QUALITY EVALUATION OF SPAGHETTI MADE FROM TWO SUBCLASSES OF DURUM WHEAT AND FROM HARD WINTER WHEATS OF DIFFERENT DARK HARD AND VITREOUS COUNT

by

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INTRODUCTION

Macaroni products are made from a basic mixture of durum semolina or durum flour, or granular and water ; formed into some convenient shape, and then immediately cooked or dried for consumption at a later date. According to Brabender (3), macaroni production in its simplest form involves nothing else than reshaping the structure of the wheat kernel endosperm previously extracted by the milling process.

In his report on bread stuff of the United States published in 1949, Beck - Quoted by Leclerc (44) - called attention to the high gluten content of durum wheat varieties stating that :"this wheat is worthy of a trial in the United States. The color of the flour might perhaps be an objection to its use for making bread but it would answer well for the manufacture of macaroni and vermicelli".

Now it is a general belief that the best macaroni products are made from high quality durum wheat. This wheat is very hard, has a tough, horny endosperm. It tends to be higher in protein content and has more yellow pigment than does bread wheat (41).

However, Irvine (38) observed that while many of the claims made for the superiority of durum apply to a comparison of durum and soft European wheats, they are not nearly as apparent when comparing durum with hard wheats of similar protein levels. According to Fabriani, quoted by Irvine (38), who has conducted an extensive survey of those laboratories, principally in Europe, which deal with semolina and macaroni products, there appears to be no criteria of quality, except perhaps natural yellow pigmentation, which distinguish durum wheat from the other classes of wheat as raw material for the macaroni industry.

The objectives of this study were : (1), to optimize the milling yields of semolina and farina made respectively from two subclasses of durum wheat and from hard red winter wheats having different dark hard and vitreous kernel counts and protein levels ; (2) to process these products into spaghetti under optimum standard conditions ; (3) to assess the quality of the finished products.

REVIEW OF LITERATURE

Wheat grading system :

According to Murphy (56) " the factors which go to make up the wheat grades are : first, classes and subclasses. Each class has its own characteristics resulting from variety, soil, climate, habit of production, and end uses ; subclasses reflect in general high or low protein content... ; then comes damaged kernels, test weight, foreign matter, and mixture of other classes. Moisture content is treated as a basic limitation, with excess moisture cared for in sample grade". That is, to determine wheat grades physical factors such as test weight, kernel vitreousness, amount of damaged kernels, and extraneous material are considered, Each of these factors has a significant impact on the quality of the wheat.

To understand durum wheat quality, it is necessary to be familiar with the terms used to describe durum wheat and durum wheat grades. According to the Official Grain Standards of the United States (69), durum wheat is divided into the following three subclasses : "Hard Amber Durum Wheat", which must contain 75 percent or more hard vitreous kernels ; "Amber Durum Wheat", which must contain more than 60 percent but less than 75 percent hard vitreous kernels ; and "Durum Wheat", which contains less than 60 percent hard vitreous kernels. Within the three subclasses for durum wheat, there are also numerical grades which are assigned. In addition, the classification of "heavy" also may be assigned to the grade to indicate that the wheat has a test weight greater than 62 pounds per bushel. Accordingly, the highest possible grade for durum in the United States is "U.S. No 1 Heavy Hard Amber Durum" (64).

The class Hard Red Winter, in the current grading system, does not contain any subclasses. However, in the old standards (68), this class of wheat was divided into the following three subclasses - which we shall name since their understanding is basic to our work - : "Dark Winter Wheat", which must contain 75 percent or more of dark hard and vitreous kernels ; "Hard Winter Wheat" which must contain more than 40 percent but less than 75 percent dark hard and vitréous kernels ; and "Yellow Hard Winter Wheat", which contains less than 40 percent dark hard and vitreous kernels.

Semolina and farina milling :

The National Macaroni Manufacturers Association, quoted by Irvine (41), defines semolina and farina as follows : Semolina is the purified middling obtained from the grinding of durum wheat, it is free from bran and other offal and shall contain not more than 13.5 percent moisture and not more than 1 percent flour ; farina is the purified middling obtained from the grinding of hard wheat other than durum wheat, it is free from bran and other offal and shall contain not more than 13.5 percent moisture and not more than 1 percent flour.

According to these definitions, there appears to be no difference in the physical characteristics of both products. Consequently, all that will be said on semolina milling can be applied to farina milling.

The objective of semolina milling is different than flour milling. Consequently, the flow of a semolina milling process is quite different than that of a flour milling process. Basically, durum wheat processing consists of four steps : cleaning, tempering, milling, and purifying (10).

The object of cleaning is to remove all foreign matters from the wheat before tempering (conditioning) for milling. An excessive amount of foreign matter can be detrimental to the appearance and eating quality of the finished product.

The principal aim of tempering is to condition the wheat so that the bran and endosperm can be separated efficiently, and to mellow the endosperm so that it may be reduced to yield a maximum amount of semolina and a minimum amount of flour, In the old times, millers used to temper for 24 hours or more (4, 26, 27, 35). This time is now reduced to 6 hours, and is usually divided into three stages. Two tenths to five-tenths percent water is added in the third temper stage with a 30 minute duration. According to Abercrombie (2), if a long single rest period were used, too much moisture penetration would occur. Undesirable fines and flour would be produced during grinding, The semolina would lose brightness and have a whiter color. The second and third temper have an advantage in that the bran retains a lot of the water and is less apt to shatter or break apart into fragments during the break grinding. The middlings thus are easier to purify and the grinding gives a lower release of flour.

Durum milling is a complex procedure of repetitive grinding and sieving. The conditioned wheat is ground on a series of corrugated break rolls with different spacing between the rolls. The purpose of this first step is to open up and scrape the wheat grains to release the endosperm from the bran. A second set of rolls, called sizing rolls, with much finer corrugations is used for grinding the middlings to the proper size. Various stacks of sieves are used between the grinding steps to allow for most efficient reduction of the endosperm to a proper granular size.

In the final stage of milling, the semolina is purified to remove as many of the small bran particles as possible.

To accomplish this milling task many flow sheets have been designed. As early as 1936, Binnington (4) made a comprehensive study of the durum milling equipment and formulated a flow sheet with five breaks and two purifications. The equipment utilized consisted of a two stand Allis-Chalmers experimental mill and a small scale purifier. Fifield (26) in 1937 devised another flow with four breaks and a double purification. Harris (35) published a more complex flow in 1942, with ten breaks and three purification steps. Semolina yield was increased from an average of 31 percent for the two former to around 66 percent for the unpurified semolina and 43 percent for the purified semolina. Finally, Fisher (27) in 1946 published a flow with four breaks, two reductions done on lightly frosted rolls, and a double purification. Semolina yield was around 53 percent. More recently, Black (10) described a laboratory purifier that, used in conjunction with a three stand Allis-Chalmers laboratory mill gave a semolina yield of 55 to 60 percent.

Quality characteristics of semolina and farina :

According to the code of federal regulations, as of April 1, 1981:

- Farina is the food prepared by grinding and bolting clean wheat, other than durum, to such fineness that it passes through a No.20 sieve, but not more than 3 percent passes through a No.100 sieve. It is free from bran to such an extent that the percent of ash, calculated to a moisture free basis, is not more than 0.6 percent. Its moisture content is not more than 15 percent.

- Semolina is the food prepared by grinding and bolting clean durum wheat to such fineness that it passes through a No.20 sieve, but not more than 3 percent passes through a No.100 sieve. It is free from bran to such an extend that the percent of ash, calculated to a moisture free basis, is not more than 0.92 percent. Its moisture content is not more than 15 percent.

Beside these official standards, many researchers have formulated norms and standards of what a good semolina ought to be as far as granulation, speck count, color, and ash.

Granulation : Walsh (64) gives the following particle size distribution for a typical U.S. Commercial semolina.

Table I. Particle Size Distribution for a Typical U.S. Commercial semolina.

U.S.Sieve No.	Sieve opening (mm)	% total semolina
On 20	0.86	0.0
On 40	0.38	22.8
On 60	0.23	51.6
On 80	0.18	14.6
On 100	0.14	9.3
Through 100	0.00	1.7

Banasik (10) refers to the same table saying that most U.S. macaroni manufacturers prefer a semolina that has a uniform particle size rather than a coarse ground semolina. With fine granulation. the semolina and water can be mixed more easily to form a uniform dough for extrusion. If the semolina is not uniform but consists of fine as well as coarse particles, the fine particles tend to absorb water faster than the larger particles. Consequently, the coarse particles remain dry throughout the mixing operation and tend to cause white specks in pasta.

According to Charles (12), a typical test on a good quality semolina might show the following percentages on the various screens : U.S. No.20- none ; U.S. No. 40 - 30 percent ; U.S. No. 60 - 50 percent ; U.S. No.80 - 15 percent ; U.S. No.100 - 4 percent ; pan - 1 percent. still according to Charles (12), reliable millers and investigators believe that a semolina handles best in presses and makes better macaroni if a large proportion of particles are in the same size classification, stating the following specifications of an "ideal" semolina : U.S. No. 20 - 0 percent ; U.S. No. 40 - 4 percent ; U.S. No. 60 -80 percent ; U.S. No. 80 - 10 percent ; U.S. No. 100-5 percent, pan - 1 percent.

Abercrombie (20) extends this view by giving the following granulation range for commercial semolina:

OVERS	30 W	40 W	45 W	60 W	100 W	PAN
	0	20-28	10-30	30-40	10-15	3 %

Finally, in an article called "Durum Milling" taken from material submitted for use in the proposed Cereal Millers Handbook - Vol. II, we find the following granulation specifications for semolina :

OVERS	30 W	42 W	60 W	100 W	PAN
	1 % Max	25-35	45-55	10-20	0-3 %

all the percentages are based on 100 percent semolina, sifting 100 grams for 3 minutes on U.S. Sieve Series Screens.

Speck count : Since black specks and bran particles can detract from the appearance of macaroni products, the speck count is a simple but valuable test of semolina quality. However, there is no overall standard for the number of specks per square inch. Different Companies or individuals may have different standards. That is, for Walsh (64) values of 10 to 20 specks per 10 square inches are considered normal for good quality semolina. For Banasik (10), if the number of small bran specks or other colored material has been reduced to less than 6 or 7 per square inch of flattened surface, the result will be a product with satisfactory appearance. For Charles (12) a passable grade of semolina would have about 140 bran specks in 100 square inches, and a really good grade would test 65.

Color : Color is in many cases the most important point of quality as far as semolina is concerned. As mentioned earlier, the endosperm of durum wheat has a characteristic clear bright yellow color imparted by the carotenoid pigment xanthophyll. To salvage as much as possible of this original color is the main goal of semolina milling. The coarser the granulation, the deeper the yellowness ; the finer the granulation, the lighter the color gets. According to Matz (52), many macaroni manufacturers are accustomed to grading semolina color visually, comparing the unknown sample with a standard. This method has some value but its many shortcomings are immediately apparent. For example, no printed color can satisfactorily duplicate the appearance of a semolina sample.

Since it is much easier to measure the transmitted color of a transparent sample than it is to measure the reflected color of an opaque substance, many investigators have tried to simplify the problem of color evaluation by extracting semolina or farina pigments and working with clear solutions (6, 39, 40, 51, 53).

