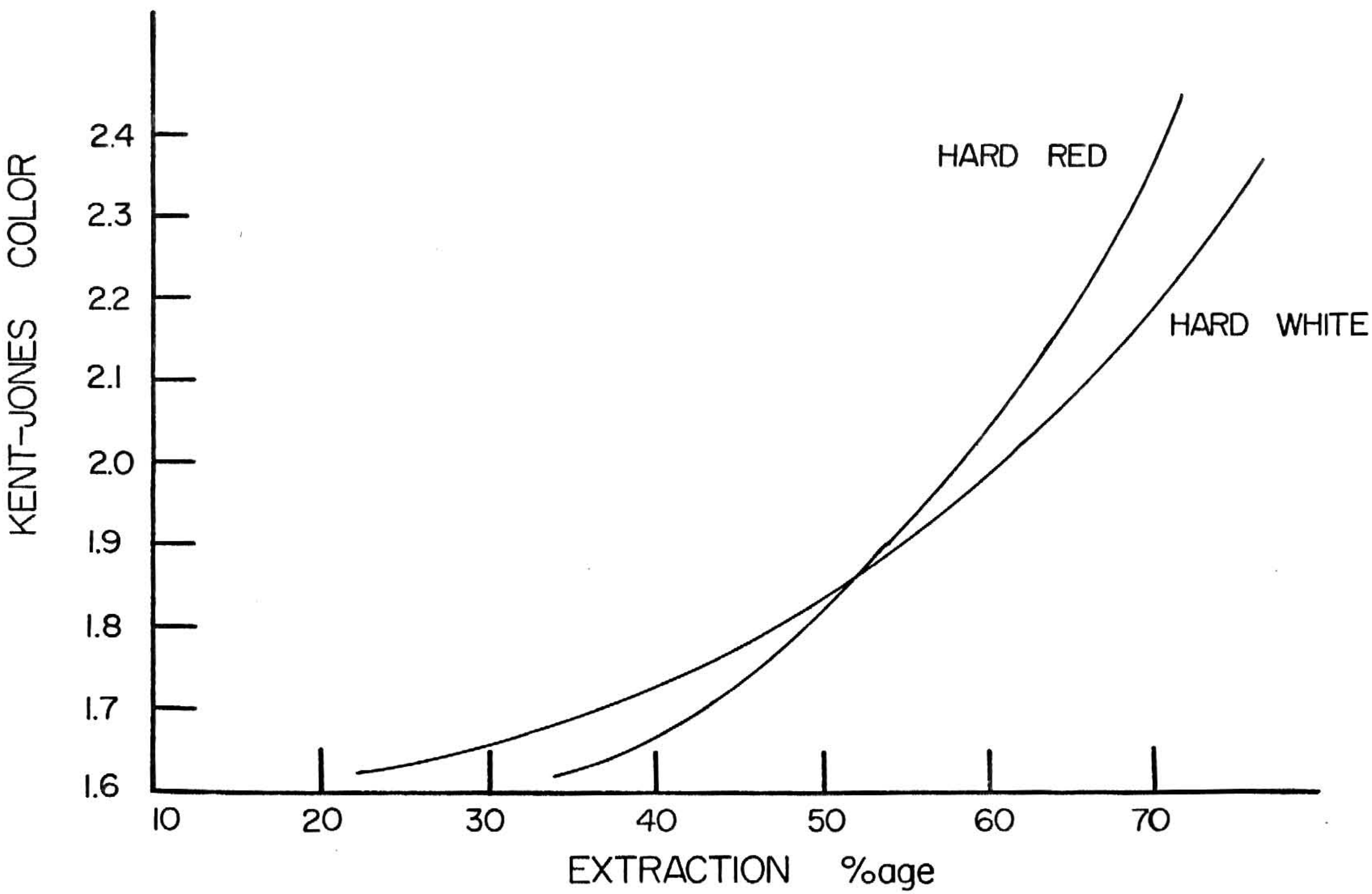


Fig. 10 CUMULATIVE ASH CURVE
EXPERIMENTAL MILLING TEST NO: 4

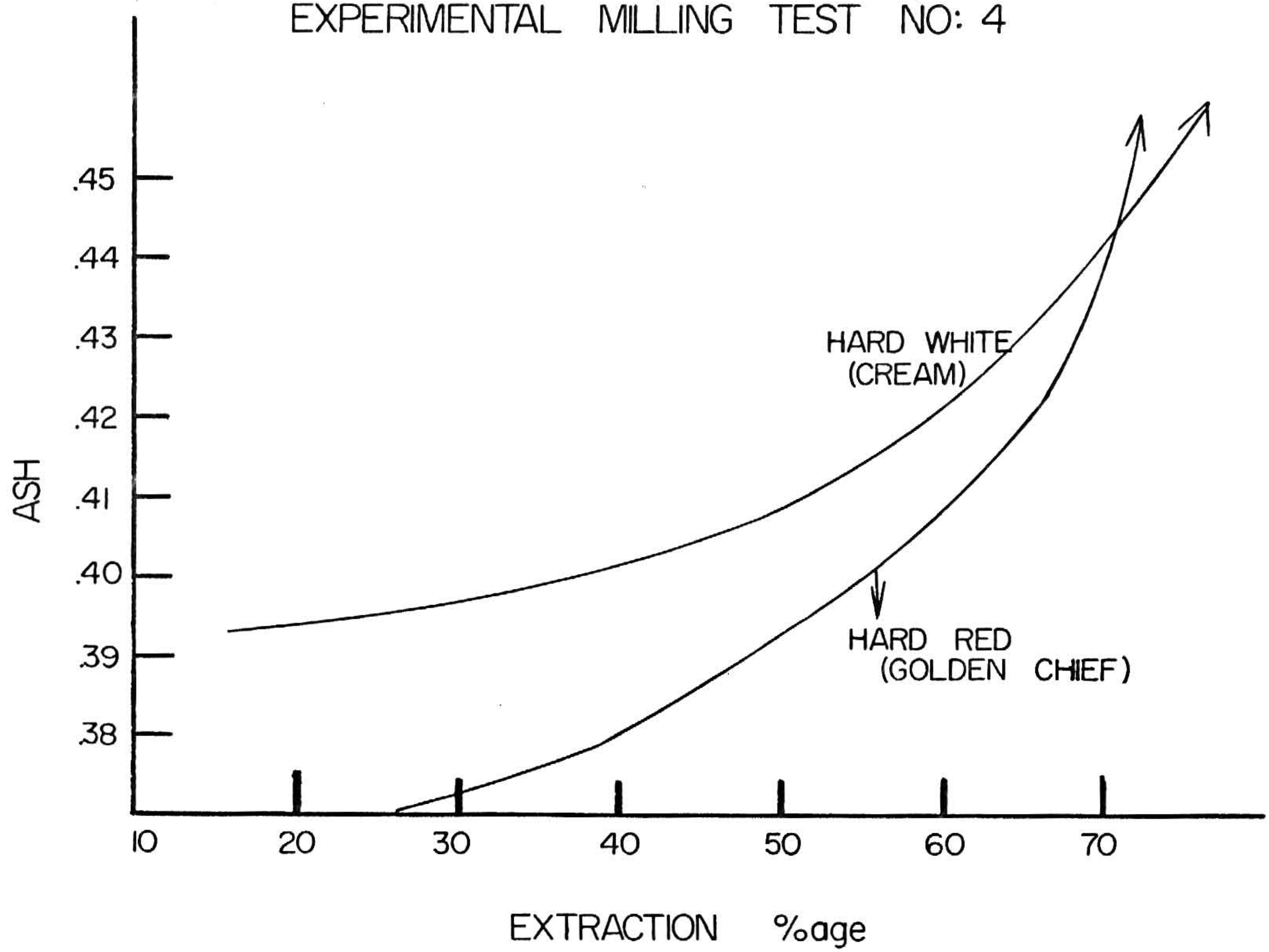
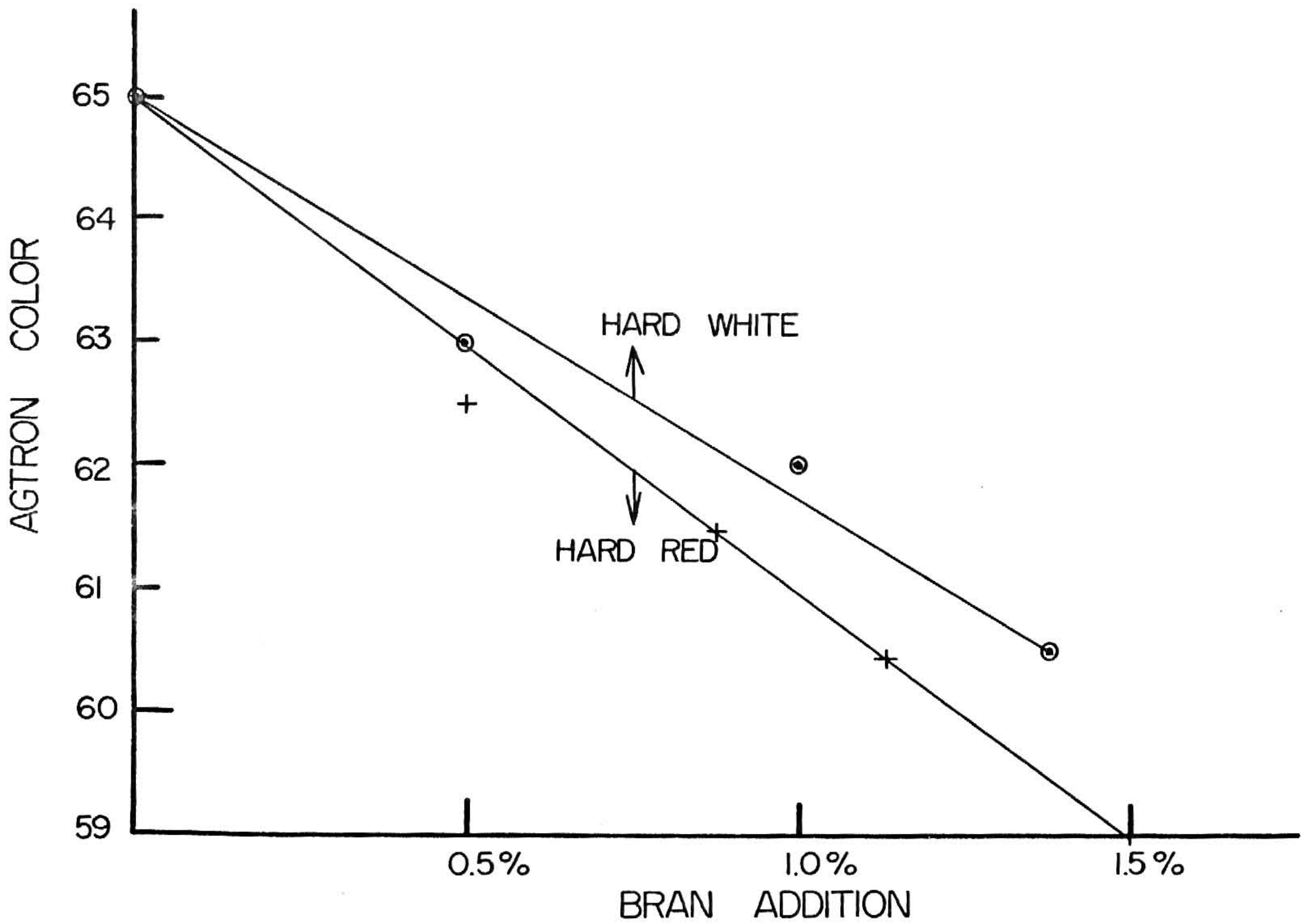


TABLE 24. EFFECT OF BRAN FLOUR ON GREEN AGTRON COLOR (KANSAS WHITE VS KANSAS RED)

Base Stream %	Bran %	Agtron Color White Bran	Agtron Color Red Bran
100%	0%	65	65
99.5%	9.5%	63	62.5%
99%	1.0%	62	61.5%
98.5%	1.5%	60.5%	59

Fig. II EFFECT OF BRAN ADDITION ON FLOUR COLOR



level.

In Experimental Milling Test No. 2 a set was done on effect of bran additions on color (see Fig. 6A and Table 20). A similar experiment was repeated with this milling. Bran from the respective millings of Red and White wheat was taken and remilled on the roller mills, pin-milled and then reground to flour fineness and sieved through a 11xx sieve. The "thrus" were taken as bran flour and added to a base stream, in varying proportions and the color checked. Results are tabulated in Table 24 and plotted on Fig. 11 and we notice a confirmation of Red bran's greater discoloring power as compared to White bran.

Experimental Milling Test Nos. 5 & 6.

To confirm the above mentioned results two more sets were done. The only change was that both wheats were tempered to 15% and the mill was set optimally for each variety.

Results are tabulated in Tables 25 and 26. These show a slightly higher extraction for Hard White combined with a better color value. This confirms that with proper mill operation, the Hard White gives the better extraction-color relationship.

Review of Experimental Milling Test Nos. 1-6

This series with the Kansas Hard Wheats, Red and White, gave the following major points for attention:

a) In Experimental Milling Test No. 1 the break flour of the White wheat tended to be substantially higher and this affected straight grade color adversely.