Although colorimetric measurements of extracted pigments add some degree of objectivity to color evaluation, they have many defects when used for determining semolina color. First, pigments are not the only determinant of color. In granular substance such as semolina, particle size, among other factors, affect color (40). Furthermore, granule size and shape will affect the rate of extraction of pigments. According to Matz (52), a complete recovery of the carotenoid pigments by extraction is difficult, especially when particle size is relatively large.

A logical way to avoid the disadvantages of the extraction procedure is to measure the color of the product itself. Matz (52) described a method of recording the color of the product by utilizing a rapid scanning spectrophotometer and found out that the greatest difference in the amount of reflected light appear near 435 millimicrons, suggesting that the comparisons should be made near this wavelength.

Gillis (28) developed a method for color measurement of cereal products with the Agtron reflectance spectrophotometer utilizing the 546 millimicrons line of mercury for green and the 436 millimicrons line of mercury for blue, this later wavelength being the same as the one noted by Matz (52), Furthermore, the blue spectrum operates in the yellow - white region, rendering it more suitable to yellowness measurement of semolina.

Ash : According to Irvine (41) the endosperm of durum wheat tends to be higher in ash than that of common wheats, and semolina milled to comparable extraction rates are generally 25 to 50 percent higher in ash. A durum semolina of about 65 percent extraction (Wheat basis) will normally have an ash content in the range of 0.55 to 0.75 percent (14 percent moisture basis), depending both on the type of wheat from which it was milled and on the efficiency of the milling operation. Higher ash values usually indicate longer extraction rate or inefficient milling. Farina milled from bread wheats are normally lower by 0.10 percent or more in ash than those milled from durum. Leclerc (44) also remarked that farina have a lower ash content (0.45 percent) when compared to semolina (0.60 percent).

Spaghetti processing :

Basically, the production process for spaghetti consists of adding water to semolina or farina in such quantity as to produce a mixture of 31 percent moisture, mixing these ingredients together for a short period of time, kneading the dough to obtain a plastic homogeneous mass and then extruding the mass through dies under pressure. After extrusion, products are dried and packaged.

Processing : Until about 1935 or 1940 most spaghetti were made by a batch process (4, 5, 12, 33, 34, 44, 64). That is the semolina and water were weighed and combined in a batch mixer. The mixer was operated for approximately ten minutes and then dumped into a kneader or gramola . The loose dough was compacted in the kneader by subjecting it to heavy corrugated rollers which bore down on the dough as it passed under the roller in a rotating pan. Slabs of plastic dough were cut from the kneader and placed in the chamber of the hydraulic press. Pressure was then brought to bear on the dough to force it through dies at the bottom end of the hydraulic chamber (44).

More recently, the functions of mixing, kneading, and extrusion have been combined in the continuous press normally equipped with volumetric feeders which provide a continuous flow of semolina and water to the press. The continuous mixers are equipped with horizontal shaft and blades that move the product slowly forward while mixing the dough. At the end of the mixer, the dough drops into a specially designed auger which is in a tightly sealed cast housing. The auger moves the dough forward and at the same time compacts it, building up pressure and kneading the dough simultaneously.

Then the plastic dough feeds into a chamber behind the die. The pressure built up on the dough by the auger causes the dough to be forced through the die forming it into the characteristic tubular shape of spaghetti.

According to Irvine (38), two major steps were taken to improve the physical characteristics of spaghetti produced by the new process : application of vacuum and teflon dies.

The vacuum process, originally developed by Buhler brothers, Uzwil-Switzerland (12), is applied to the pasta either by enclosing the entire mixer in a vacuum chamber, or by drawing a vacuum on the pasta just before extrusion. According to Banasik (10), if air is not removed small bubbles will form and give the finished product a white, chalky appearance. Air bubbles also can diminish the strength of the dried product. In addition, oxidation of the pigments will occur causing the product to be pale and unattractive. By applying the vacuum it is possible to remove air bubbles which enable the product to be more dense with a deeper, more translucent yellow color. The dried product will have a slightly longer cooking time with better resistance to overcooking.

Following the application of vacuum, dies with teflon insert were produced which gave a very smooth, waxy surface to the spaghetti and permitted the processing of tougher dough without the usual accompaniment of a very rough (and hence pale) surface (38).

Drying : In the spaghetti manufacturing process, one of the most important operations is that of drying. When the pasta product is extruded from the press, it contains approximately 30 percent moisture. This moisture must be reduced, carefully and deliberately, to obtain a hard translucent product, free from "checks", having approximately 12 percent moisture at the end of the drying period. If the moisture is removed too rapidly, the product will tend to crack ; if the rate of removal is too slow, the "long goods" which are suspended on rods, will tend to stretch. In addition, with the growth of microorganisms, the product may become sour (10, 12, 22, 29). Consequently, to obtain a product with a high degree of acceptability, the drying process must be carefully controlled. Factors available to the technologist to permit this control include placement of the product within the dryer and physical factors pertaining to the drying air such as temperature, humidity and velocity within the cabinet (29).

To accomplish this task, many dryer designs and drying cycles have been used. Leclerc (44) reports that in Italy spaghetti were dried in the sunshine, in the open air. However,this method was considered unhygienic as it exposed the product to all kinds of germ-laden dust. Modern manufacturrers dry spaghetti in specially constructed drying rooms through which a current of filtered air is blown by means of fans. The air laden with moisture from the spaghetti is thus being continually replaced by clean dry air. Walsh (64) reports the following as an example of a drying cycle successfully used for spaghetti. The predryer exposes the product to air at 150°F for one and half hour at 65 percent relative humidity that lowers its moisture content from 31 percent to 25 percent. After that, the product enters the final dryer where temperature is held constant at 130°F and the relative humidity is varied. In the first stage, the product is held at 95 percent relative humidity for one and half hour. This is called "sweating" or rest period. In the second stage the product is exposed to a relative humidity of 83 percent for four hours after which its moisture content is about 18 percent. Additional moisture is removed in the third drying stage where the product is held for eight hours at a relative humidity of 70 percent. Manser (58) used a high temperature, short time drying cycle, and compared the quality of the product dried by this method against a standard low temperature, long time drying cycle. He concluded that the product dried with high temperature had a better color and overall quality. Dexter and coworkers (20) also compared the characteristics of spaghetti produced from two high temperature drying cycles. One cycle featured high temperature at the initial stage of drying, the other featured high temperature during the latter stages of drying. The control was spaghetti produced by low temperature drying. They concluded that, beside a greatly reduced drying time, spaghetti dried with high temperature (especially when applied at the later stages) had better color and also better cooking qualities.

Quality evaluation of spaghetti:

According to Leclerc (44) the characteristics of good spaghetti are hardness, brittleness, translucency, elasticity, and a rich amber color. The fracture should be glassy, producing only a few pieces and no splinters. long pieces should have sufficient pliability to allow considerable bending before breaking. However, the final proof of the quality of spaghetti is in the eating. For that the behavior of spaghetti upon cooking is the most important. According to Hummel (33), when cooked a good macaroni product should absorb at least twice its weight of water, and swell to three or four times its original volume. It should retain its shape and firmness, develop a clear appetizing odor characteristic of hard wheats, and does not become pasty. Therefore, the most important factors associated with pasta are : color ; mechanical strength ; and cooking characteristics such as water absorption, swelling, resistance to disintegration, and tenderness.

Color : The tradition is that if spaghetti is yellow, it is a superior product. This tradition is still current today, although there are a number of other wheats which can produce good spaghetti but do not yield a yellow product.

The factors associated with a good spaghetti color are quite complex, involving not only the pigment content but also translucency and vitreousness which, in turn, are apparently dependent upon the quantity and quality of proteins, the degree of hydration of starch, and the processing conditions (4, 6). Clear deep-yellow pasta is obtained from semolina of high yellow pigment content and low lipoxidase activity, which has been milled to a fairly low extraction (60-65 %). As semolina extraction rate increases, the color becomes increasingly brownish.

Small differences in pasta color can be detected by visual observation. Therefore, pasta color can be assessed by visual comparison against standard samples. However, errors in visual measurement can arise due to changes in color of standard samples with age, differences in concept of color among judges, and lack of precision in describing the color (66).

In an attempt to eliminate these errors, objective measurements of spaghetti color have been introduced. Fifield (26) measured the yellow color of moist semolina with a Munsell spinning disk. Matz(52) tested the accuracy of several photoelectric instruments for measuring the color of durum semolina and found that the Hunter color - difference meter, the photovolt reflectance meter, and the Densichron reflectance meter gave good results ; but gave no data on color measurement of spaghetti or other finished products. Matsuo (50) reported differences in the reflectance spectra between yellow and brown pasta using the Ten Selected Ordinate method. Later, Walsh (66) outlined a method for color measurement of spaghetti utilizing the Magnuson engineers Agtron Reflectance Photometer Model M-500 equipped with a M-300 wide area viewer, the Carl Zeiss photoelectric reflectance Photometer, and the Hunter Color Difference Meter equipped with a D-25 optical unit. With each instrument he measured the color of different samples of spaghetti and recorded the values in terms of percent brightness and percent yellowness. Based on these values he devised color maps for each instrument combining these two values into a single color score value.

Mechanical strength : The test for spaghetti breaking strength is usually performed manually and hence is subjective. Several repports describe machines for recording breaking strength : Binnington and Geddes (4), and Holliger (30). But the rather poor reproducibility of such tests generally limits their usefulness in establishing relations between other factors and breaking strength. Strong, elastic spaghetti usually indicates a well processed product of reasonably high protein content ; the physical properties of the dried product give little indication, however, on the cooking quality and hence are of limited value (41).

Cooking characteristics : The test for spaghetti cooking quality is usually made on a fixed quantity of dried product with a fixed volume of water held at a constant boiling temperature. The test involves measurement of percent swelling, of the quantity of residue in the cooking water, and of product tenderness, after a fixed period of boiling (41).

For firmness measurement, most often the "bite test" and taste panel test are used, but these tests are not reliable as they are subject to individual bias.

Several workers (6, 30, 43) have introduced objective measurements of pasta firmness. Such tests are much more preferable and reproducible than organoleptic assessments. However, no data on texture of cooked spaghetti were given. Holliger (30) suggested that the tensile strength of uncooked spaghetti was related to firmness but gave no data on the texture or eating quality of the cooked spaghetti. Walsh (62) used an Instron Universal Testing Machine to cut the spaghetti strand. The area under the force-deformation curve was used as an index of firmness of the cooked spaghetti. This was found to correlate with sensory analysis. Latter, Walsh (63) showed the results of texture or "bite" of three cooked macaroni products (spaghetti, egg noodles, and elbow macaroni) against a taste panel, and concluded that the shear test was much more convenient and efficient than taste panels for evaluating the firmness of cooked macaroni products.

MATERIAL AND METHODS

Durum wheat used in this study was obtained from PEAVY INERNATIONAL INC. Minneapolis - Minnesota. Hard red winter wheats with different amounts of dark hard and vitreous kernels count, and different protein content have been made available by FAR-MAR-CO., INC. Hutchinson - Kansas. The wheats were analyzed and evaluated prior to experimentation. Standard measurements were used to indicate the characteristics of each type of wheat. The results of these tests are shown in table 2.

Wheat Cleaning and Sample Preparation :

Cleaning of wheats preparatory to analysis and sample make-up were done by passing the wheats through the Carter Dockage Tester. The cleaned wheat was distributed into the proper amount and number of samples required for testing. Each sample was packaged in a plastic bag to prevent moisture fluctuation prior to tempering. Random procedures were followed in the preparation of the samples.

Conditioning or tempering :

All wheat samples were tempered in the same manner prior to milling, in three stages. In the first stage, the moisture content of the sample was raised to 13 percent and was left undisturbed in a metal can for two and half hours. In the second stage, the moisture content was raised to 16 percent and again the sample was left to rest for two and half hours. 30 minutes pior to milling, a sufficient amount of water was added to raise its moisture content to 16.5 percent.

Samples were tempered by adding the necessary amount of water in the form of a fine mist to the sample of wheat rotating in a metal blending drum. The amount of water to be added to the sample was determined by using the following formula :

Table 2. Analyses of the wheats used in the research study

	DURUM		HARD RED WINTER				
	H.A.D.	DURUM	1	2	3	4	5
Moisture (%)	11.1	11.6	11.1	10.8	10.0	9.5	10.8
Protein * (%)	12.5	13.2	13.0	12.2	11.3	12.5	13.5
Ash * (%)	1.55	1.56	1.64	1.74	1.62	1.71	1.66
Test weight (Lbs/bu)	61.7	61.1	57.6	60.9	58.2	61.8	61.3
Pearling value (%)	93.1	87.4	73.3	78.4	71.2	68.5	74.7
1000 kernel weight (gms)*	31.7	30.6	27.2	23.3	25.2	27.6	26.7
Wheat size							
Over 7 W (%)	63.3	69.3	49.1	39.5	51.7	58.3	54.6
Over 9 W (%)	36.1	29.7	49.2	57.1	46.6	40.1	44.1
Over 12 W (%)	0.6	1.0	1.6	3.3	1.7	1.6	1.3
Density	1.36	1.34	1.40	1.44	1.36	1.40	1.41
% Vitreousness	76	54	-	-	-	-	-
% D.H.V.	-	-	18	12	60	64	78
Falling number	381	400	373	411	497	562	394
Wet gluten (%)	32.8	34.7	36.7	34.0	33.9	36.7	35.6
Grade	1 H.A.D	1 DURUM	3 H.R.W	2 H.R.W	2 H.R.W	2 H.R.W	1 H.R.W

* 14 % moisture basis.

$$\frac{100 - M1}{100 - M2} \times W1 = W1 + H$$

M1 = percent moisture in the untempered wheat sample.

M2 = percent moisture desired in the wheat sample.

W1 = weight of untempered wheat.

H = amount of water to be added, in grams.

Grinding procedure :

The milling of the sample was done in a laboratory Ross mill according to the flow given in figure 1. This flow consists of five breaks, two chunks, two sizings, one tailling and a double purification. The break releases and extractions schedule are given in figure 2 and table 3. The overs of 44 wire cloth of all the breaks and chunks were collected together and purified before sizing. The overs of the flour clothes were also collected and sent to the grader. From here on, the overs of the 44 and 60 wire clothes were regrouped and further purified by mean of a seed blower using an adequate air flow strong enough to lift the branny particles. The overs of the flour cloth were further ground on smooth rolls to reduce them to flour.

The milling material utilized in this study had the following specifications :

Two stands of corrugated Ross 9" X 6" roller mills running dull to dull at a differential of 2,5 : 1 were used for the break, chunk, sizing, and tailing systems. The stand utilized for the primary - first, second, and third - breaks had a pitch of 14 corrugations /inch for both fast and slow rolls and a quarter inch per linear foot spiral. The corrugations were of Getchel type. The stand used for the secondary - fourth and fifth - breaks, chunk, sizing, and tailing had a pitch of 22 corrugations /inch for both fast and slow roll, and a half inch per linear foot spiral. The corrugations

STREAMS	LOAD TO	% RELEASE	% EXTRACTION	Σ % EXTRACTION
1 BK	100.0	20	20.0	20.0
2 BK	80.0	30	24.0	44.0
3 BK	56.0	30	16.8	60.8
4 BK	39.2	25	9.8	70.6
5 BK	29.4	25	7.4	78.0

TABLE 3 — BREAK RELEASE—EXTRACTION SCHEDULE

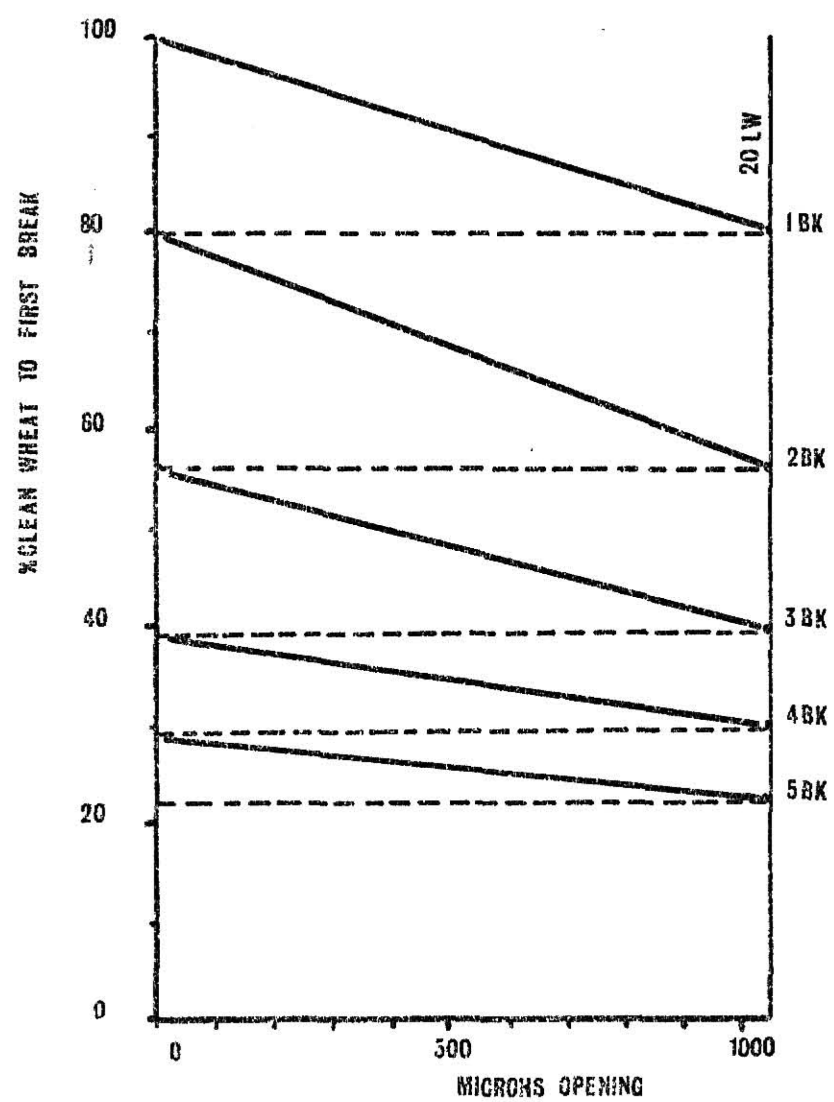


FIGURE Nº2 — BREAK EXTRACTION CURVES

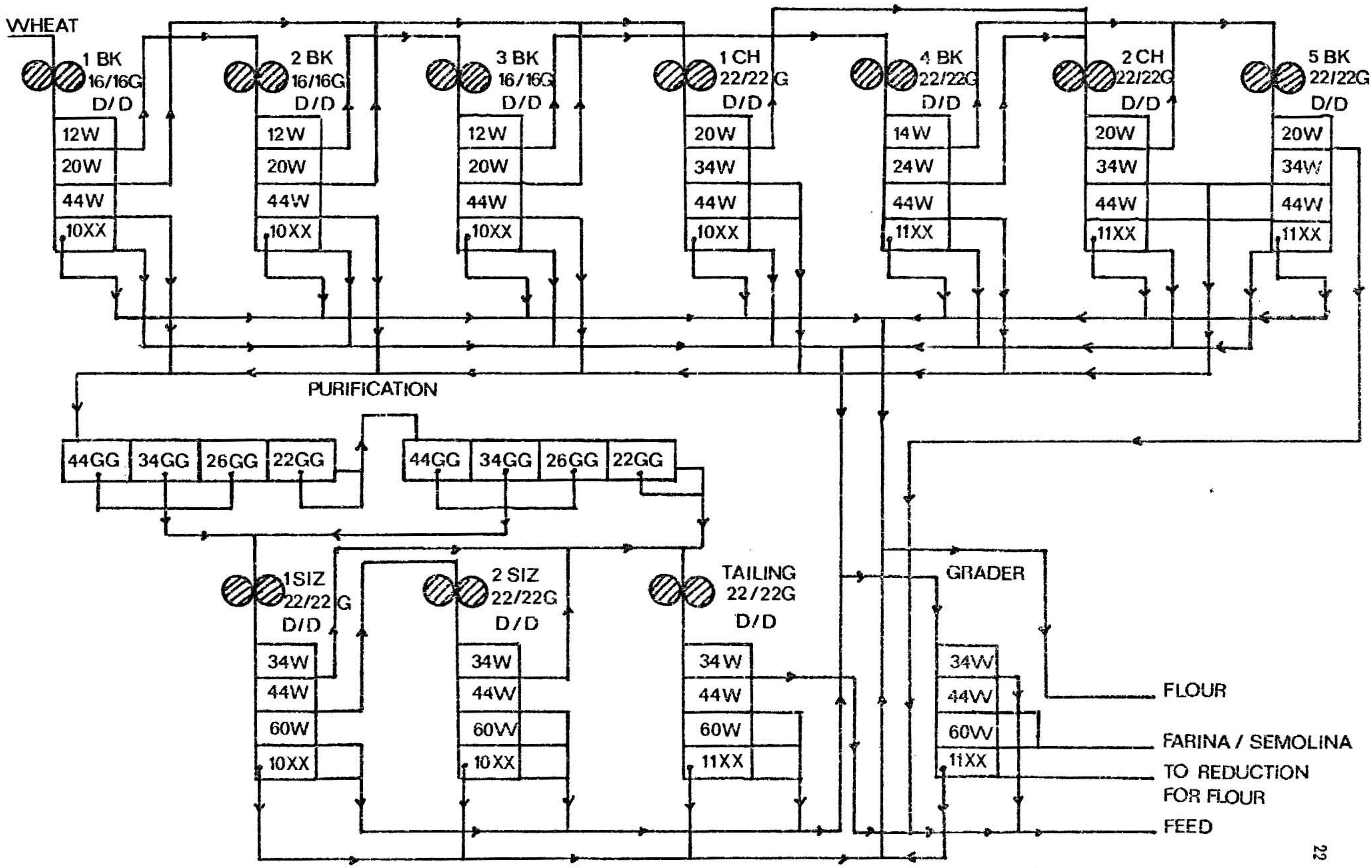


FIGURE 1 _ DURUM SEMOLINA & H.R.W. FARINA FLOW-SHEET were also of Getchel type. The reduction was done on a pair of smooth rolls running at a differential of 1.5 : 1.

Between each grinding step, the stock was sifted and graded in a Smico laboratory sifter runnings at 240 revolutions per minute with 1 ½ inches circle of gyration.

The sizing stock was purified in a small 4 square feet laboratory purifier running at 600 strokes per minute with ½ inch throw. The purifier had a suction system with cyclone and a fan with variable speed drive able to circulate up to 113 cubic feet per minute of air.