TABLE 25. RESULTS OF EXPERIMENTAL MILLING TEST NO. 5

	Hard White-Kansas Clark's Cream				Hard Red-Kansas Golden Chief			
Sample Weight	3000 gms.				3000 gms.			
Milling Moisture	14.85%				14.95%			
	% of Total Products	Ash 14%M.B.	Green Agtron Color	Kent-Jones Color	% of Total Products	Ash 14%M.B.	Green Agtron Color	Kent-Jones Color
1st Break	4.9%				4.28%			
2nd Break	4.63%				4.90%			
3rd Break	1.36%				1.43%			
Break Flour	10.89%				10.61%			
1st Reduction	34.83%				33.70%			
2nd Reduction	18.61%				18.61%			
3rd Reduction	6.5%				7.03%			
Reduction Flour	59.94%				59.34%			
Straight Grade	70.82%	0.4	67.0	2.3	69.95%	0.41	65.0	2.4
Bran %age			17.89%				18.89%	
Shorts %age			11.30%				11.25%	
Production Loss			2%				4.17%	
Flour Moisture			13.3%				13.4%	
Flour Ash, 14%M.B.			0.40%				0.40%	
Flour Protein, 14%M.B.			11.8%				11.5%	
Average Particle Size, Fisher			23				24	

TABLE 26. RESULTS OF EXPERIMENTAL MILLING TEST NO. 6

	Hard White				Hard Red			
Sample Weight	3000 gms.				3000 gms.			
Milling Moisture	15.0%				14.85%			
	% of Total Products	Ash 14%M.B.	Green Agtron Color	Kent-Jones Color	% of Total Products	Ash 14%M.B.	Green Agtron Color	Kent-Jones Color
1st Break	5.78%				4.99%			
2nd Break	5.16%				5.67%			
3rd Break	1.34%				1.39%			
Break Flour	12.28%				12.05%			
1st Reduction	28.19%				27.64%			
2nd Reduction	22.10%				24.57%			
3rd Reduction	8.06%				5.35%			
Reduction Flour	58.35%				57.56%			
Straight Grade	70.64	.387	67	2.25	69.62%	.386	66	2.35
Bran %age			19.21%				19.15%	
Shorts %age			10.15%				11.23%	
Production Loss			2.0%				3.7%	
Flour Moisture			13.4%				13.0%	
Flour Ash, 14%M.B.			.387%				.386%	
Flour Protein, 14%M.B.			11.81%				11.95%	

b) When mill settings were altered to set the mill optimally for each variety, the break flour of the plumper White kernel was controlled better. Subsequently much better straight grade colors were noted for White wheat rather than for Red wheat and this was confirmed by Cumulative color curves where the White wheat flour had a better color profile especially at higher extraction levels.

c) It was also confirmed by addition of comparative levels of shorts and bran flour, that white wheat had a substantially lower discoloring power than red wheat.

The only problem was that the difference in color between these particular samples of Red and White wheats was not as distinct as was expected.

Therefore as a follow-up a set of Wheats from Washington were tested. These wheats were not as hard as Kansas wheats, but the color differential between the Red and White was much more substantial and normal. It was felt that these wheats would give a more specific indication of the color profile difference between White wheat flour and Red wheat flour.

Experimental Milling No. 7

As noted in Tables 8 and 9, the Washington wheat series were of lower protein content, and were much "softer" wheats than the Kansas series. The 1975 series was used for the milling test.

Initial milling tests with these wheats at a milling moisture above 15% gave considerable problems on the Buhler, the Coulee (White) caused problems even at 15%. Therefore the Burt and Wanser samples were tempered to 14.5% approximately and Coulee to 13.85%. The Buhler was set optimally for each variety in a manner similar to the settings for the Kansas varieties. Separate streams of each milling were collected and after testing for moisture, protein, ash and color, the straight grade was made. The results obtained are tabulated in Table 27. This shows that:

a) In all three samples, we had a very high proportion of 1st Break Flour, i.e., 10.24%, 9.13%, and 7.79% for Burt, Coulee and Wanser respectively. This was as expected with the softer wheats.

b) The difference between the three varieties for total break flour was not so wide i.e., 15.86% for Burt-White, 13.34% for Wanser-Red, and 12.95% for Coulee-White.

c) Due to the whiteness of Hard White Bran, the high break flour did not affect color seriously. Both the White flours, Burt and Coulee, had a higher straight grade with better color.

d) This is illustrated well on the Cumulative Ash and Color calculations (Tables 28 and 29) and Graphs (Figs. 12A, 12B, and 12C). Even though Wanser has a better ash profile as compared to Burt, the color profile of Burt is better at all extractions which is in contrast

TABLE 27. RESULTS OF EXPERIMENTAL MILLING TEST NO. 7

	Washington White Burt				Washington Red Wanser				Washington White Coulee			
Sample Wt.	5000 gms.				5000 gms.				5000 gms.			
Milling Moisture	14.6%				14.5%				13.85%			
	% of Total Prod.	Ash 14%MB	Green Agtron Color	Kent-Jones Color	% of Total Prod.	Ash 14%MB	Green Agtron Color	Kent-Jones Color	% of Total Prod.	Ash 14%MB	Green Agtron Color	Kent-Jones Color
1st Bk.	10.24%	0.406	61.0	2.55	7.79	0.384	62.0	2.4	9.13	0.371	73.5	0.8
2nd Bk.	4.59%	0.451	64.0	2.35	4.76	0.392	64.5	2.25	2.36	0.389	67.5	1.5
3rd Bk.	1.04%	0.679	50.0	3.0	0.8	0.406	50.0	3.0	1.46	0.561	60.0	2.35
Bk. Flour	15.86%				13.34%				12.95%			
1st Red.	29.27%	0.395	72.5	1.1	24.24	0.389	69.0	1.4	35.22	0.332	77.0	0.3
2nd Red.	21.72%	0.415	69.0	1.15	25.61	0.384	72.0	1.05	16.58	0.463	69.5	1.3
3rd Red.	5.8%	0.583	57.5	2.9	7.49	0.403	56.0	2.85	6.58	0.644	57.0	2.95
Red. Flour	56.79%				57.34%				58.33%			
Str. Grade	72.66%	0.42	68.0	1.6	70.69	0.41	66.0	1.8	71.33	0.402		1.1
Bran %age	17.51%				18.20%				21.68%			
Shorts %age	9.83%				11.11%				7.01%			
Prod. Loss	3%				5.2%				5.3%			
Flour Moisture	12.5%				12.65%				11.43%			
Flour Ash, 14%M.B.	0.43%				0.41%				0.40%			
Flour Prod., 14%MB	7.32%				7.95%				7.87%			

TABLE 28. CUMULATIVE ASH OF EXPERIMENTAL MILLING TEST NO. 7

Flour Stream	% of Total Product Q	Cum.% of Total S of Q	% Ash 14%MB A	% of Total Prod. x % Total Ash Q x A	Cum. Q x A	Cum.% of Ash = Cum.QxA / s of Q
1R	29.25%	29.25%	.395	11.562	11.562	.395
1B	10.24	39.49	.406	4.157	15.719	.398
2R	21.72	61.21	.415	9.014	24.733	.404
2B	4.59	65.80	.451	2.070	26.803	.407
3M	5.80	71.60	.583	3.381	30.184	.422
3B	1.04	72.64	.679	0.706	30.890	.425
				Wanser-Washington		
		Ash				
2M	25.61%	25.61	.384	9.834	9.834	.384
1B	7.79%	33.40	.386	3.007	12.841	.385
1M	24.24%	57.64	.395	9.575	22.416	.389
2B	4.76	62.40	.433	2.061	24.477	.392
3M	7.49	69.89	.489	3.663	28.140	.403
3B	0.80	70.69	.672	0.538	28.678	.406
				Coulee-Washington		
		Ash				
1M	35.22	35.22	.332	11.693	11.693	.332
1B	9.13	44.35	.371	3.387	15.080	.340
2B	2.36	46.71	.389	0.918	15.998	.342
2M	16.58	63.29	.463	7.677	23.675	.374
3B	1.46	64.75	.561	0.819	24.494	.378
3M	6.58	71.33	.644	4.238	28.732	.403

TABLE 29. CUMULATIVE COLOR OF EXPERIMENTAL MILLING TEST No. 7

Flour Stream	% of Total Product Q	Cum. % of Total Prod. S of Q	Color C	% of Total Product = Q x C	Cum. Color S of Q x C	Cum.% of Color = S of Q xC / s of Q	Color C	%ATPP x Color=QxC	Cum. Color S of QxC	Cum.% of Color =s of QxC / S of Q
BURT-WASHINGTON WHITE										
	Ash		Agtron-Color				Kent-Jones Color			
1R	29.27	29.27	72.75	2164.31	2164.31	72.75	1.1	32.20	32.20	1.1
2R	21.72	50.99	69.00	1498.68	3662.99	71.84	1.15	24.98	57.18	1.12
2B	4.59	55.58	64	293.76	3956.75	71.19	2.35	10.79	67.97	1.22
1B	10.24	65.82	61	624.64	4581.39	69.61	2.55	26.11	94.08	1.43
3R	5.8	71.62	57.5	333.5	4914.89	68.62	2.9	16.82	110.90	1.55
3B	1.04	72.66	50	52	4966.89	68.33	3.2	3.33	114.23	1.57
WANSER-WASHINGTON RED										
	Ash		Agtron-Color				Kent-Jones Color			
2R	25.61	25.61	72	1843.92	1843.92	72	1.05	26.89	26.89	1.05
1R	24.24	49.85	69	1672.56	3516.44	70.54	1.4	33.94	60.83	1.22
2B	4.76	54.61	64.5	307.02	3823.46	70.01	2.25	10.71	71.54	1.31
1B	7.79	62.40	62	482.98	4306.44	69.01	2.4	18.70	90.24	1.46
3R	7.49	69.89	56	419.44	4725.88	67.62	2.85	21.35	111.59	1.60
3B	0.80	70.69	50	40	4765.88	67.42	3.2	2.56	114.15	1.62
COULEE-WASHINGTON WHITE										
	Ash		Agtron Color				Kent-Jones Color			
1R	35.22	35.22	77	2711.94	2711.94	77	0.3	10.57	10.57	.3
1B	9.13	44.35	73.5	671.06	33.83	76.28	0.8	7.30	17.87	.4
2R	16.58	60.93	69.5	1152.31	4535.31	74.43	1.3	22.55	39.42	.65
2B	2.36	63.29	67.5	159.3	4694.61	74.18	1.5	3.54	42.96	.68
3B	1.46	64.75	60	87.6	4782.21	73.86	2.35	3.43	46.39	.72
3R	6.58	71.33	57	375.06	5157.27	72.30	2.95	19.41	65.80	.97

Fig. 12a CUMULATIVE AGTRON COLOR CURVE
EXPERIMENTAL MILLING TEST NO: 7

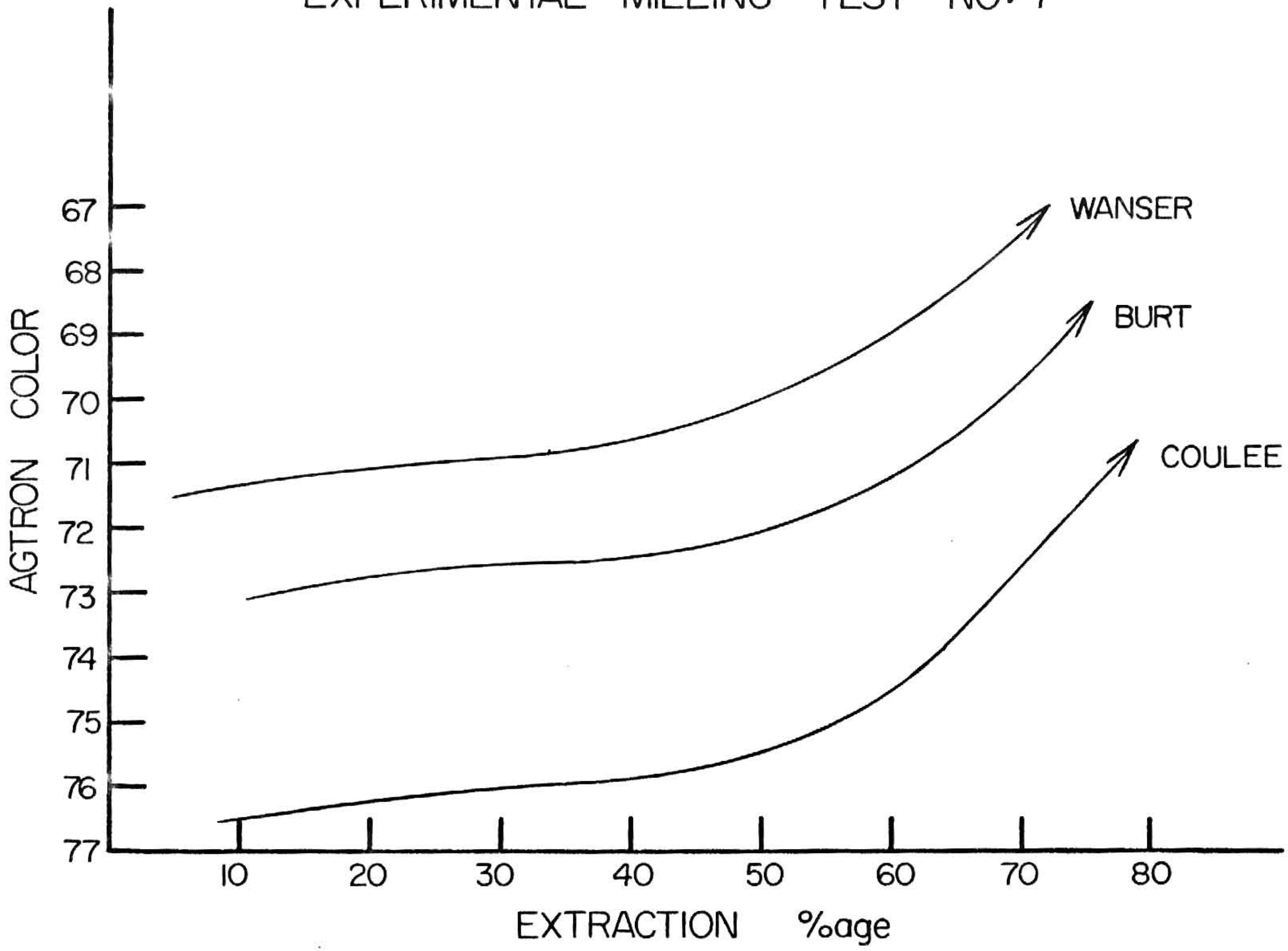


Fig. 12b CUMULATIVE ASH CURVE
EXPERIMENTAL MILLING TEST NO: 7

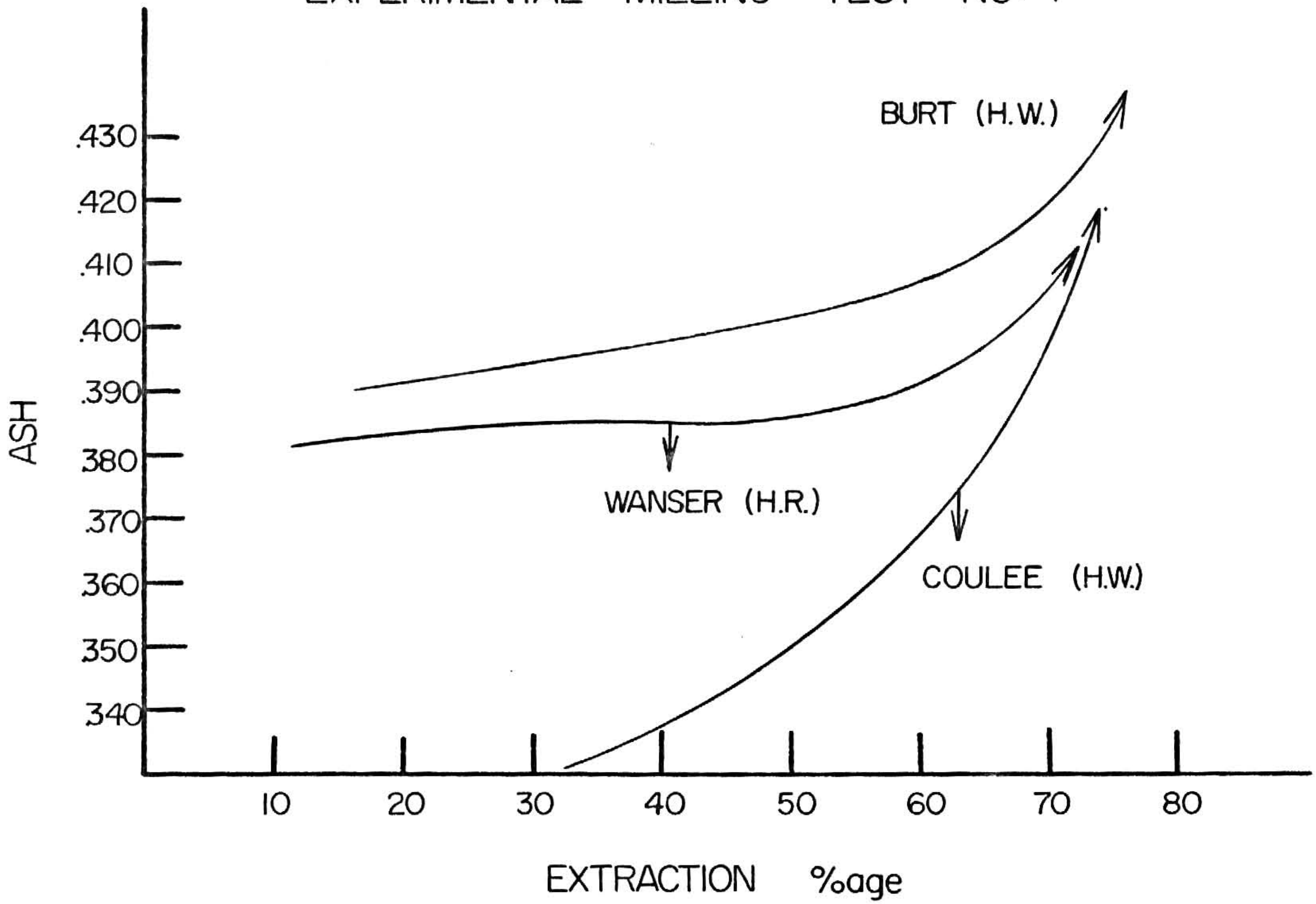
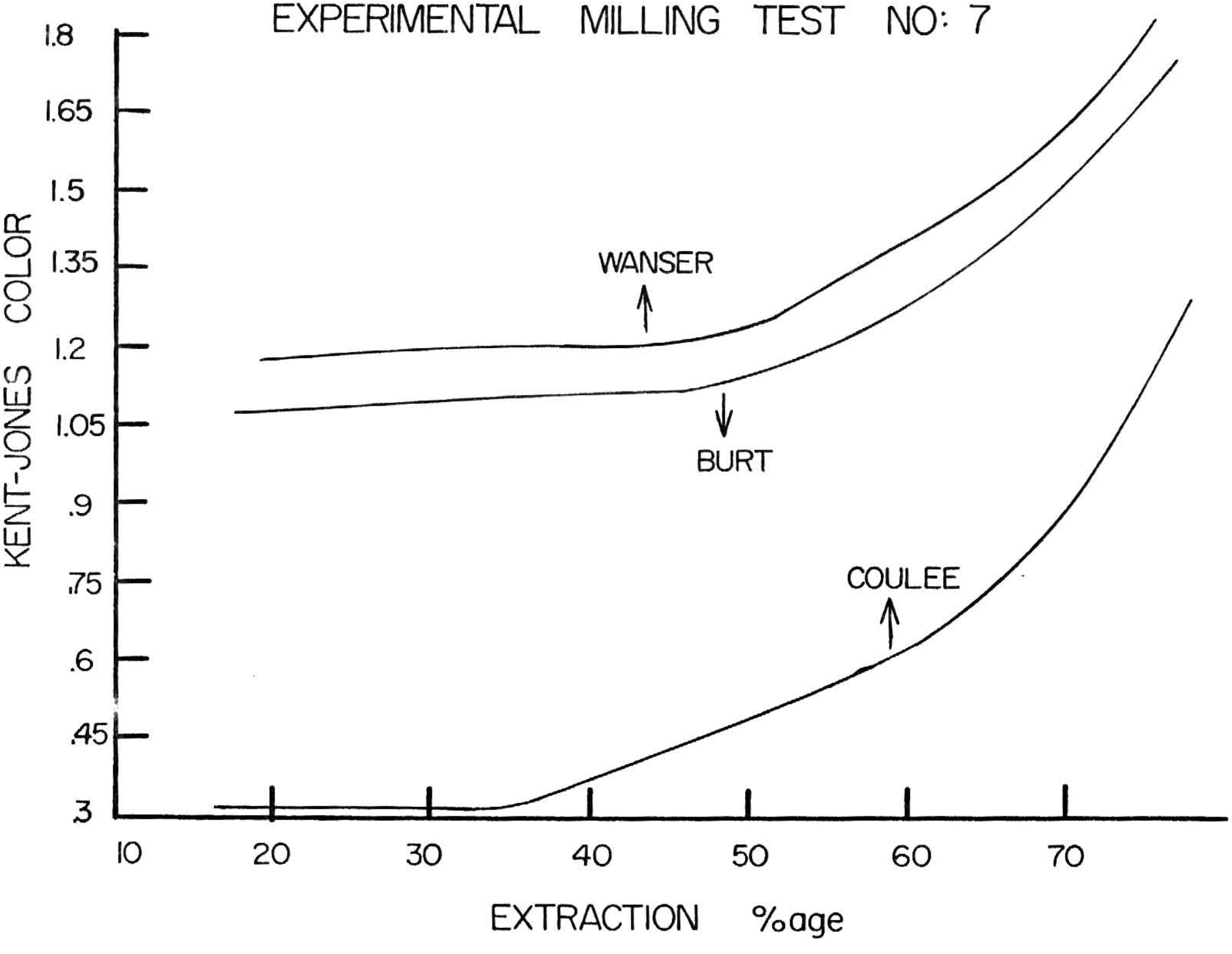


Fig. 12c CUMULATIVE KENT-JONES COLOR CURVE
EXPERIMENTAL MILLING TEST NO: 7



to the Kansas varieties. This shows that if the bran color is sufficiently white, we can get a higher White wheat extraction than Red wheat.

e) The three brans (Burt, Coulee and Wanser) were ground on mills, pin-milled to flour fineness and then sieved over a 11xx sieve and the "thrus" collected as Bran flour. Color was checked on the Kent-Jones color meter giving the following results:

Burt Bran Flour---------------14.35 (White)

Coulee Bran Flour-------------14.55 (White)

Wanser Bran Flour-------------17.25 (Red)

This is in comparison to the Kansas Bran Flour as checked in Experimental Milling Test No. 2.

Clark's Cream Bran Flour------18.0 (White)

Golden Chief Bran Flour-------18.6 (Red)

This confirms the importance of whiteness of bran.

Experimental Milling No. 8

In this series, Burt (White) and Wanser (Red) were tested against each other to check effect of high extraction. Mill settings were optimal for each variety as described previously. Results obtained are tabulated on Table 30. We note that at 68.18% extraction, the White Burt has a better color. To check higher extraction, shorts flour and pin-milled shorts flour were added progressively to increase extraction levels and at each level the color was checked. The color values are tabulated on Table

TABLE 30. EXPERIMENTAL MILLING TEST NO. 8

	Hard White-Washington Burt				Hard Red-Washington Wanser			
Sample Weight	3000 gms.				3000 gms.			
Milling Moisture	15.2%				14.9%			
	% of Total Products	Ash 14%M.B.	Green Agtron Color	Kent-Jones Color	% of Total Products	Ash 14%M.B.	Green Agtron Color	Kent-Jones Color
1st Break	9.39				7.68			
2nd Break	4.43				3.66			
3rd Break	1.17				0.96			
Break Flour	14.99%				12.30%			
1st Reduction	25.55				26.41			
2nd Reduction	18.32				21.31			
3rd Reduction	7.19				8.15			
Reduction Flour	53.19%				55.87%			
Straight Grade	68.18	0.435	71	1.45	68.17	0.424	69	1.8
Bran %age			21.08%				19.56%	
Shorts %age			10.74%				12.27%	
Production Loss			3%				5%	
Flour Moisture			13%				12.8%	
Flour Ash, 14%M.B.			0.435 %				0.424%	
Flour Protein, 14%M.B.			7.03%				7.9%	
Average Particle Size, Fisher			18.5				21.5	

TABLE 31. EFFECT OF INCREASED EXTRACTION ON COLOR--(BURT VS. WANSER)

BURT--HARD WHITE			WANSER--HARD RED		
Extraction	Agtron Color	Kent-Jones Color	Extraction	Agtron Color	Kent-Jones Color
68.18%	71	1.45	68.17%	69	1.67%
69.49%	70.5	1.65	69.68%	67.5	1.95
71.3%	69.5	1.9	71.73%	65.5	2.26

TABLE 32. EFFECT OF BRAN FLOUR ON AGTRON COLOR--(BURT VS WANSER)

Burt-Straight Grade %age	Bran %age	White Bran Agtron Color	Red Bran Agtron Color
100%	0%	71	71
99.5%	0.5%	79.75	68.75
99%	1.0%	68.75%	66.75
98.5%	1.5%	67.5	65