For each type of wheat, six four thousand gram samples were milled. Moisture, protein, and ash analyses were made on each sample of milled semolina and farina. In addition, a granulation test, a speck count, and a color evaluation were performed. For the flour, moisture, protein, ash and wet gluten analyses were performed before discarding the samples.

Spaghetti Manufacturing Procedure :

Before processing the samples into spaghetti, the six samples were blended together in a blender. Moisture, protein, ash, granulation test, speck count, and color evaluation were performed. The samples were kept in the cold storage room in sealed plastic bags until processing. Spaghetti was processed in duplicate from each semolina and farina blend.

The processing equipment consisted in a Damaco semi-commercial scale extruder equipped with a mixing chamber having two horizontal and parallel shafts with blades, an extrusion screw revolving at a speed of 30 R.P.M. tightly sealed in a cast housing, and a die head supporting the brass die. The diameter of the die holes was 1.9 mm. Both the mixing chamber and the auger were jacketed and provided with hot water at 39°C. to ensure a constant working temperature. In addition, the entire mixing chamber and the auger were put under a vacuum of 15 pounds per square inch.

Before processing, each batch of semolina or farina was put in a Hobart mixer and a sufficient amount of water at 38°C. was added while blending. Mixing time was divided into two steps : a slow speed mixing step while adding water, followed by a mixing period at medium speed. After mixing, the dough was immediately put in the mixing chamber of the laboratory press and processed.

After extrusion, spaghetti was placed on stainless steel rods and placed in the drying cabinet of a Demaco Semi-Commercial dryer provided with a Honeywell automatic temperature and relative humidity control system. Spaghetti was dried for 10 hours according to the high temperature drying cycle described by Dexter and coworkers (20) - modified to accomodate our dryer - , and summarized in figure 3.

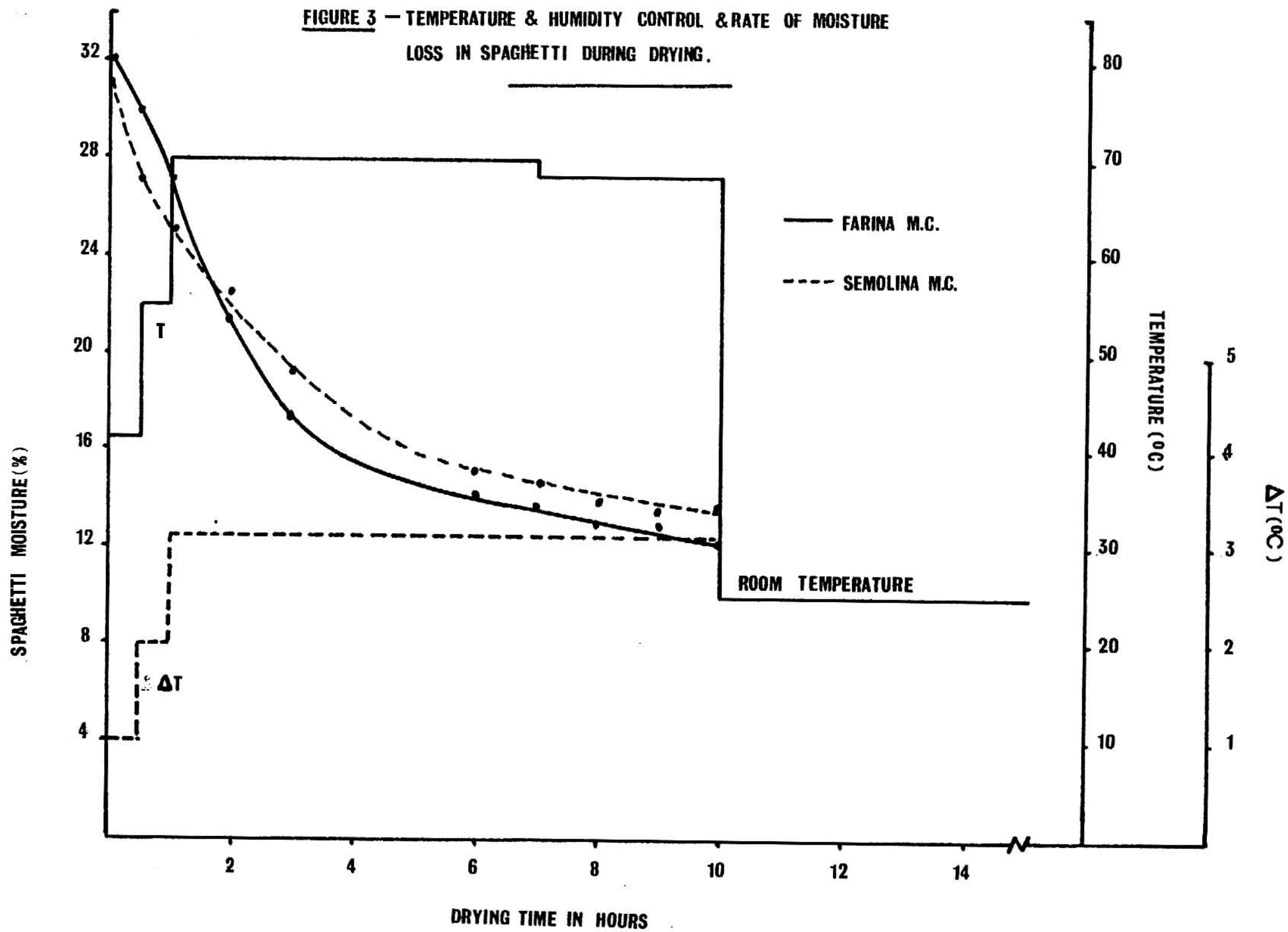
Physical Methods of Determination :

Wheat : The moisture, protein and ash analyses for wheat, semolina, farina, and flour were determined by procedures 44-15, 08-01, and 46-11, respectively in Cereal Laboratory Methods (1).

The pearling value test was performed as outlined by Mc Cluggage (54), by using 20 grams of sample wheat for the test. The wheat was pearled in a strong Scott barley pearling machine for 60 seconds. The product then was removed and sifted on a number 20 wire sieve manually for 30 seconds to separate the product. The wheat remaining on the number 20 sieve was weighed and recorded as a percentage of the original sample.

The wheat size test was performed according to the following method. Two hundred grams of wheat were placed on the top of a stack of 3 Tyler standard sieves (Number 7, 9, 12). This stack was inserted in a Tyler Ro - Tap testing sieve shaker and the machine run for 60 seconds. The amount

FIGURE 3 — TEMPERATURE & HUMIDITY CONTROL & RATE OF MOISTURE LOSS IN SPAGHETTI DURING DRYING.



retained on each sieve was recorded as a percentage of the total sample weight. The purpose of the test was to assign a universal size designation to the wheats used in the experiment.

The 1,000 kernels count was determined with an electronic seed counter using 40 grams of wheat, and using the count of this weight to determine the weight of 1,000 kernels.

The density was determined with a Bechman Air Pycnometer using a 14.4 grams sample according to the method outlined in the manufacturer's manual.

$$\text{Density} = \frac{14.4 \text{ grams}}{\text{Volume (cc)}}$$

The percentage of dark hard and vitreous kernels was determined with a wheat slicer on 100 kernels hand picked at random from a 100 grams sample of clean wheat from which all the broken and shrunken kernels have been removed. 50 percent starchy endosperm was considered as an arbitrary cut-off point between yellow hard or starchy endosperm, and dark hard and vitreous endosperm (plates I & II, figure 4).

The Falling Number is a value indicative of the presence or absence of sprouted wheat. In normal porduction years, the Falling Number for durum wheat will average around 400 units. Falling Number values less than 300 units generally indicates the presence of sprouting. The test was determined on 7 grams of ground wheat according to the method outlined by Doty (21).

The gluten content was determined with a Glutomatic - 2200, using a 10 grams sample of ground wheat according to the method outlined in the manufacturer's manual.

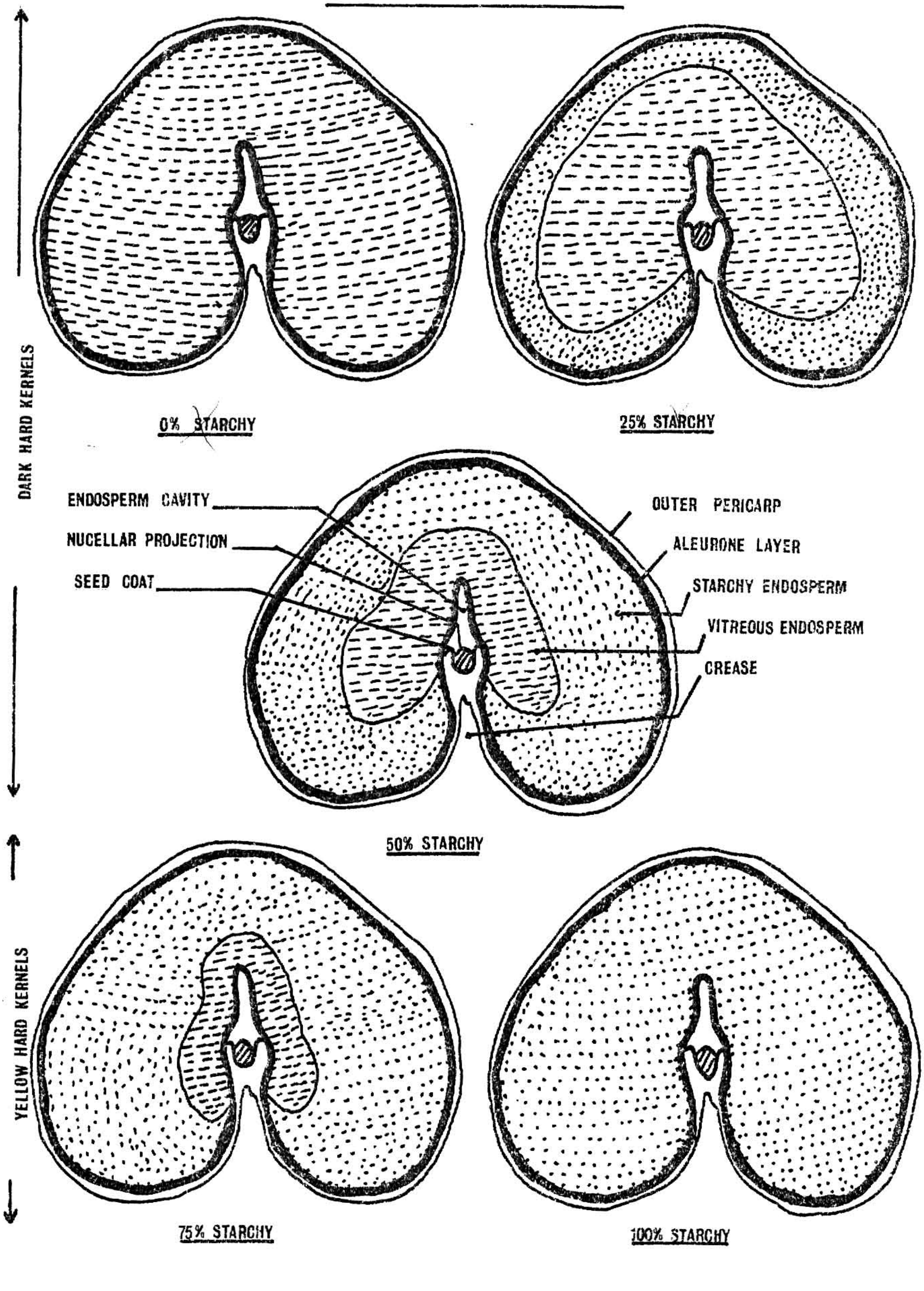
Semolina and farina :