Fig. 13a EFFECT OF INCREASED EXTRACTION THROUGH SHORTS ADDITION ON AGTRON COLOR EXPERIMENTAL MILLING TEST NO: 8

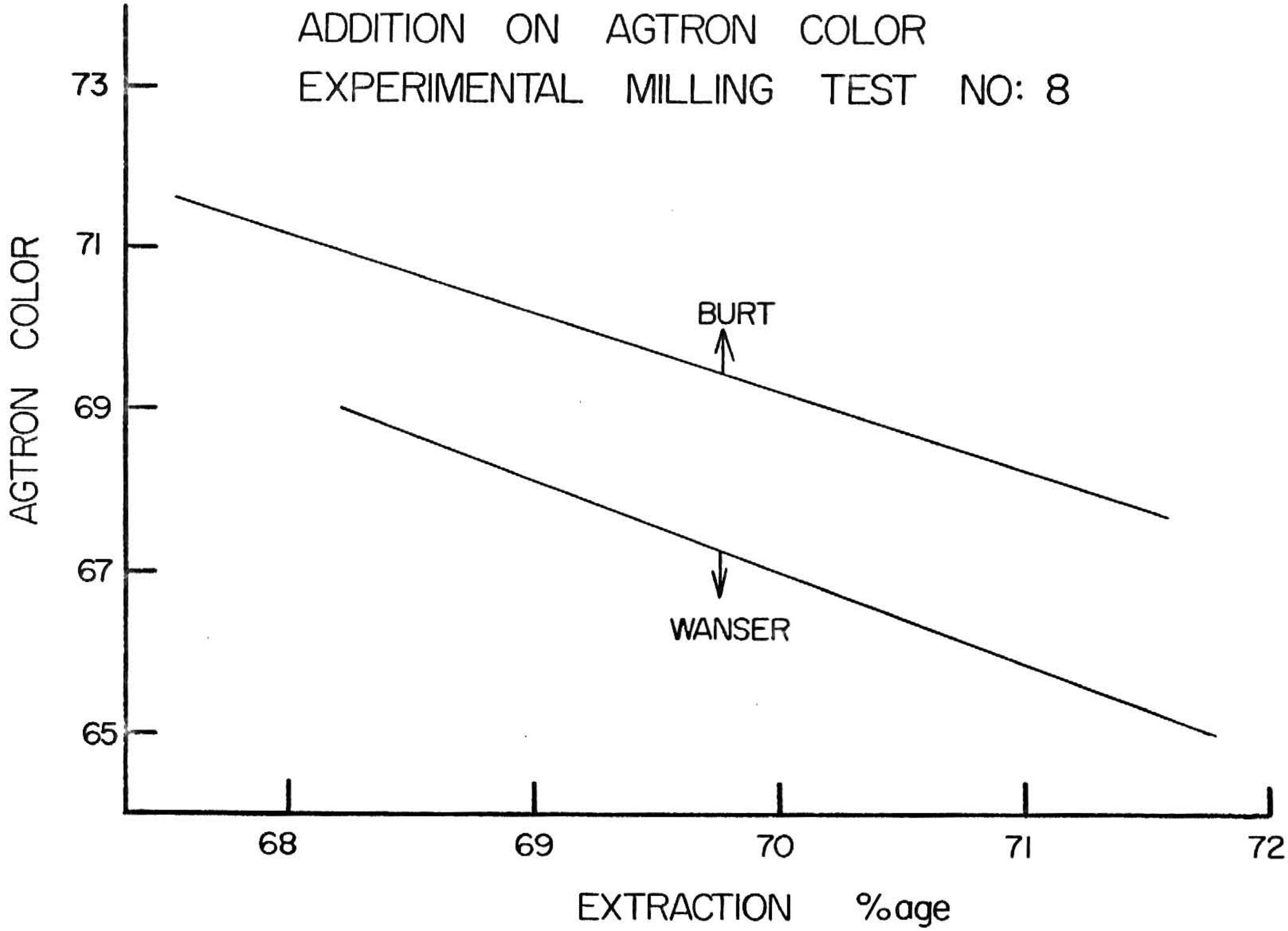


Fig. 13b EFFECT OF INCREASED EXTRACTION THROUGH SHORTS ADDITION ON KENT-JONES COLOR EXPERIMENTAL MILLING TEST NO: 8

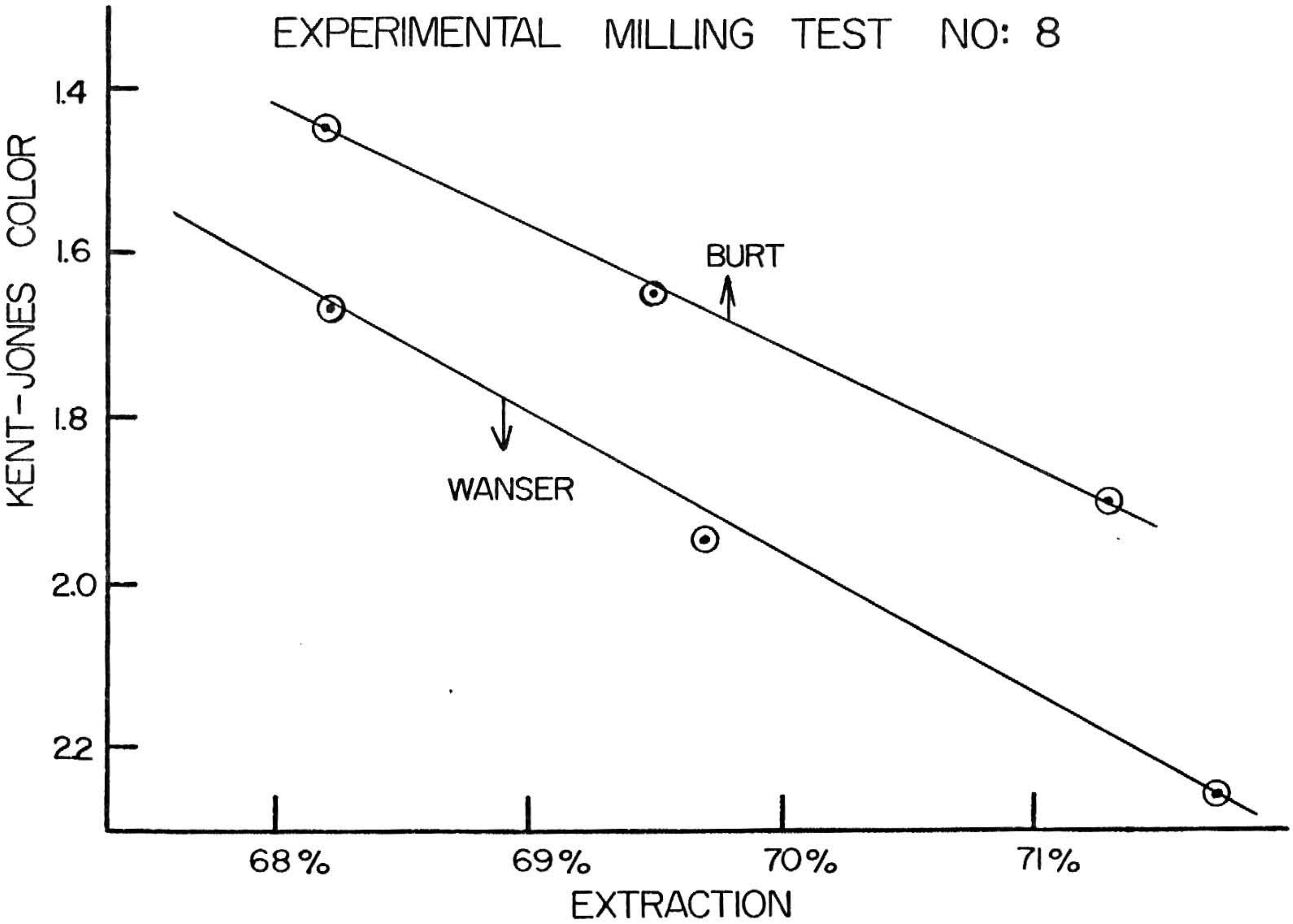
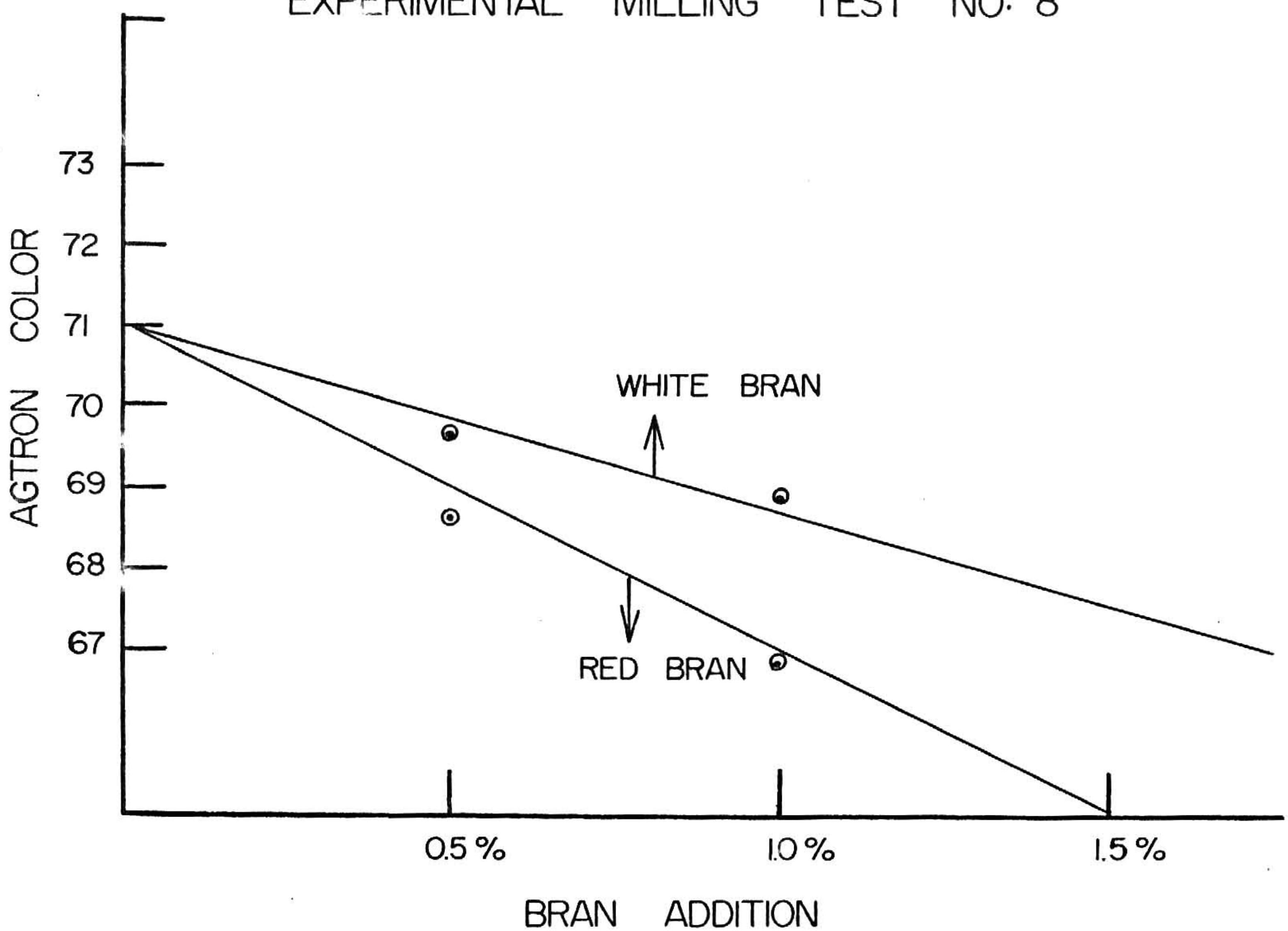


Fig. 14 EFFECT OF BRAN ADDITION ON AGTRON FLOUR COLOR
EXPERIMENTAL MILLING TEST NO: 8



31 and plotted on Figures 13A and 13B. The Agtron and the Kent-Jones colors shows that the white wheat has a lower discoloring power and consequent better potential for higher extraction.

As a further test bran flour of Wanser and Burt were prepared and added to Burt straight grade. Results are tabulated in Table 32 and Fig. 14 and again confirm the greater discoloring power of Red Bran.

Experimental Milling No. 9

This last series was done as a final confirmatory series for previous results. This time all three wheats, Burt (White), Wanser (Red) and Coulee (White) were used. Settings were optimal for each variety. Results are tabulated on Table 33. These show that White wheats give a much better color/extraction and profile. This confirms previous results.

Experimental Milling Conclusions

Overall this series of Experimental Milling Tests indicate that White Wheat could easily give a higher extraction than Red wheat at a similar color level. Extractions at a Agtron level of 60 are shown on Table 34. These results are taken from the Kansas Wheat Milling Tests. Even with bran addition, we get a 0.45% advantage for White wheat and with shorts addition we get 1.65% advantage for White wheat. Normally on increasing extraction, the effect is more similar to shorts addition, and therefore under proper milling conditions we can easily expect

TABLE 33. RESULTS OF EXPERIMENTAL MILLING TEST NO. 9

	Washington White Burt				Washington Red Wanser				Washington White Coulee			
Sample Wt.	3000 gms.				3000 gms.				3000 gms.			
Milling Moisture	13.75%				14.5%				14.0%			
	%age of Total Prod.	Ash 14%MB	Green Agtron Color	Kent-Jones Color	%age of Total Prod.	Ash 14%MB	Green Agtron Color	Kent-Jones Color	%age of Total Prod.	Ash 14%MB	Green Agtron Color	Kent-Jones Color
1st Bk.	4.7				5				3.41			
2nd Bk.	5.8				6.05				4.8			
3rd Bk.	2.08				2.1				2.23			
Dk. Flour	12.58				13.15				12.45			
1st Red.	14.06				12.65				12.85			
2nd Red.	25.99				18.94				25.42			
3rd Red.	17.34				2.22				19.11			
Red. Flour	57.39				53.29				57.37			
Str. Grade	69.97	.407	63.5	2.15	66.94	.399	60	2.85	67.82	.466	66	1.85
Bran %age		14.77%				15.83%				14.92%		
Shorts		15.26%				17.74%				15.26%		
Prod. Loss		4.5%				4.5%				5.0 %		
Flour Moisture		11.2%				11.7%				11.5%		
Flour Ash, 14%M.B.		.407%				.399%				.466%		
Flour Prod., 14%M.B.		7.95%				8.08%				7.75%		

TABLE 34. COMPARATIVE EXTRACTION LEVELS AT GREEN AGTRON COLOR OF 60.

Sample Condition	Red Wheat Extraction	White Wheat Extraction	White Wheat Advantage
Wheat tempered to 14% initially + 1% an hour before milling Total=15%	75.2%	76.55%	1.35%
Wheat tempered to 15%	74.6%	76.5%	1.9%
Wheat tempered to 16%	75.75	76.3%	0.55%
Wheat tempered to 17%	74.95%	75.15%	0.25%
Shorts addition	72.1%	73.75%	1.65%
Bran addition	-	-	0.45%

at least 1.5% more White wheat extraction. This is with the Kansas White Wheat which we have noted is not as white as it should be.

The Washington White (Burt) and Washington Red (Wanser) show the White Wheat advantage more pronounced. At a Agtron level of 67 we see White Wheat has an advantage of 2.1%, which could be extrapolated to 2.5% to 3.0% advantage at an Agtron level of 60. For Bran addition we see white wheat having 0.6% advantage at color 67. At Agtron level of 60 we could extrapolate this to a 1.4% advantage for White wheat extraction (see Fig. 13A, 13B and 14).

Using shorts addition as a more realistic guide, we can expect 2.5% extraction increase with the Washington White as compared to the Washington Red.

In conclusion, these Experimental Milling Results indicate that between 1.5% to 2.5% higher extraction can be obtained with White wheat than with Red wheat at an Agtron level of 60. The exact increase in extraction depends on the whiteness of the wheat kernel and the milling conditions.

FLOUR

Physico-Chemical Dough Tests

Next a batch of standard dough tests were carried out on the flours milled from the wheats.

a) Gas Production Test

Table 35 and 36 give the results of the Gas Production

TABLE 35. GAS PRODUCTION TESTS-KANSAS WHEATS

W = Clark's Cream Hard White R = Golden Chief Hard Red

	Sample 1		Sample 2		Sample 3		Sample 4		Sample 5		Sample 6	
	W	R	W	R	W	R	W	R	W	R	W	R
30mts	62	50	25	10	28	50	50	32	45	40	45	39
60mts	102	102	65	55	75	102	105	85	102	92	98	95
90mts	150	150	100	100	130	155	155	148	152	142	150	139
120mts	207	205	160	160	190	200	215	198	210	198	200	190
150mts	245	225	195	202	239	212	258	225	252	229	230	205
180mts	261	232	207	212	265	220	277	235	271	242	248	218
210mts	271	239	218	225	275	225	288	240	282	252	260	225
240mts	279	242	228	229	282	230	292	245	292	260	265	230
270mts	285	248	232	232	295	235	302	250	295	265	267	232
300mts	290	252	245	235	302	240	308	252	305	270	272	240

TABLE 36. GAS PRODUCTION TESTS-WASHINGTON WHEATS

W_1= Burt Hard White; R = Wanser Hard Red; W_2 = Coulee Hard White

	Sample 1		Sample 2		Sample 3			Sample 4		
	W_1	R	W_1	R	W_1	R	W_2	W_1	R	W_2
30mts	52	55	30	38	45	30	40	38	52	45
60mts	115	125	85	90	105	85	90	110	110	120
90mts	182	180	150	155	160	148	145	182	180	181
120mts	240	240	220	205	212	202	188	238	230	231
150mts	302	282	272	262	268	255	245	312	282	258
180mts	330	298	325	200	325	300	305	345	302	265
210mts	345	308	375	310	365	312	362	360	310	269
240mts	352	312	390	315	380	320	410	365	320	272
270mts	359	315	398	325	390	325	440	372	323	279
300mts	369	322	408	329	398	355	459	377	328	282

Test. These show that invariably the Hard White Wheat produces more gas than the Hard Red Wheat. In almost all the samples, the gas production rates are nearly identical up to about 120 minutes. After 120 minutes, in almost all cases the White Flour starts producing gas at a faster rate than the Red Flour.

It is probable, that in the initial 120 minutes the gas is formed as a reault of the initial reducing sugar present in the flour and after this the gas formation is due to the sugar formed by the diastatic activity of the flour itself. In normal flours we can expect that the diastatic enzymes are not excessive. Therefore, it seems that the White flour produces more sugars due to greater starch damage, and this starch damage may be attributed to the harder wheat. As noted earlier, more reduction pressure was used on the harder White wheat, resulting in a slightly higher starch damage, resulting in White wheat flour having better gas production abilities.

b) Amylograph Test

The results of the Amylograph test are tabulated on Table 37, and plotted on Figures 15 and 16. Each set represents a set of wheats milled together under similar conditions, except for optimization of mill settings for each wheat.

These results show that in the Kansas wheats, the Hard White (Clark's Cream) invariably had a lower peak, which means that the Hard White had a slightly higher Alpha-Amylase activity than the Hard Red. This is probably due to a higher starch

TABLE 37. AMYLOGRAPH TESTS

Sample No.	Sample	Gel. Time mts.	Gel. Temp. °F.	Peak
		KANSAS WHEATS		
SET 1	G. Chief Hard Red	22	63	780
	Cream Hard White	22	63	680
SET 2	G. Chief Hard Red	22	63	750
	Cream Hard White	21	61.5	670
SET 3	G. Chief Hard Red	22	63	750
	Cream Hard White	21	61.5	710
SET 4	G. Chief Hard Red	22	63	770
	Cream Hard White	22	63	780
SET 5	G. Chief Hard Red	22	63	700
	Cream Hard White	21	61.5	600
		WASHINGTON WHEATS		
SET 1	Coulee Hard White	20	60	660
	Burt Hard White	20	60	720
	Wanser Hard Red	20	60	620
SET 2	Burt Hard White	20	60	790
	Wanser Hard Red	20	60	730

TABLE 37. (continued)

Sample No.	Sample	Gel. Time mts.	Gel. Temp. °F.	Peak
	WASHINGTON WHEATS (continued)			
SET 3	Burt Hard White	20	60	620
	Wanser Hard Red	20	60	610
SET 4	Coulee Hard White	21	61.5	520
	Burt Hard White	20	60	590
	Wanser Hard Red	21	61.5	520

AMYLOGRAM

KANSAS WHEATS

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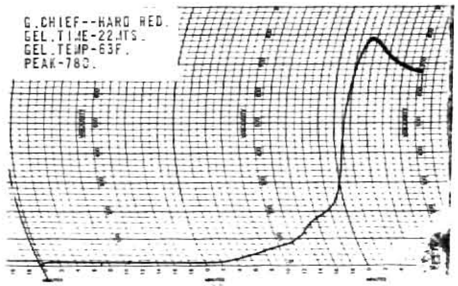

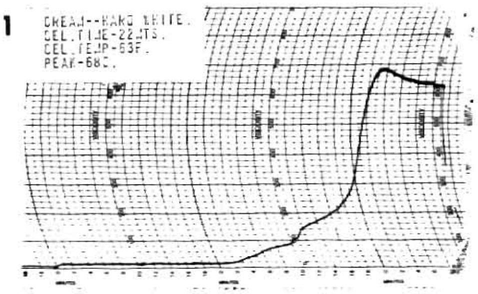

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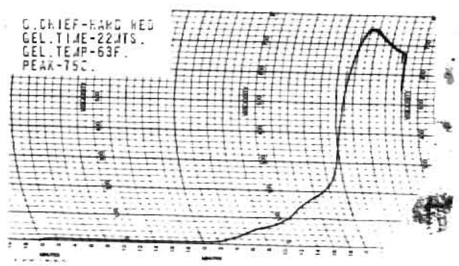

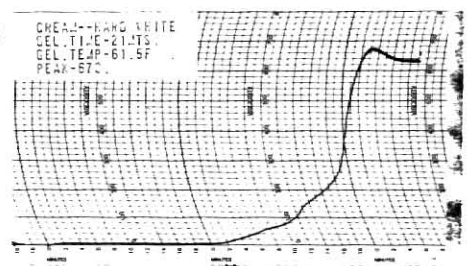

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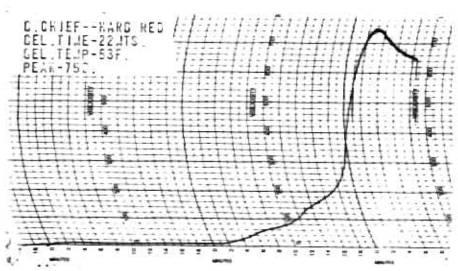

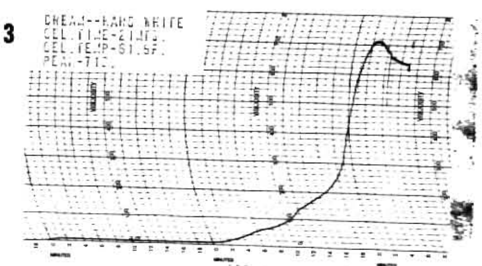

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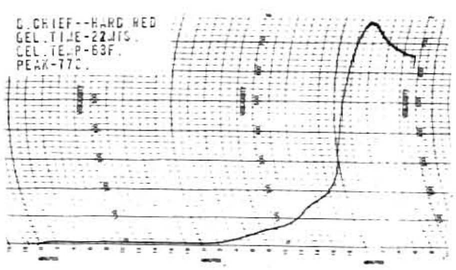

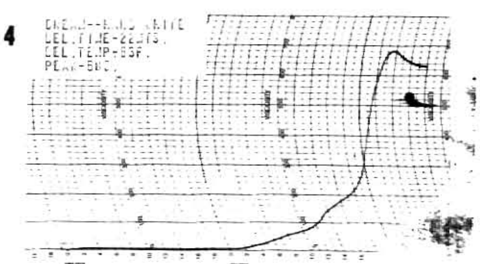

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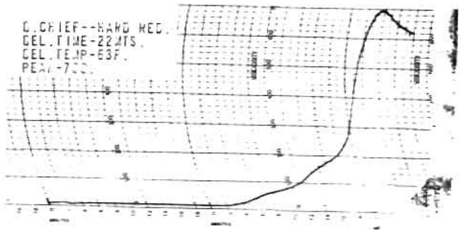
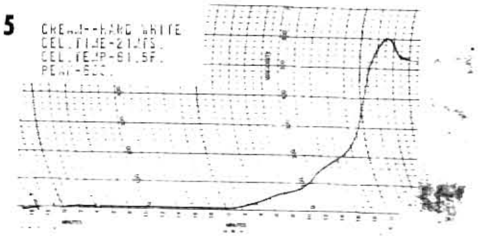
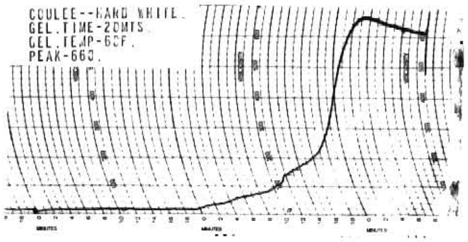
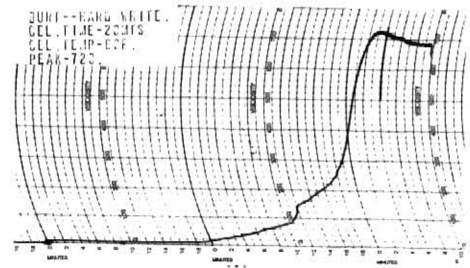


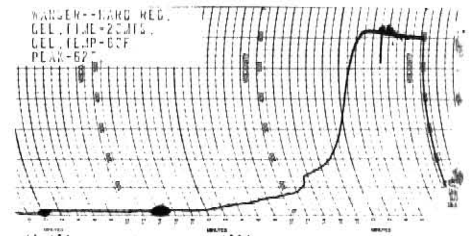


AMYLOGRAM
WASHINGTON WHEATS

SAMPLE 1







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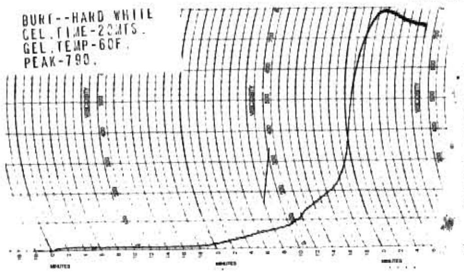

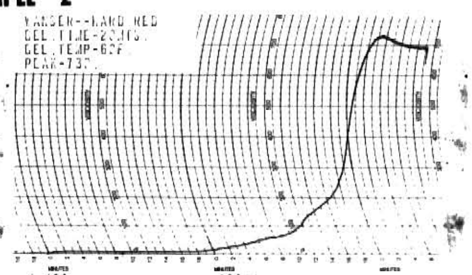

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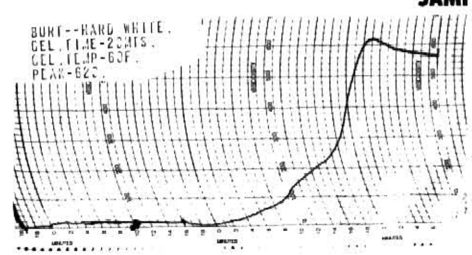

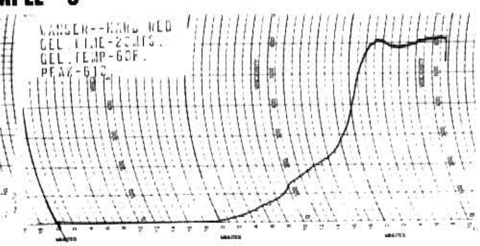

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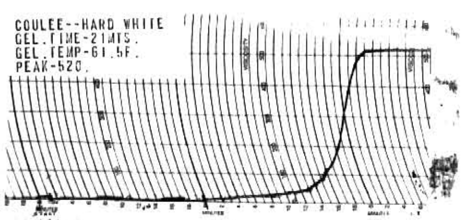
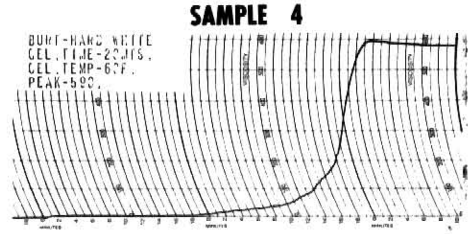
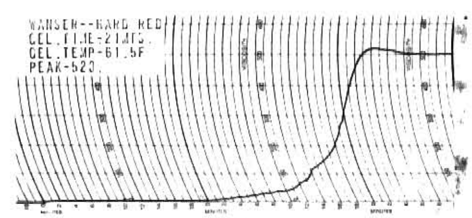






damage caused by reduction pressure level needed for the greater hardness of the White wheat and also its plumper kernels. For baking purposes the significance of this is that the Kansas Hard White will need less malt addition than Kansas Hard Red.