The particle size test (granulation) was determined using the Tyler Ro-Tap testing sieve shaker and the following Tyler number sieves : 30, 42, 60, and 100 wire mesh. 100 grams of the ground product were put on the top

FIGURE 4 — SCHEMATIC REPRESENTATION OF THE TRANSECTION OF WHEAT ABOVE THE GERM (41)

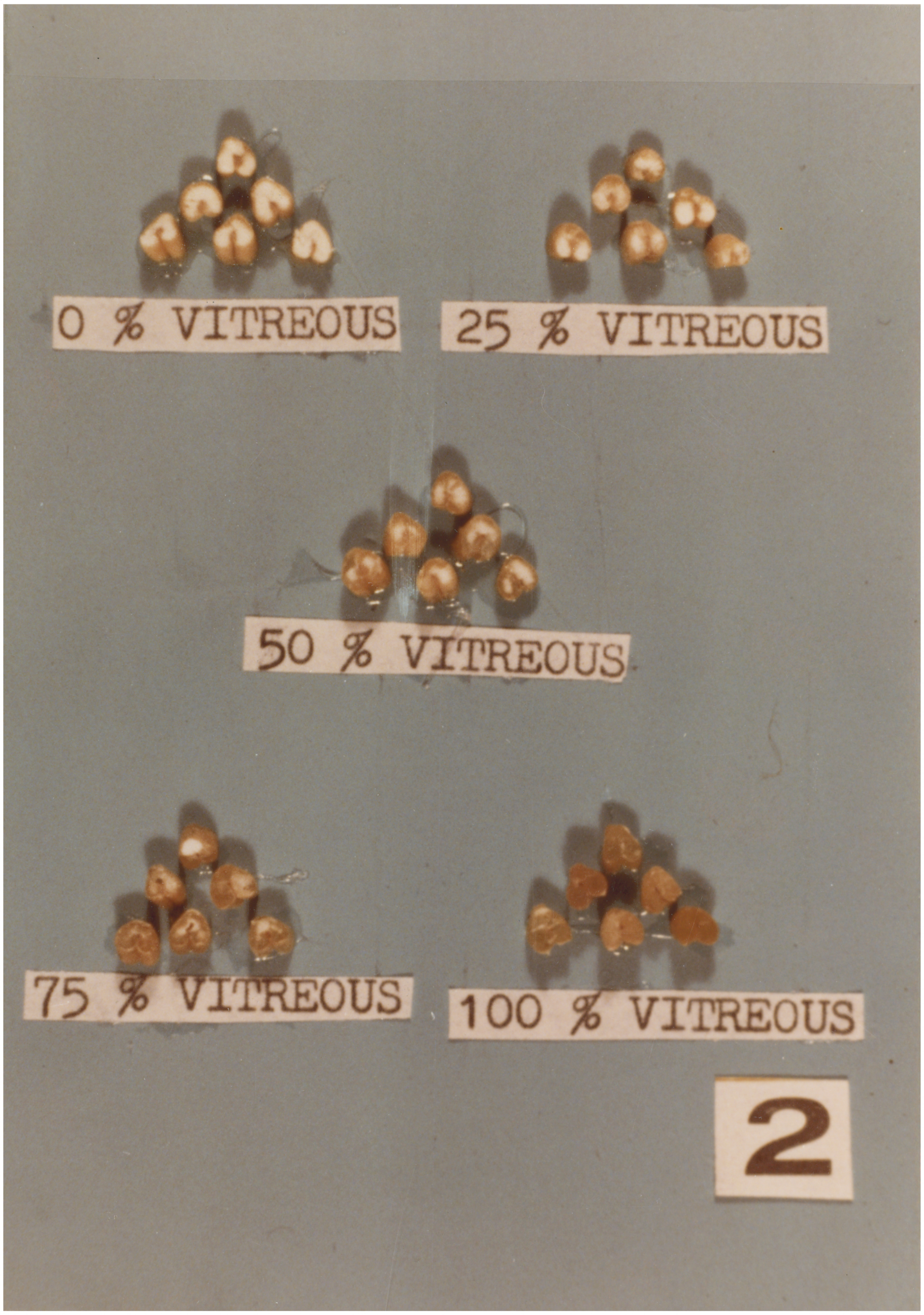
DASHES : VITREOUS ENDOSPERM

POINTS : STARCHY ENDOSPERM



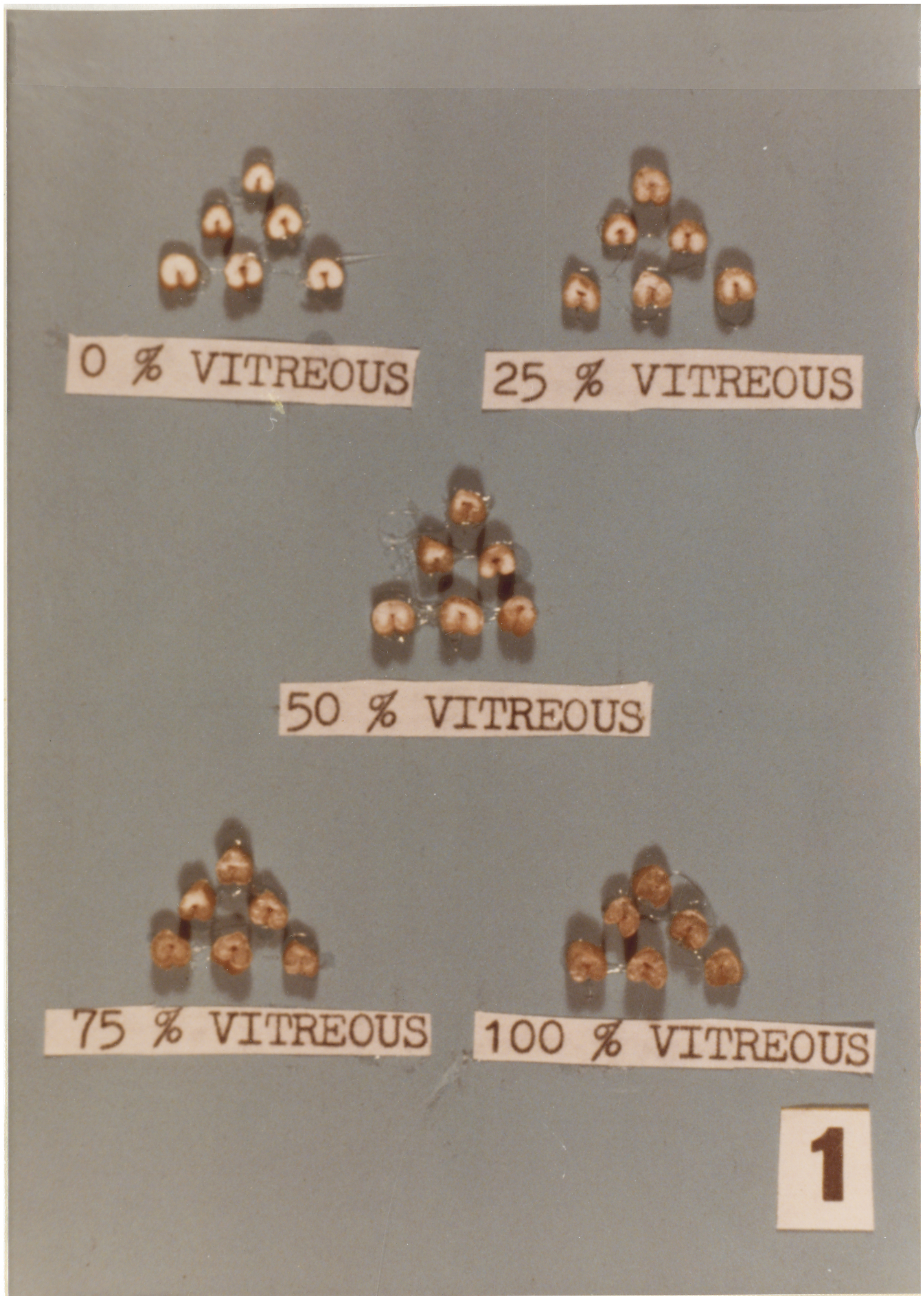
EXPLANATION OF PLATE I

Transection of durum wheat kernels.
White endosperm : Chalky
Dark endosperm : Vitreous


0 % VITREOUS
25 % VITREOUS
50 % VITREOUS
75 % VITREOUS
100 % VITREOUS
2

EXPLANATION OF PLATE II

Transection of hard red winter wheat kernels.
White endosperm : Chalky
Dark endosperm : Vitreous


0 % VITREOUS
25 % VITREOUS
50 % VITREOUS
75 % VITREOUS
100 % VITREOUS
1

sieve and the Ro-Tap run for 3 minutes. The product remaining on each sieve was weighed and expressed as percent over.

The speck count was determined according to the following method outlined by Walsh (64). A well-blended sample of semolina or farina was poured on a flat surface. A 10 X 10 inches glass plate with 1 inch square window was placed at random on the semolina surface and the visible specks (bran or black particles) within the window were counted. The determination was repeated 3 times, and the average was expressed as speck count per 10 square inches.

The color was measured with an Agtron M - 500 photoelectric colorimeter. The standard disks No. 0 and No. 97 were calibrated to read 0 and 100 respectively, with a blue spectrum. A sample of 25 grams was poured into the cup, packed uniformly by lifting and dropping it 40 times. The cup was then placed in the cell and the color reading recorded. The determination was repeated three times. The percent yellowness was calculated by subtracting the average reading from 100.

Pigment content was determined according to the method outlined by Dexter and Matsuo (14) on 8 grams of semolina and farina extracted overnight with 40 milliliters of water saturated n - butyl alcohol. After filtering the extract, light transmission was determined in a BAUSCH & LOMB spectrophotometer at a wavelength of 436 millimicrons, and concentration was calculated on the basis of β carotens.

Spaghetti :

Spaghetti color was measured with an Agtron photoelectric colorimeter equipped with a M - 300 wide area viewer. 16 spaghetti strands were plased in a special holder 1 3/8 X 6 inches, covered with a 30 square inches 0 % reflectance black plastic holder and placed over the wide area viewer.

The optical viewer was calibrated to compare spaghetti reflectance against a No. 90 standard disk. Reflectance was measured through red, green and blue optical filters, and the data were converted to yellowness values (b%) and brightness values (1%) using the formula described by the AACC Method 14-22 (1) . The color map devised by Walsh (66) was used to convert 1% and b% values to spaghetti color scores.

Cooking characteristics : Each spaghetti was cooked to its optimal cooking time. Optimal cooking time was defined by Dexter and coworkers (17,20) as the time required for the white core to dissapear. This was determined by removing a strand from the cooking water every minute and crushing it between two glass plates.

Cooking weight : 10 grams of spaghetti strands were placed in a 600 ml. beaker containing 300 ml. of water, covered with a watch glass, and boiled for the established optimum cooking time in a constant temperature bath at 98 - 99oC. Cooked weight was measured after draining the sample on a wire screen for 5 minutes.

Cooking loss : Cooking water was dried in an air oven at 95oC for 12 hours, and then dried to dryness at 130oC for 1 hour to determine the amount of residue.