The Washington wheats had the opposite results. Here the Hard Red (Wanser) has a lower peak than the Hard White (Burt) but it must be borne in mind that the Washington wheats were not "hard" as such. However as the Washington wheats and the Kansas wheats give differing trends, we cannot conclusively say that the White has an advantage over Red or vice versa, though we note that the Hard White definitely does not have an excessive Alpha-Amylase activity when unsprouted. Therefore when the sprouting problem is not present, the Alpha Amylase activity of White Wheat is normal.

c) Farinograph Test

Results of Farinograph are tabulated on Table 38 and Table 39 and the Farinograms are on Fig. 17 and 18.

Kansas Wheats

Mean Farinogram values for water absorption show that in Kansas wheats the Hard Red has a marginally higher water absorption which is probably due to the relatively finer flour granulation of the Hard Red flour as it is not as hard as Hard White. Generally the water absorption was nearly equal and only in one case did the Hard Red have a substantially higher water absorption.

TABLE 38. FARINOGRAMS

Set	Sample	Water Absorption	Mixing Time	Stability	Valorimeter
		KANSAS WHEATS			
1	Cream Hard White	62.6%	7mts	11mts	70
	Golden Chief Hard Red	62.8%	6.5mts	16mts	70
2	Cream Hard White	63%	9.5mts	11.5mts	77
	Golden Chief Hard Red	63%	8mts	11.5mts	71
3	Cream Hard White	62.2%	8mts	10mts	73
	Golden Chief Hard Red	62%	10mts	12mts	80
4	Cream Hard White	64%	8.5mts	13mts	73
	Golden Chief Hard Red	64%	10mts	14mts	80
5	Cream Hard White	64%	7mts	14mts	71
	Golden Chief Hard Red	64.3%	10mts	14mts	75
6	Cream Hard White	61%	9mts	14.5mts	74
	Golden Chief Hard Red	62%	9mts	14.5mts	76
7	Cream-100% Shorts Flour-0%	65.5%	8.5mts	11mts	71
	Cream-99.5% Shorts Flour--0.5%	66.4%	7.5mts	9.5mts	67
	Cream-99.0% Shorts Flour--1.0%	67%	8.0mts	8.5mts	69

TABLE 38 (continued)

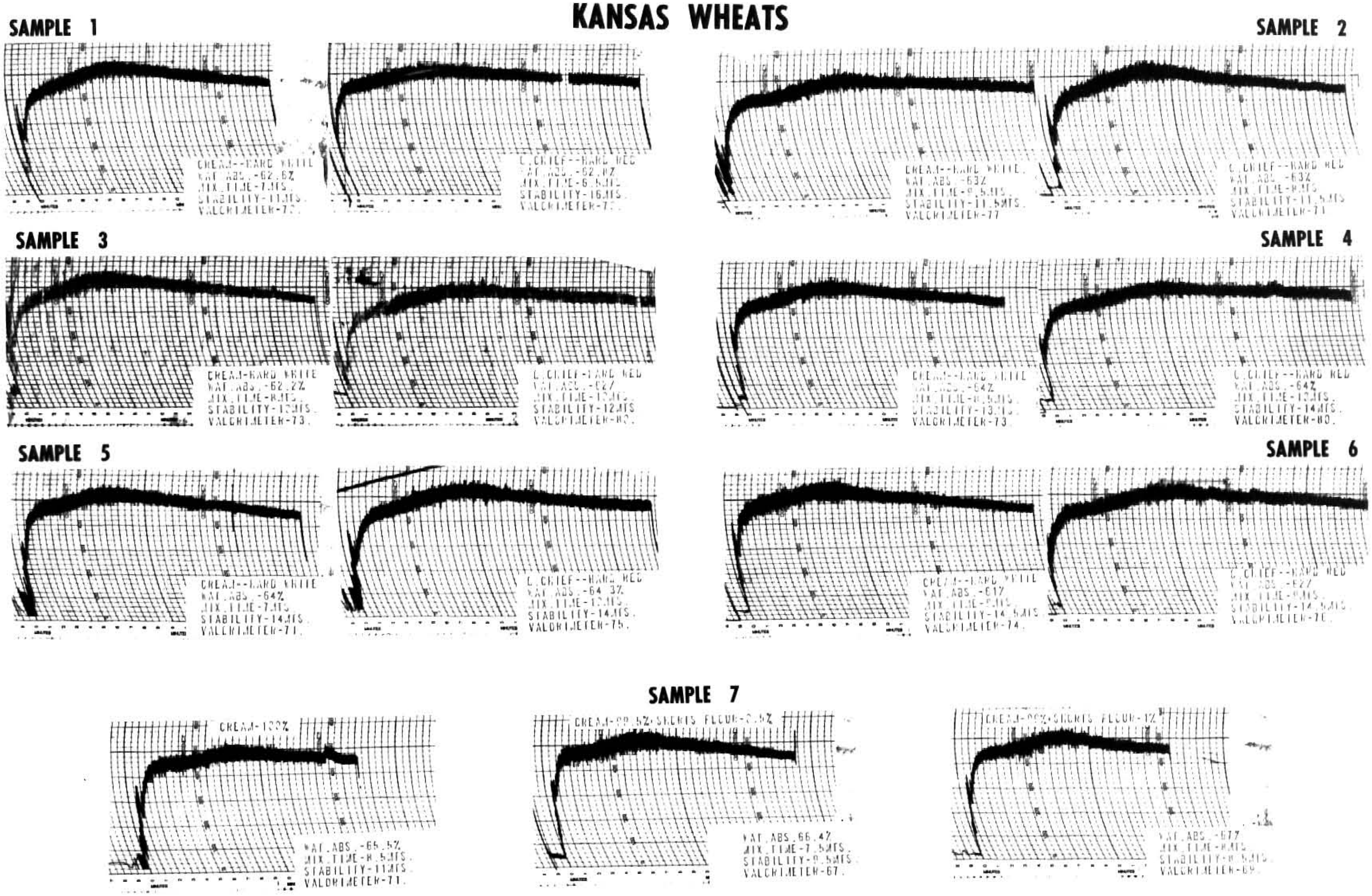
Set No.	Sample	Water Absorption	Mixing Time	Stability	Valori-meter
		WASHINGTON WHEAT			
1	Burt Hard White	59.9%	6mts	9mts	63
	Coulee Hard White	60.1%	2.5mts	4mts	36
	Wanser Hard Red	61.1%	8mts	11.5mts	74
2	Burt Hard White	59%	4.5mts	9mts	63
	Coulee Hard White	57.2%	2.5mts	4.25mts	42
	Wanser Hard Red	59.7%	5mts	11.25mts	64
3	Coulee Hard White	61%	8.5mts	16mts	73
	Burt Hard White	60.2%	5mts	9mts	63
	Wanser Hard Red	59.6%	7.5mts	11mts	67

TABLE 39. AVERAGE FARINOGRAM VALUES

Sample	Water Absorption	Mixing Time	Stability	Valormeter
Kansas				
Cream (Hard White)	62.8%	8.17mts	12.33mts	73
G. Chief (Hard Red)	63.02%	8.92mts	13.67mts	75
Washington				
Burt (Hard White)	59.7%	5.17mts	9.00mts	63
Coulee (Hard White)	59.5%	4.5mts	8.08mts	50.3
Wanser (Hard Red)	60.1%	6.83mts	11.25mts	68.3

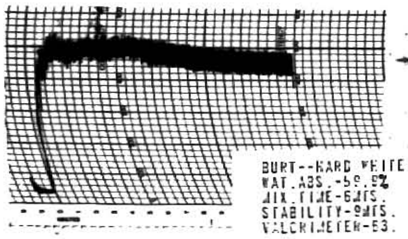
FARINOGRAMS

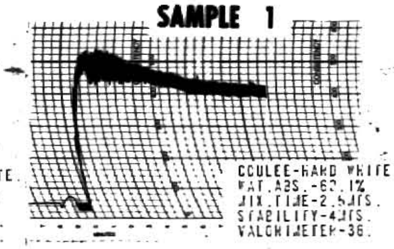
KANSAS WHEATS

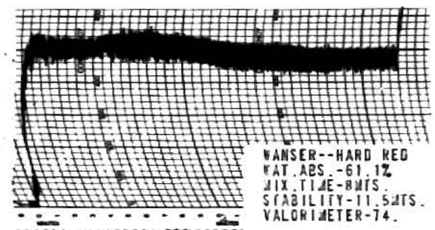


FARINOGRAMS
WASHINGTON WHEATS

SAMPLE 1







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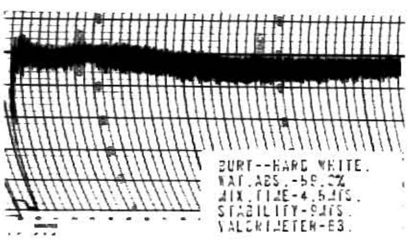
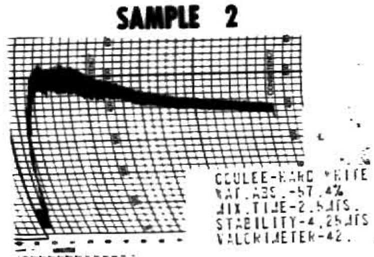
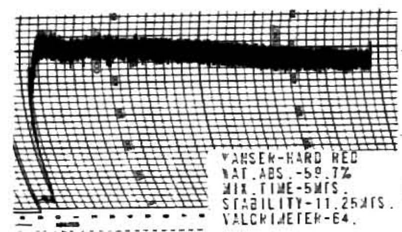
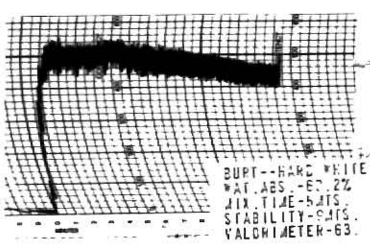
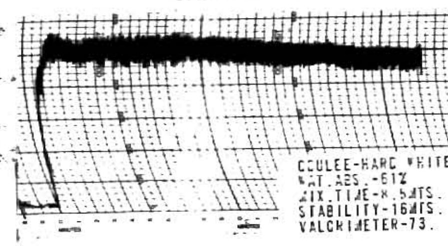


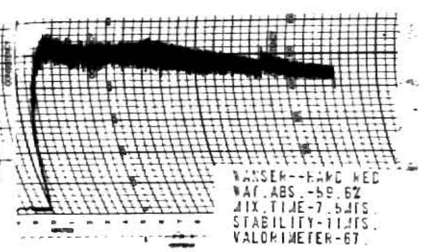




SAMPLE 3







Mixing time of the White wheats are generally marginally lower, as also the stability values. But this is not a major difference between the two varieties. It may be noted that some plant bakers prefer a shorter mixing time.

Finally the Valorimeter readings of the two are almost equal. As the valorimeter values are taken as rough indicators of loaf volume potential, no difference can be noted between the two.

Washington Wheats

These were not "hard" flours and so these results should be viewed with caution. Here too we see the same trends between Hard White (Burt) and Hard Red (Wanser) namely:

i) Hard White has a slightly lower Water absorption.

ii) The relationship between the two for mixing time, Stability and Valorimeter values are fairly similar. The Coulee samples (White) showed wide variation, as some samples were much weaker than others and hence are not very indicative.

The main point that needs further attention is the respective Water Absorption values. While it is possible that the Hard Red has a higher Water Absorption probably due to its finer granulation, further studies should be made to investigate this aspect in greater detail.

Finally, a test with the addition of various proportions of shorts flour was carried out (see Sample 7 of Kansas Wheat on Table 38). Addition of shorts flour resulted in increase of water absorption and a slight decrease in stability but mixing time and valorimeter value changes were not very significant. Therefore within limits, increased extraction will not cause unacceptable change in rheological properties, but will give increase in Water Absorption which should be very attractive to the professional baker.

d) Extensigraph Test

Results obtained are tabulated in Table 40 (Kansas Wheats) and Table 41 (Washington Wheats). The Extensigraphs are shown in Figure 19.

In the Kansas wheats it is noted that the White wheat generally tends to have a lower resistance initially, which tends later to be equal to Red Wheat after 90 minutes. But generally the "Resistances" are comparable. Extensibility though tends to be slightly lower in white wheats. Consequently the Elasticity as expressed by the R/E ratio, is slightly inferior for White wheat as compared to Red wheat.

In the Washington Wheats we see that Burt (White) has a better resistance to Extensibility ratio; thus here the White (Burt) has a slightly better elasticity than the Red Wheat. The elasticity characteristics need to be investigated in depth in subsequent investigations. But generally speaking no substantial difference between White Wheat Flours and Red Wheat Flours can

TABLE 40. EXTENSIGRAM - KANSAS WHEATS

H.W. = Cream H.R. = G. Chief

	Sample 1				Sample 2				Sample 3				Average			
	45mts		90mts		45mts		90mts		45mts		90mts		45mts		90mts	
	H.W.	H.R.	H.W.	H.R.	H.W.	H.R.	H.W.	H.R.	H.W.	H.R.	H.W.	H.R.	H.W.	H.R.	H.W.	H.R.
R_{max}	500	580	790	820	540	560	710	660	550	570	680	680	530	570	727	720
R_5	370	380	660	570	380	360	580	440	400	360	520	450	383	367	587	487
E	185	225	150	200	195	220	170	200	180	210	160	195	187	218	160	198
R_{max}/E	2.70	2.58	5.27	4.1	2.77	2.55	4.18	3.3	3.06	2.71	4.25	3.49	2.83	2.61	4.54	3.64
R_5/E	2	1.71	4.4	2.85	1.95	1.61	3.41	2.2	2.22	1.71	3.25	2.31	2.05	1.68	3.67	2.46
Area	126	172	153	206	137	159	154	170	127	149	140	170	130	160	149	183

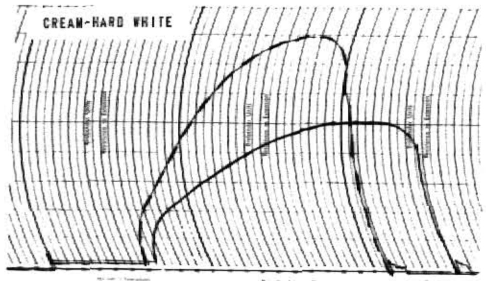
TABLE 41. EXTENSIGRAM - WASHINGTON WHEATS

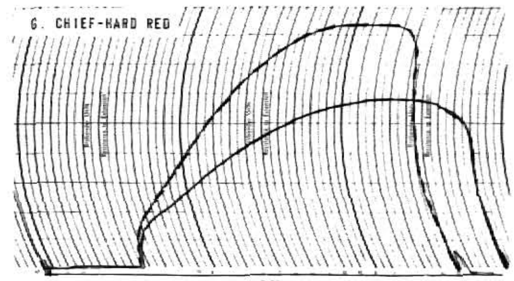
$H.W._1$ = Coulee; $H.W._2$ = Burt; H.R. = Wanser

	SAMPLE 1						SAMPLE 2						AVERAGE			
	45mts			90mts			45mts			90mts			45mts		90mts.	
	$H.W._1$	$H.W._2$	H.R.	$H.W._1$	$H.W._2$	H.R.	$H.W._1$	$H.W._2$	H.R.	$H.W._1$	$H.W._2$	H.R.	$H.W._2$	H.R.	$H.W._2$	H.R.
R_{max}	290	430	450	370	610	600	480	470	460	690	680	590	450	455	645	595
R_5	270	210	400	350	590	570	390	400	400	580	640	520	405	400	615	545
E	140	130	130	138	120	120	165	145	160	150	125	140	138	145	123	130
R_{max}/E	2.07	3.31	3.46	2.68	5.08	5	2.91	3.24	2.88	4.6	5.44	4.21	3.26	3.14	5.24	4.58
R_5/E	1.93	3.15	3.08	2.54	4.92	4.75	2.39	2.76	2.5	2.87	5.12	4.21	2.93	2.76	5	4.19
Area	60	83	78	72	98	100	105	94	100	141	112	107	88.5	89	105	103.5

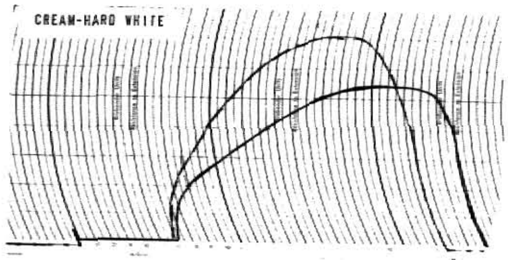
EXTENSIGRAMS
KANSAS WHEATS

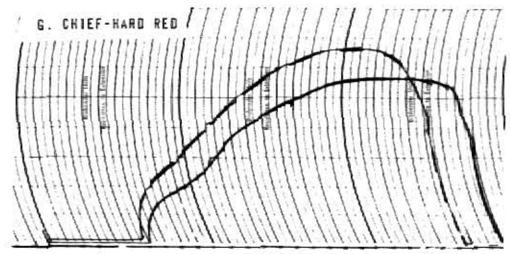
SAMPLE 1





SAMPLE 2





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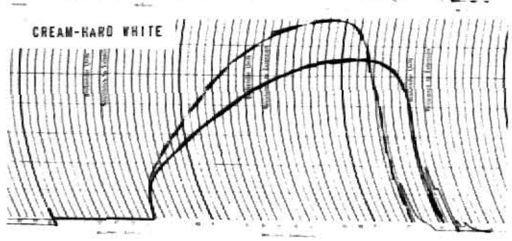
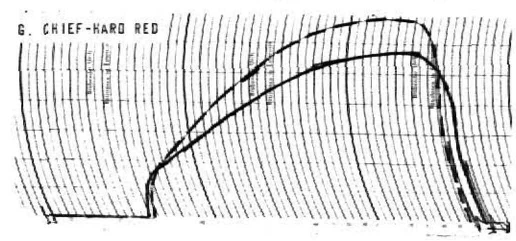
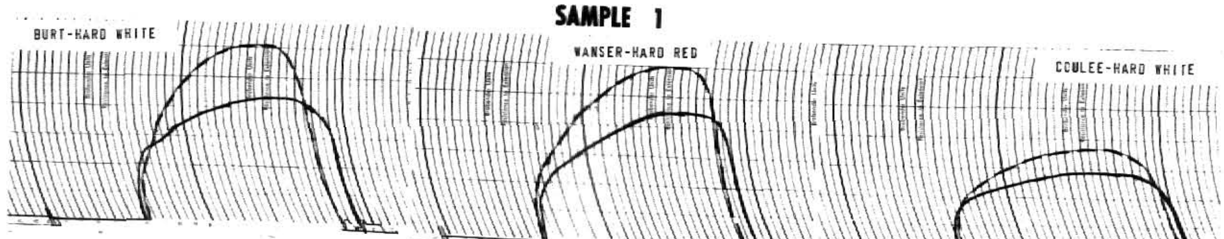


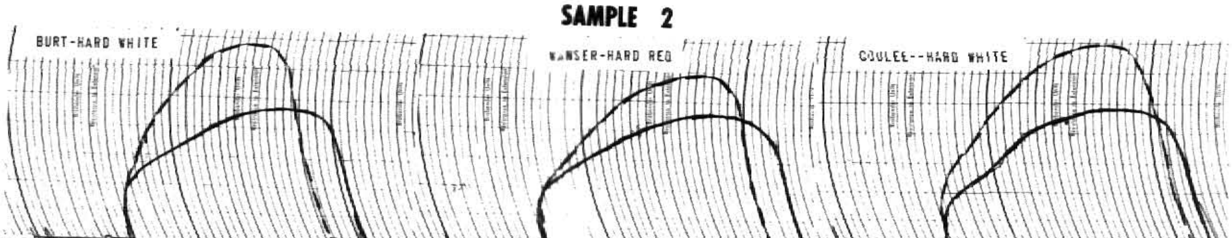


EXTENSIGRAMS
WASHINGTON WHEATS

SAMPLE 1



SAMPLE 2



be noted.

It may be noted that in Table 41 (Washington Wheats) no average is worked out for Coulee. This is as the first sample is a very soft sample and the second is comparatively harder and an average under these circumstances would be unrealistic. However this suggests that extensigram characteristics may not be due to kernel color as such but depend on various other conditions; in this case on the growing conditions. It should therefore be possible to select a white wheat which can give optimum extensigram characteristics in the right growing conditions.

e) Mixogram Test

Results of the Mixogram test are tabulated in Table 42. Charts can be seen on Figure 20.

These show that the Water Absorption of Cream (Kansas White) and Golden Chief (Kansas Red) is very comparable. Golden Chief has a marginally higher water absorption, as already seen in the Farinographs and again is probably due to the finer granulation of Red Wheat as explained in detail in Experimental Milling Results. Even though the difference is not large, it must be noted that if observed differences are due to granulation in proper milling practices.

Mixing times are also similar, though here the White Wheats have a slightly higher Mixing Time. This is in contrast to the Farinograph, where the Mixing Times for the Red Wheats are

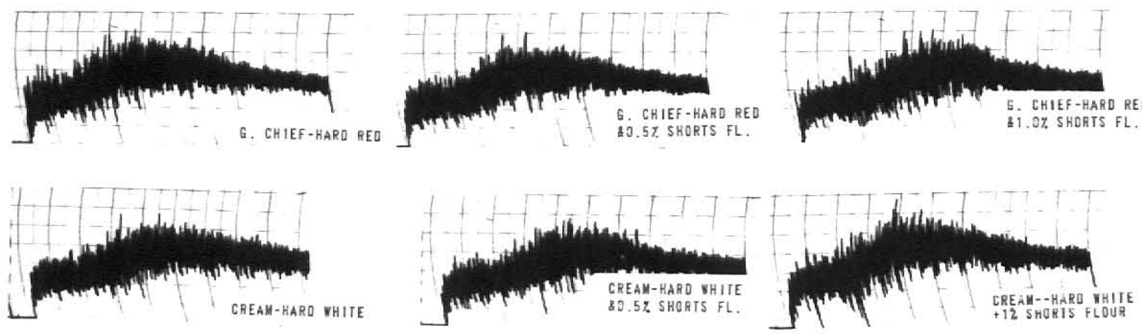
TABLE 42. MIXOGRAPH

KANSAS WHEATS				
	Abs.	M.T.	Peak	Stab.
Cream Wheat-Hard White	65.75%	4.25mts	47	4.5mts
Cream Wheat+0.25% Bran Flour	67.25%	4mts	47	4.25mts
Cream Wheat+0.5% Bran Flour	68.75%	4mts	45	4.5mts
G. Chief-Hard Red	66.25%	4mts	50	5mts
G. Chief+0.25% Bran Flour	67.5%	4mts	47	4.5mts
G. Chief+0.5% Bran Flour	69.0%	4.25mts	45	5mts
Cream Wheat+0.5% Shorts Flour	67.75%	4.5mts	40	5.75mts
Cream Wheat-Hard White	66.5%	4.5mts	40	6mts
Cream Wheat+1% Shorts Flour	68.75%	4.5mts	45	4.75mts
G. Chief-Hard Red	66.5%	4.25mts	42	5.75mts
G. Chief+0.5% Shorts Flour	67.5%	4.25mts	40	5.75mts
G. Chief+1% Shorts Flour	68.5%	4.5mts	40	5mts
WASHINGTON WHEATS				
Coulee-White	63.5%	6mts	35	-
Burt-White	64%	5mts	32	-
Wanser-Red	63%	5.5mts	35	-
Coulee-White	61%	2mts	28	-
Burt-White	62%	5.5mts	28	-
Wanser-Red	63%	6mts	30	-

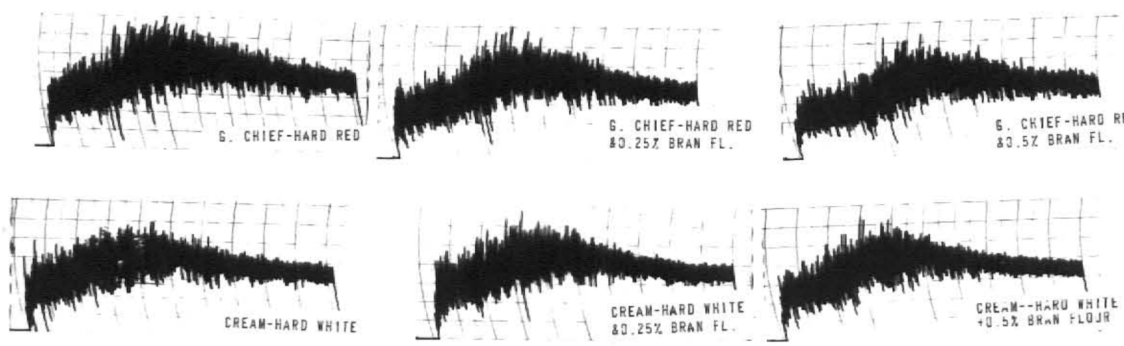
MIXOGRAMS

KANSAS WHEATS

SAMPLE 1

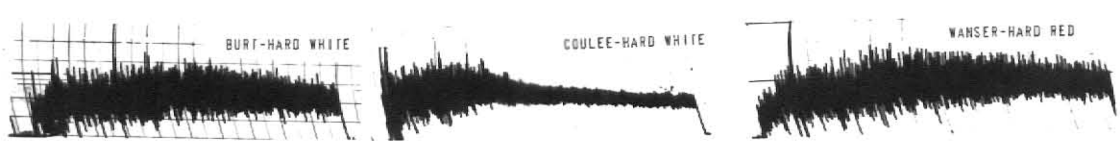


SAMPLE 2



WASHINGTON WHEATS

SAMPLE 1



SAMPLE 2

marginally higher.

Mixing peaks and stabilities are identical. The overall conclusion is that as far as Mixograph results go, the Hard White and the Hard Red samples of the Kansas Wheats are identical.

A further set of tests was done to see the effect of bran and shorts flour on Mixograph characteristics. From the results we note:

i) Addition of bran flour or shorts flour increases Water Absorption, roughly proportionately to the amount of addition. Bran flour causes a bigger increase in Water Absorption than Shorts flour.

ii) Mixing time remains the same. There is very slight tendency for Mixing time to increase. But at the levels of Bran and Shorts flour added here, the increase is not of consequence.

iii) Peak and Stability tend to drop; however, the drop at the levels of bran or shorts added is minor.