Firmness or tenderness : Cooked spaghetti was cooled in distilled water at room temperature for 10 minutes before testing for firmness. The cooking water was removed and the sample was covered with a watch glass for the firmness measurements. A modified Instron machine equipped with an amplifier and a recorder was used to measure the firmness of the cooked spaghetti strands (expressed in grams of sheer force).

These tests were also done after overcooking the spaghetti samples for 10 minutes, mainly to determine the resistance to disintegration due to overcooking.

RESULTS AND DISCUSSION

Milling results and discussion :

The average of the milling results ; moisture, protein and ash analyses for durum semolina and hard red winter farina ; and moisture, protein, ash, and wet gluten analyses for flour are shown in tables 4, 5, and 6 respectively (see appendices for complete test results).

Analyses of variance (tables 7, 8, 9) were performed for the milling results, color and speck count ; semolina and farina granulations ; and hard red winter farina and flour yields.

Total extraction : The percentages of total extraction seemed to be different. For that, a Least Significant Difference (L.S.D.) test was performed (table 10). This test showed that the only significant differences, at the 0.05 level, mainly occured between hard red winter (H.R.W.) samples number 2 through 4 and durum and hard amber durum samples. However, these differences in yield, even though significant, did not exceed 3.5 percent. Also, it should be pointed out that hard amber durum and durum wheat samples were milled first, followed by hard wheat samples as they became available. As we progressed through the experiment, the results were somewhat improved. This might be due to a better control of the milling technique.

Farina, semolina, and flour extractions : The amount of farina, semolina and flour extracted was also significantly different at the 0.05 level. The L.S.D. tests (tables 11, 12) showed that the main difference occured between hard amber durum and durum semolina, and the different types of hard red winter farina. This was expected and was in accord with observations from the literature (41), since durum wheat yields higher amounts of semolina and consequently lower amounts of flour when compared to hard red winter at similar extraction levels.

Going further in our analysis. We performed an analysis of variance for hard red winter farina and flour yields. This analysis coupled with the L.S.D. tests (tables 14, 15) showed that the results were significantly different at the 0.05 level of significance. For that, regression analyses were done in order to relate both farina and flour yields to the dark hard and vitreous (D.H.V.) count. It was found that farina yield increased linearly ($R^2 = 0.98$) with the D.H.V. count (figure 5) ; while flour yield decreased linearly ($R^2 = 0.07$) with the D.H.V. count (figure 6). However, these results might not be totally reliable since the D.H.V. count was not increased in regular increments. We especially do not know what could happen to both farina and flour yields in the range of 30 to 50 percent D.H.V.

Color : Semolina and farina color also seemed to be different. The L.S.D. test (table 13) showed that the color scores were significantly different at the 0.05 level of significance. The differences seemed to occur mainly between durum semolina and hard red winter farina. As we did for farina and flour yields, we also performed a regression analysis for farina color in order to relate it to the D.H.V. count. It was found that the color improved linearly ($R^2 = 0.75$) with the D.H.V. count (figure 7).

Speck count : The analysis of variance for the speck count on both semolina and farina showed no differences between samples at the 0.05 level of significance. However, these numbers are somewhat higher than the norms found in the literature (64). This high speck count might be due to two things. First, since our primary purpose was to optimize the yields of farina and semolina, it was necessary to grind closer in the secondary breaks, and use a tailing step in order to recover as much product as possible. This of course increased the speck count and lowered the color. Second, the purifier was a little bit too big for the load. This coupled with a somewhat low air volume resulted in a poor purification. The seed blower utilized to remove some more of the branny particles from the finished product helped somewhat but was not totally efficient.

Granulation : The analysis of variance of the granulation on both semolina and farina also showed no difference between samples at the 0.05 level of sighificance. Granulation curves were also drawn (figure 8, 9) in order to better visualize the similarities of the particle size distribution for the different semolina and farina samples. Also, when compared to the norms given in the literature (20), our products seemed to be somewhat coarser and more homogeneous since the bulk of the product (about 85 %) was composed by the through of a 30 wire and over a 60 wire.

Protein, gluten, and ash analyses : In all cases, the protein content of the flour was higher by at least one percentage point than that of the semolina or farina. The protein content of some of the flour samples exceeded that of the original wheat from which they were milled. This would indicate a concentration of the proteins in the finer particle size fractions.

In all cases, the gluten content of the flour was similar to that of the wheat from which they were milled. Quantitatively all flours have a high gluten content. However, it might have been useful to run a sedimentation test in order to determine the gluten strength.

The ash content of the semolina and farina was somewhat in accord with observations from the literature (41). However, it seems that the ash content is high, and this is related to the high speck count. Flour ash was also higher than normal for a straight grade flour, especially for durum and hard amber durum. The reasons for that might be similar to that of the speck count.

Table 4 - Averages of the Milling Results

Product	% Extraction	% Farina	% flour	% Feed	% Loss	Speck/ 10sq.In	Color % yellow	Granulation				
								Over 30	Over 42	Over 60	Over 100	Thru 100
H.A.Durum	68.3	53.6	14.8	29.7	2.0	41	56.9	.7	42.3	45.1	9.6	2.3
Durum	67.1	47.2	19.9	30.3	2.8	41	53.7	Trace	42.5	46.0	9.0	2.5
H.R.W. (1)	68.5	37.6	31.0	28.5	3.0	41	35.4	Trace	42.1	45.8	9.4	2.7
H.R.W. (2)	69.7	36.7	33.0	28.1	2.1	37	33.5	Trace	42.8	45.0	9.4	2.8
H.R.W. (3)	70.1	42.3	27.8	27.0	2.9	43	35.5	Trace	43.0	45.2	9.3	2.6
H.R.W. (4)	70.6	43.8	26.8	26.3	3.2	41	37.1	Trace	42.6	45.4	9.5	2.6
H.R.W. (5)	70.6	44.9	25.7	26.1	3.3	41	36.7	Trace	42.9	45.3	9.3	2.6

Table 5 - Average moisture, protein, ash
Analyses for farina & semolina.

Products	Moisture	Protein *	Ash *
Hard Amber D. Semolina	15.0	11.9	.78
Durum Semolina	15.2	12.3	.75
Hard Red Winter (1) Farina	15.4	11.6	.58
Hard Red Winter (2) Farina	15.3	10.8	.56
Hard Red Winter (3) Farina	14.5	10.2	.56
Hard Red Winter (4) Farina	14.2	10.7	.49
Hard Red Winter (5) Farina	14.2	10.9	.49

* 14 % Moisture basis.

Table 6 - Average Moisture, Protein, Ash, & wet Gluten Analyses for flour

Product	Moisture	Protein *	Ash *	Wet Gluten
Hard Amber D. Flour	15.1	14.0	.98	33.1
Durum Flour	15.4	14.1	.89	32.7
Hard Red Winter (1) Flour	15.7	12.8	.63	33.5
Hard Red Winter (2) Flour	15.9	11.8	.60	31.4
Hard Red Winter (3) Flour	15.2	11.6	.68	31.0
Hard Red Winter (4) Flour	14.6	13.4	.66	35.7
Hard Rec Winter (5) Flour	15.0	13.1	.63	35.5

* 14 % Moisture Basis.

Table 7 - Analysis of variance of the milling results, color, and speck count.

Source of variation	d.f	Mean Square Significance				
		% Ext.	% far. & sem.	% Flour	Speck count	Color
Between classes	6	10.787 *	198.840 *	240.211 *	15.598 ns.	565.137 *
Within classes	35	1.142	35.510	1.281	14.939	1.902
Total	41					

n.s. Non significant at the 0.05 level.
* Significant at the 0.05 level.

Table 8 - Analysis of variance of durum semolina and H.R.W. farina granulations.

Sources of variation	d.f	Mean Square Significance			
		over 42	over 60	over 100	thru 100
Between classes	6	0.725 n.s	0.817 n.s.	0.263 n.s.	0.137 n.s.
Within classes	35	0.890	0.712	0.688	0.092
Total	42				

n.s. Non significant at the 0.05 level.

Table 9 - Analysis of variance for H.R.W. farina and flour yields.

Source of Variation	d.f.	Mean Square Significance	
		% farina	% flour
Between classes	4	80.250 *	55.409 *
Within classes	25	0.605	0.761
Total	29		

* Significant at the 0.05 level.

Table 10 - Ordered array of means for percent extraction

Classes	$\bar{X}$	L.S.D.
H.R.W. # 4	70.62	1.253
H.R.W. # 5	70.55	
H.R.W. # 3	70.10	
H.R.W. # 2	69.73	
H.R.W. # 1	68.52	
Durum	68.30	
H.A. Durum	67.05	

Table 11 - Ordered array of means for percent farina and semolina yields.

Classes	$\bar{X}$	L.S.D.
H.A. Durum	53.55	6.980
Durum	47.18	
H.R.W. 5	44.88	
H.R.W 4	43.78	
H.R.W 3	42.33	
H.R.W. 1	37.55	
H.R.W 2	36.73	

* Lines join difference between means lower than L.S.D.

Table 12 - Ordered array of means for percent flour yields

Classes	$\bar{X}$	L.S.D.
H.R.W. # 2	33.00	18.165
H.R.W. # 1	30.97	
H.R.W. # 3	27.77	
H.R.W. # 4	26.77	
H.R.W. # 5	25.73	
Durum	19.87	
H.A.Durum	14.75	

Table 13 - Ordered array of means for color

Classes	$\bar{X}$	L.S.D.
H.A. Durum	56.92	1.620
Durum	53.67	
H.R.W. # 5	37.08	
H.R.W. # 4	36.67	
H.R.W. # 3	35.50	
H.R.W. # 1	35.41	
H.R.W. # 2	33.50	

* Lines join difference in mean lower than L.S.D.

Table 14 - Ordered array of means for H.R.W. farina yield

Classes	$\bar{X}$	L.S.D
H.R.W. # 5	44.88	0.925
H.R.W. # 4	43.78	
H.R.W. # 3	42.33	
H.R.W. # 2	37.55 |	
H.R.W. # 1	36.73 |	

Table 15 -Ordered array of means for H.R.W. flour yields

Classes	$\bar{X}$	L.S.D.
H.R.W. # 2	33.00	1.037
H.R.W. # 1	30.97	
H.R.W. # 3	27.77 |	
H.R.W. # 4	26.77 | |	
H.R.W. # 5	25.73 |	

* Lines join differences in mean lower than L.S.D.

FIGURE 5: REGRESSION CURVE

H.R.W. FARINA YIELD VS. D.H.V. COUNT.