Thus we can conclude that up to 1% shorts flour addition, the Mixograph characteristics are not affected appreciably. Thus 1% increase in extraction seems rheologically acceptable. This is confirmed by addition of 0.5% bran flour which is equivalent to adding 2% shorts flour at the least. Again as mixograph characteristics are not seriously affected, it is obvious we can go to an increase of at least 2% in extraction without unacceptable adverse effect on Mixing properties.

f) Baking Tests

Results obtained in Baking Test are tabulated in Table 43. These show that the Cream Wheat (Kansas Hard White) and Golden Chief (Kansas Hard Red) have very identical loaf volume to loaf weight ratios. Thus we see no difference in breadmaking potential due to kernel color.

Similar conclusions can be drawn by inspecting the results of Baking Test done on Burt (Washington White), Coulee (Washington White) and Wanser (Washington Red). A further set of tests was done to check the effect of increased extraction on breadmaking potential of the Kansas Hard Wheats. These results are tabulated on Table 44. From these we see a slight increase in Loaf Volume to Loaf Weight as the extraction increases i.e., up to 1% Shorts Flour or 0.5% Bran Flour addition. But we must be careful in drawing conclusion from this. It may be wrong to conclude that increased extraction improves breadmaking potential, but we can note here that at the least within limits, an increase in extraction does not cause a deterioration in breadmaking potential.

Breadmaking potential is largely a measure of protein quantity and quality. In comparing two flours if protein quantity is similar, then the ratio of volume to weight is a reflection of protein quality, if baking tests conditions optimize loaf volume for each variety under test. But the standard test baking procedures in this country, ask for a standard procedure for all flours to eliminate the effect of human error. Therefore,

TABLE 43. BAKE TEST RESULTS

No.	Sample	Loaf Wt.	Loaf Vol.	Loaf Wt./ Loaf Vol.
	KANSAS WHEATS			
1	Cream Hard White	150.5gms.	805c.c.	5.35
2	G. Chief Hard Red	149.4gms.	804c.c.	5.38
3	Cream 100%	150gms.	800c.c.	5.33
	Crea 99.5%+0.5% Sh. Fl.	151.gms.	810c.c.	5.36
	Cream 99.0%+1% Sh. Fl.	151.8gms.	815c.c.	5.37
4	Cream 100%	150.6gms.	797c.c.	5.29
	Cream 75%+0.25% Bran Flour	152.6gms.	807c.c.	5.29
	Cream 99.5%+0.5% Bran Flour	153.5gms.	800c.c.	5.21
	WASHINGTON WHEATS			
5	Wanser Hard Red	145.3gms.	730c.c.	5.02
6	Burt Hard White	148gms.	727c.c.	4.91
7	Coulee Hard White	149gms.	730c.c.	4.90

N.B a) 1 and 2 are the averages of 6 tests.

b) 3 - 7 are the averages of 4 tests each.

as mentioned above the fact that loaf volume increases with increased extraction, should be viewed in the light of experimental baking conditions.

CONCLUSION

In each of the tests described and detailed above, the attempt had been to compare White Wheat to Red Wheat. Principally the objectives of this work was to ascertain whether White Wheat had the ability to give a higher yield than Red Wheat using flour color as a quality factor. Experimental results show that this is so. Extrapolating from these results we estimate from 1% to 2.5% extra extraction for white wheat using 60 Green Agtron Color as a quality factor. Flour protein, moisture and ash for both are very comparable.

Rheological and baking tests show similar results. Addition of up to 1% shorts flour or 0.5% bran flour, did not adversely affect baking potential.

Therefore this preliminary investigation shows that Hard White Wheat is not inferior to Hard Red Wheat in milling on breadmaking properties. In the introduction we have shown that there is a market requirement for Hard White especially on the overseas market. Food quantity is a very critical factor in feeding the world. Thus White Wheat with its higher yielding capacity is bound to play a very important and vital part in the world market. Further in view of the equivalent breadmaking potential of White Wheat as compared to Red Wheat, the farmer should have no problem in selling White Wheat to local American customers. It is noted that there are no substantial disadvantages to the use of White Wheat. In fact there is one very important advantage. That is its ability to give a higher flour yield than Red Wheat at a comparable flour color standard. The increased growth of Hard White Wheat could therefore give the United States a stronger competitive advantage in the World markets.

ACKNOWLEDGMENTS

I wish to express my sincere gratitude and appreciation to Prof. Arlin Ward for his help and guidance during the preparation of this thesis as well as during the course of the research phase of the project.

I thank Dr. Jean Caul and Prof. Eugene Farrel for consenting to serve on my advisory committee, and also for their assistance in the course of this project.

I also take this opportunity to thank Dr. William J. Hoover, the Head of the Department of Grain Science and Industry for having given me this opportunity to work at Kansas State University.

LITERATURE CITED

1. Foreign Agricultural Science Report, Grain and Feed Division, U.S.D.A., October, 1975.

2. "1975 Crop Production Conference Report" published by Crop Quality Council, Minneapolis, Minnesota.

3. Wheat-Field to Market, Kansas Wheat Flour Institute, Chicago, Illinois.

4. M. McMasters, J. Hinton and D. Bradbury. "Microscopic Structure and Composition of the Wheat Kernel", Wheat Chemistry and Technology. Editor, Y. Pomeranz.

5. M.L. Al-Suaidy. "Investigations on the Effect of Physical and Biochemical Premilling Treatments on Milling and Baking Properties of Hard Red Winter Wheat". KSU Thesis, 1971.

6. D. Bradbury, G. Call and M. McMasters. "Structure of Mature Wheat Kernel - Gross Anatomy and Relationship of Parts". Cereal Chemistry, 33:329 (1956).

7. T. Myamoto and F. Everson. "Biochemical and Physiological Studies of Wheat Seed Pigmentation". Agronomy Journal, 1958, P. 733.

8. Moran and Drummond- Laucet (i)- 698 (1965).

9. Royal Society Report on Availability of Nutrients with Changing Extraction - 1916 - in Modern Cereal Chemistry by D.W. Kent-Jones and A.J. Amos; Northern Publishing Company, Liverpool,England.

10. Dr. R. Passmore. "Bread and Flour in the Modern Diet". Indian Miller, April, 1974. p. 19.

11. C.R. Jones and G.J. Baker. Unpublished data, 1954, quoted in "Wheat Chemistry and Technology". Editor, Y. Pomeranz.

12. Washington Agricultural Experiment Station Technical Bulletin 61, December, 1965.

13. M. Barimore and R. Bequette. "Kernel Color and Shape as Guides To Potential Flour Performance in Wheat Marketing". Agronomy Journal, 60:223 (1968).

14. G.L. Sutton. "The Problem of Australian Strong Wheat". The Journal of the Australian Institute of Agricultural Sciences, 23:19 (March, 1957).

15. K.A. Gillis and L.D. Sibbit. "Wheat Quality" in Wheat Production and Utilization. Edited by George E. Inglett, Ph.D. Published by the Avi Publishing Company, Inc., 1974.

16. H.J. Moss, M.F. Derrerra and L.H. Balaam. "Effect of Pre-Harvest Grain on Germination in the Ear and Alpha-Amylase Activity of Australian Wheat". Australian Journal of Agricultural Research, 23:769 (1972).

17. W.F. Geddes, J.G. Dickson and C.B. Croston. Effect of Wheat Class and Malting Conditions on Gassing Power Stimulation and Alpha and Beta Amylase Activities of Malted Wheat. Cereal Chemistry, 26:414 (1949).

18. T. Aitken and W. Geddes. The Effect on Flour Strength of Increasing The Protein Content by Addition of Dried Gluten. Cereal Chemistry, 15:181 (1938).

19. J.J. Johnson. "A Review of Methods for Determination of The Quality of Wheat and Flour for Breadmaking". Technical Bulletin, 76, April, 1954. Agricultural Experiment Station, Kansas State College of Agriculture and Applied Science, Manhattan, Kansas.

20. H.L. Stenvert. "Grinding Resistance". Flour and Animal Feed Milling, July, 1974. P. 24.

21. W. Shuey. "A Wheat Sizing Technique for Predicting Flour Milling Yield". Cereal Science Today, 5:71 (1960).

22. M. Dattaraj; A. Ward and F. Neinberger. "Relation of Certain Physical Characteristics of Wheat to Milling Properties". AOM Bulletin, July, 1975. Page 3357.

23. E. Ziegler and N. Greer. "Principles of Milling" in Wheat Chemistry and Technology. Editor, Y. Pomeranz.

24. K. Finney and W. Yamazaki in "Wheat and Wheat Improvement". Edited by K.L. Quinsberry-Madison, Wisconsin, American Society of Agronomy. P. 476.

25. R. Pyler. "Bread Science and Technology". Siebel Publishing Company, Chicago, Illinois, 1973.

26. R.P. Murthy and J.H. Dietz. "Agtron in Evaluation of Cereal Flours". Cereal Chemistry, 51:126 (1974).

27. H. Shuey. Flour Color as Measure of Flour Quality. Baker's Digest. October, 1975. P. 18.

28. J.H. Gillis. Photoelectric method of Detecting Flour Color Cereal Science Today, 8:40 (1963).

29. J. Patton and M. Dishaw. Flour Color Evaluation With the Green Agtron. Cereal Science Today, 13:163 (1968).

30. M. Blish, R. Sandstedt, and G. Astleford. Sugars, Diastatic Activity and Gassing Power in Flour. Cereal Chemistry, 9:378 (1932).

31. L. Lockey, S. Luska and W. Shuey. Farinograph Handbook. American Association of Cereal Chemists, 1960.

32. G. Hubbard. Dynamic Visco-Elastic Behavior of Wheat Flour Doughs. Cereal Science Today, 13:138 (March 1968).

33. Dinesh Mehrotra. Predicting Commercial Milling Results by Experimental Means. KSU Thesis, 1963.

34. Cereal Miller's Handbook. Vol. 1, p. 405-407. Published by AOM, 1963.

35. Cereal Laboratory Methods, 1962. American Association of Cereal Chemists, St. Paul, Minnesota.

36. Kent-Jones and Martin. Flour Grades (Series II)- Operating Instructions. Published by Henry Simon Ltd., England.

37. Wheat Situation. Published by Economic Research Service, USDA, February, 1976.

38. Information Supplied by G.L. Rubenthaller - USDA. Agricultural Research Service. Pullman Washington.

39. E.J. Sebestyn. Evaluation of Wheat and Flour Quality. Flour and Animal Feed Milling, July, 1973, p. 26.

40. C. Czerniejewski, C. Shank, K.J. Bechtel and W. Beadley. "The Minerals of Wheat Flour and Bread". Cereal Chemistry, 41:65 (1964).

41. H.A. Kline. Milling Products Section. North Western Miller, 197-7-22 (1939).

42. C.R. Jones and H. Ziegler. Principles of Milling. Wheat Chemistry and Technology (AACC-1964). Editor, Y. Pomeranz.

43. J.E. Graves. The Minerals of Wheat and Their Relationship to Nutrition. Baker's Digest, 15:43 (1940).

"MILLING AND BAKING QUALITIES
OF HARD WHITE WHEAT AS COMPARED
TO HARD RED WHEAT"

by

ROY FELIX SILVA

B.S., Bombay University, 1961

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the
requirements for the degree

MASTER OF SCIENCE

Department of Grain Science and Industry

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1976

Five major classes of wheat are grown in the United States, with Red Wheat predominating. In Kansas, the production is almost entirely Hard Red. Now there is a large international wheat trade in all classes of wheat and the needs of the overseas buyer needs to be taken into account. In ascertaining these needs of the export market, there seems to be a need for Hard White Wheat. There is insufficient information about the bread making qualities of Hard White Wheat. A comparative study was therefore made to compare the relative qualities of the two wheat types-- hard red and hard white.

Physical and chemical tests were conducted on two sets of wheat. There were:

(a) a set of Kansas wheats i.e. Clark's Cream (Kansas Hard White) and Golden Chief (Kansas Hard Red).

and (b) a set of Washington wheats i.e. Burt and Coulee (Washington White) and Wanser (Washington Red).

To check physical properties, the following standard tests were determined: kernal hardness, test weight, 1000 kernal weight, wheat size test. Chemical tests used were wheat protein, ash and moisture. Values obtained were comparable between types.

Actual milling on the Buhler Experimental Mill showed:

(a) almost equivalent extraction between hard red and hard white types.

(b) the color grade values as expressed by the Agtron and Kent-Jones color graders were better for white wheat flour than for red wheat flour.

Thus, we could get a higher extraction with a white wheat using color grade value as a quality factor. This is of particular importance for overseas users where higher extraction is needed for economic reasons.

The flours were checked for: ash, moisture, protein, Farinograph characteristics, mixograph characteristics, extensigraph characteristics and amylograph characteristics. None of these tests indicated any substantial differences in baking potential due to kernel color per se. Experimental Test baking also showed very similar loaf weight to loaf volume ratios.

Overseas trade is increasing with the developing countries where, for economic reasons, higher extractions are required while maintaining quality, which includes color. Ash is a quality factor to measure bran contamination. Now color grade values are being considered to replace ash measurement by some customers. By adding equivalent quantities of white bran and red bran to straight grade flours, the color grade was affected less by white bran. Thus, more low grade white wheat flour could be added giving a higher extraction rate. A limited increase in ash may become acceptable.

This study did not indicate any substantial disadvantages to the use of white wheat flour in breadmaking. It is possible that a larger proportion of white wheat could give the United States a stronger competitive advantage in the world market.