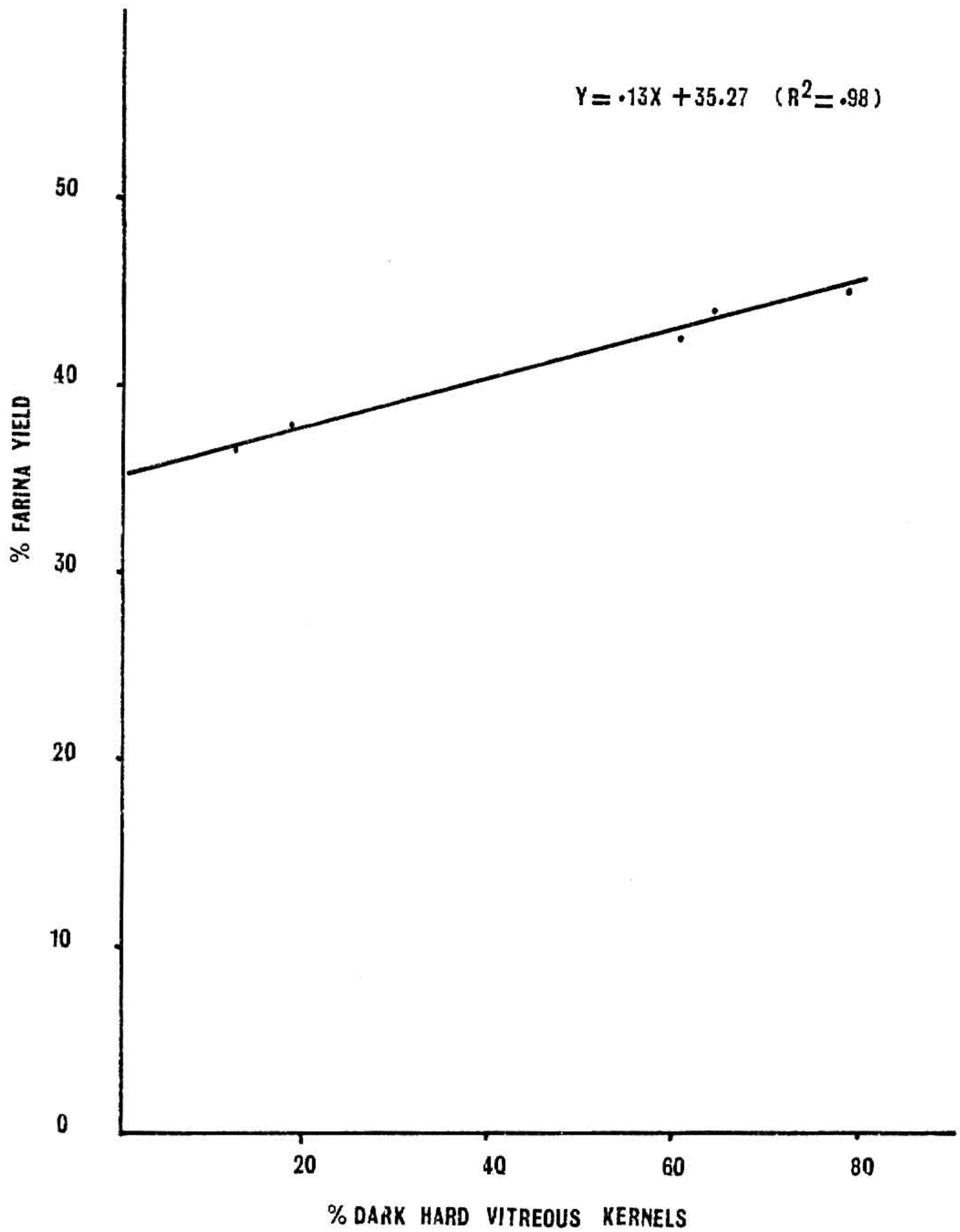


FIGURE 6 : REGRESSION CURVE

H.R.W. FLOUR EXTRACTION VS. D.H.V. COUNT

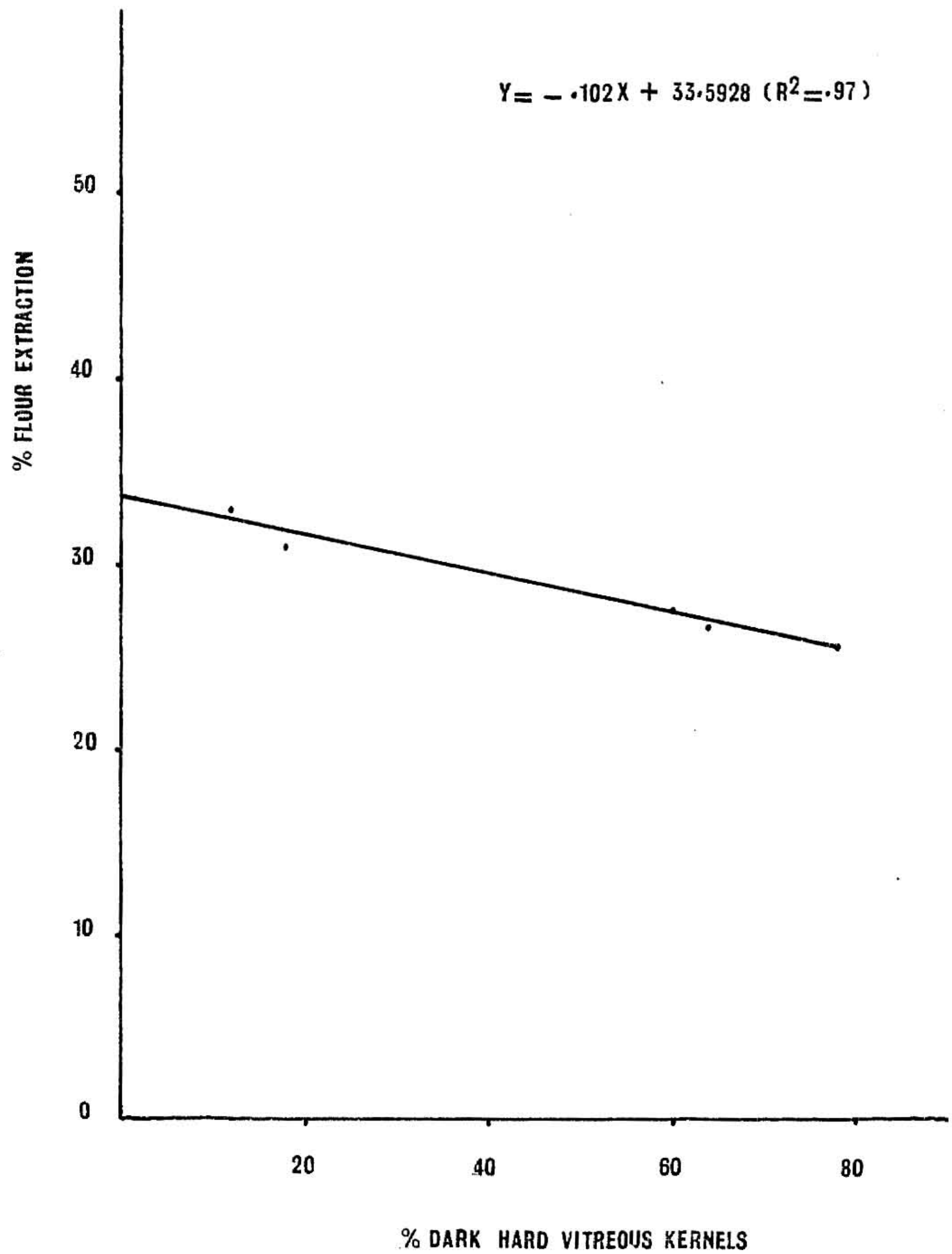


FIGURE 7 : REGRESSION CURVE

H.R.W. FARINA COLOR VS. D.H.V. COUNT

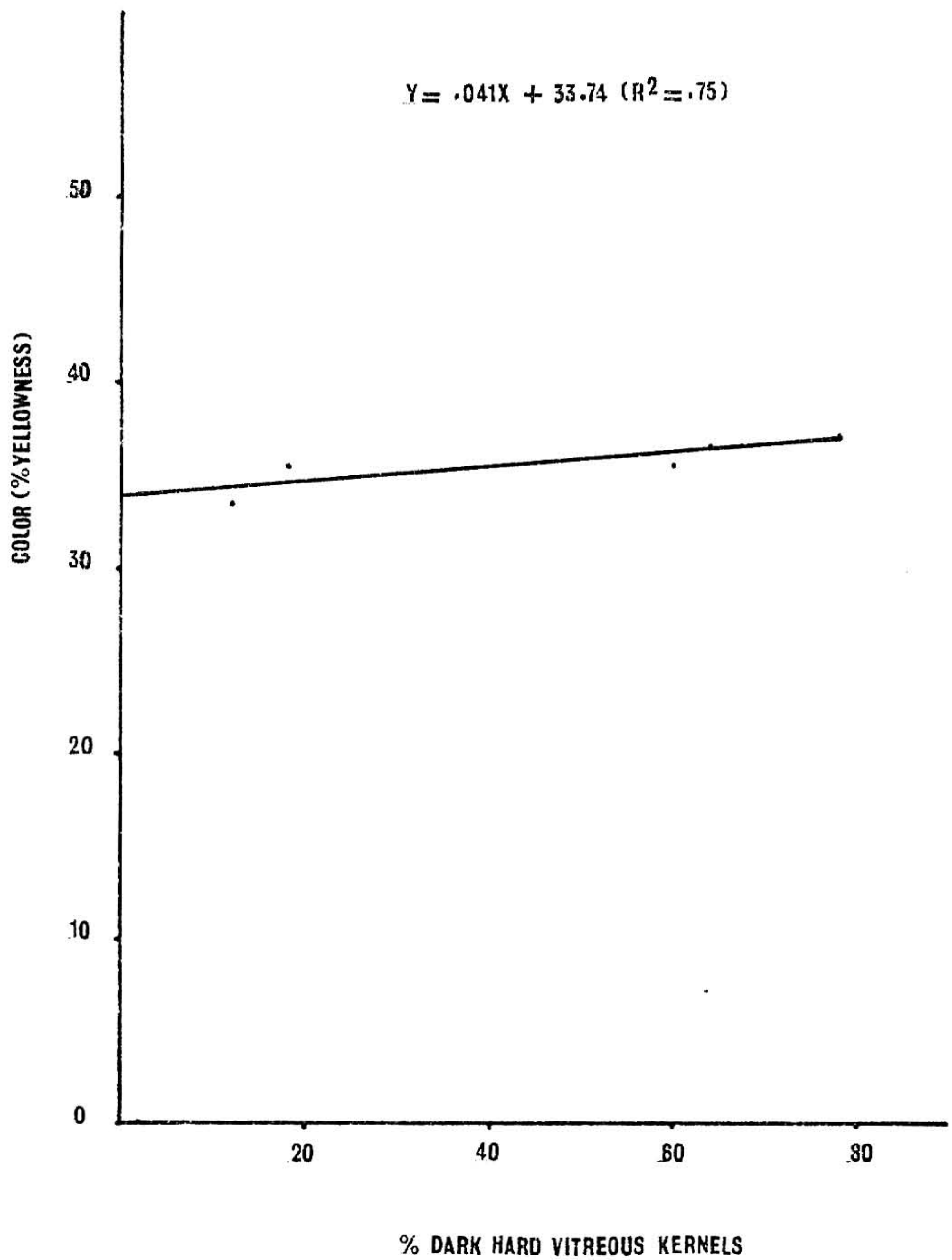


FIGURE 8: GRANULATION CURVES

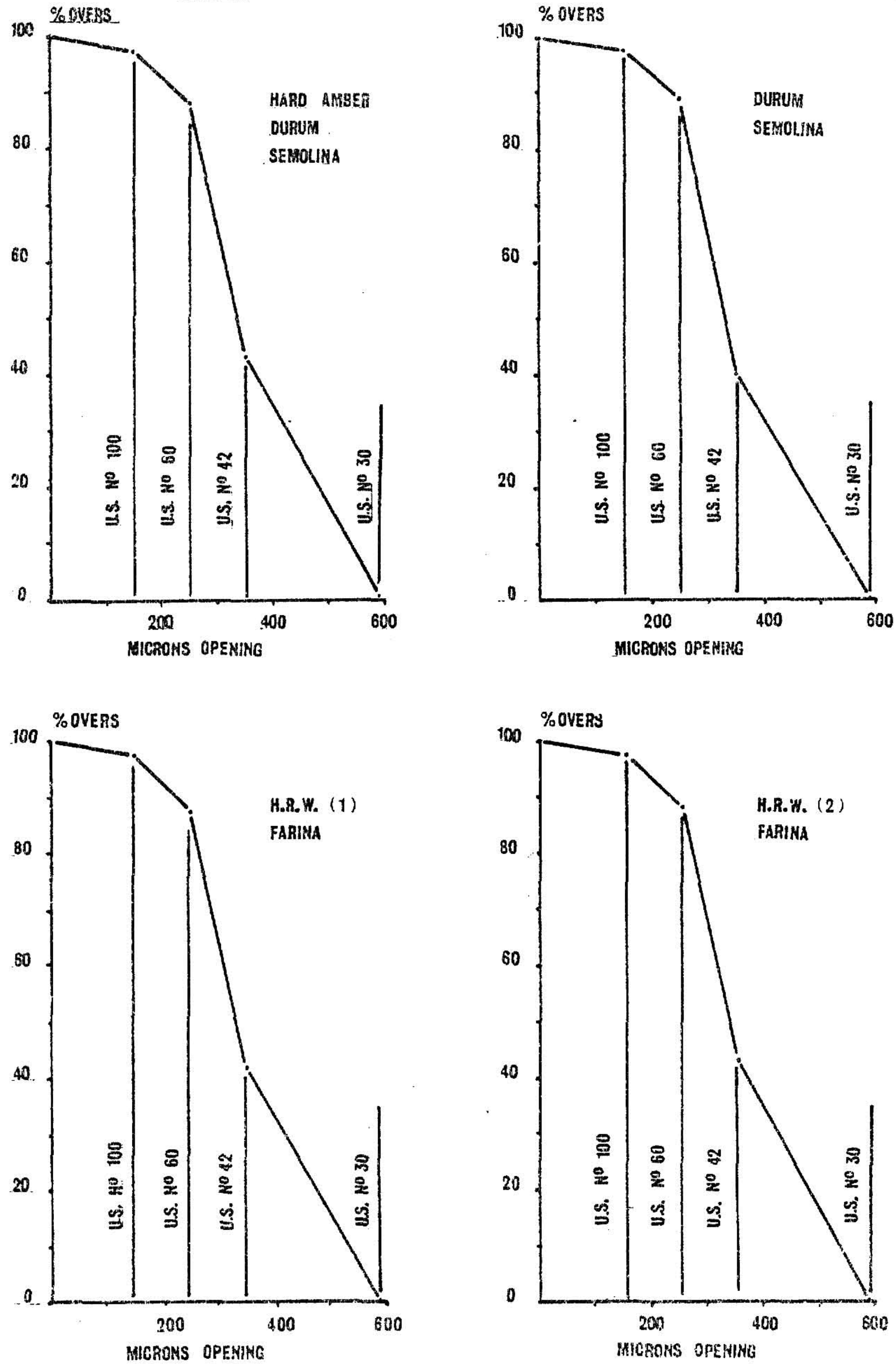
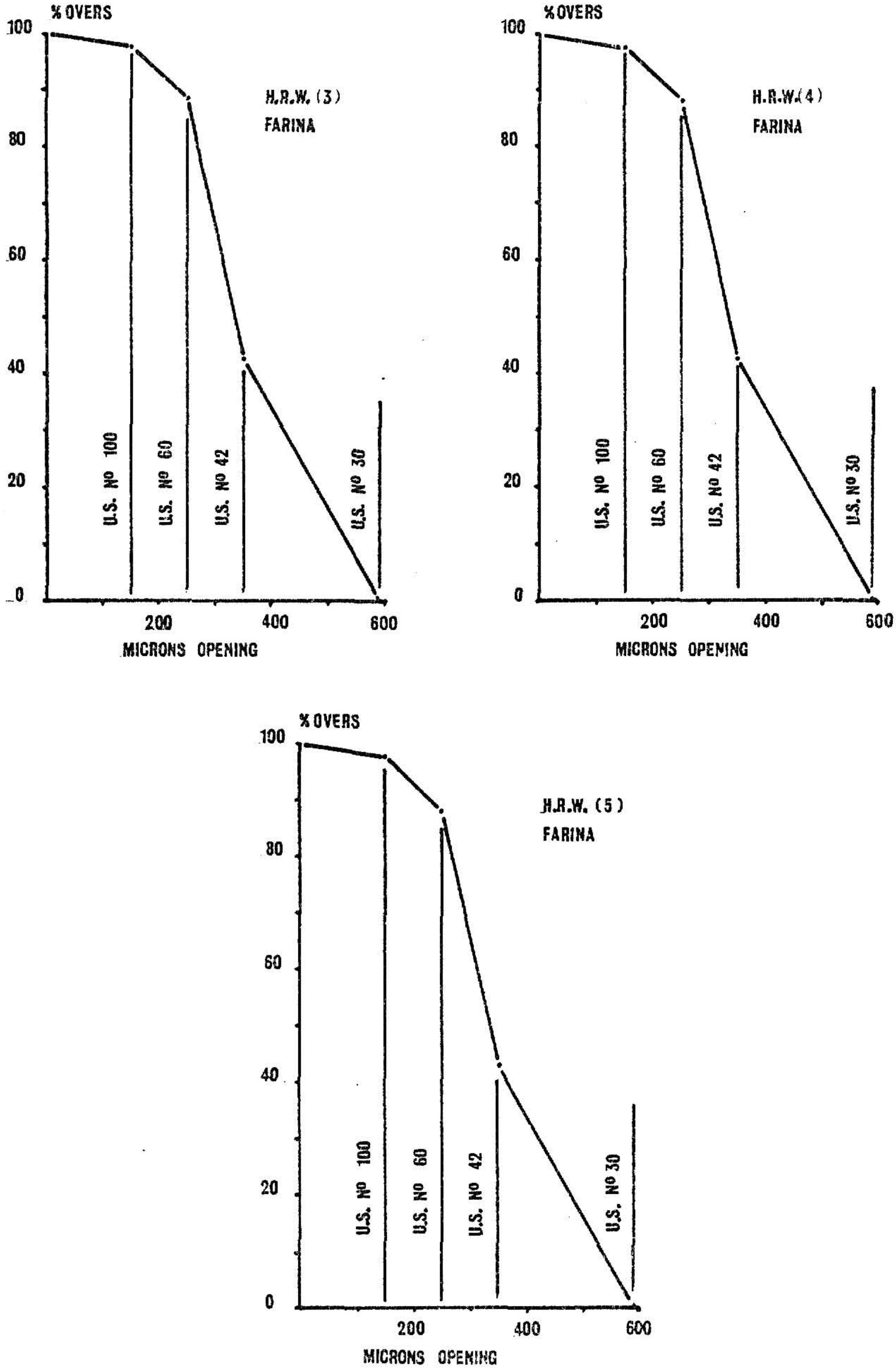


FIGURE 9: GRANULATION CURVES



Spaghetti processing results and discussion:

A mentioned earlier, the six samples milled from each type of wheat were blended together in a laboratory blender. Since the mixing of a granular type of substance is seldom perfect, a sample from each blend was taken and analyzed for moisture, protein, ash, and pigment content. Beside these analyses, a speck count, a granulation test and a color evaluation were performed. The results of these tests are shown in table 16.

Except for the protein content of hard amber durum which was higher than the average, the other results were in general very similar to the previous one.

Yellow pigment content of the samples seemed to be in agreement with the color score ; samples having the highest pigment content scoring the best. Also, it must be pointed out that for hard red winter farina, yellow pigment content increased with the D.H.V. count. H.R.W. (1) and (2) corresponding to the former subclass "Yellow Hard Winter Wheat" had the lowest pigment content. H.R.W. (3) and (4) corresponding to the former subclass "Hard Winter Wheat" had higher pigment content. H.R.W. (5) corresponding to the former subclass "Dark Hard Winter Wheat" had the highest pigment content.

Spaghetti was processed in duplicate from each blend. Water absorptions and mixing times are given in table 17. The quality of spaghetti was assessed in terms of cooking weight, cooking losses and firmness both at optimum cooking time and after overcooking. Spaghetti color was also measured. The results of these tests are shown in table 18. (See appendices for test results).

Color : Color evaluation results were expressed as percent brightness (1%), percent yellowness (b%) and color score. Spaghetti made from hard amber durum and durum had the best color score. For spaghetti made from the different types of hard red winter wheats, sample (5) was rated the same as sample (4) but had higher brightness value. Samples (1), (2) and (3) had the poorest color score. This seems to be in accord with the D.H.V. count, with spaghetti made from H.R.W. having the highest D.H.V. count yielding the best color score. Also, it must be pointed out that all the spaghetti samples were somewhat duller and more brownish than the commercial samples. This might be caused by the relatively high speck count (Plate III). The results of which were expressed in lower brightness values and overall color scores (66).

Cooking weight : Analysis of variance (table 19) showed that the mean results were different at the 0.05 level of significance. For that, the L.S.D. tests were performed (tables 20, 21). These tests showed that at optimum cooking time, there was no significant difference between spaghetti made from the two durum subclasses. However, spaghetti made from durum subclasses were significantly different from spaghetti made from H.R.W. samples. In other words, spaghetti made from the two durum subclasses absorbed about the same amount of water but significantly more than spaghetti made from the different H.R.W. wheats. Furthermore, spaghetti made from H.R.W. (2), (4), and (5) had the lowest amount of swelling, when compared to the rest of the H.R.W. samples (Plate IV).

After overcooking, spaghetti made from H.R.W. (1), (2), (3) and (4) showed the highest amount of swelling, meaning that they were the most susceptible to disintegration. Spaghetti made from H.R.W. (5) was not as good as durum but significantly better than the other H.R.W. spaghetti samples.

Cooking losses: Analysis of variance for the mean results (table 19) showed that the data were different at optimum cooking time and after overcooking. The L.S.D. tests (tables 22, 23) indicated the same type of trend. Spaghetti made from the two durum subclasses had the lowest losses, followed by H.R.W. (5). Spaghetti processed from the remaining H.R.W. farina had the highest losses.

Firmness: Analysis of variance for the mean results (table 19) also showed that the data were different both at optimum cooking time and after overcooking. The L.S.D. tests (tables 24, 25) indicated a somewhat different trend than for the two previous tests. at optimum cooking time, spaghetti made from H.R.W.(5) was firmer than spaghetti made from the two durum subclasses. Also durum spaghetti was not significantly firmer than H.R.W. (1) and (2) spaghetti. Spaghetti made from H.R.W. (3) and (4) had the lowest firmness values.

After overcooking, H.R.W. (1) scored as good as hard amber durum spaghetti, followed by H.R.W. (4) and (5), and durum. Spaghetti made from H.R.W. (2) and (3) were the least firm.

To sum up, as far as cooking qualities are consermed, spaghetti made from hard amber durum and durum had the best overall quality. Spaghetti made from H.R.W. (5) was the best of the hard wheats. Spaghetti made from H.R.W. (2) was the poorest. The remaining of the hard red winter wheat samples yielded spaghetti with somewhat similar cooking qualities. However, it should be pointed out that the firmness values were somewhat hard to discuss. It seems that beside the D.H.V. count, protein quantity and quality, and gluten quality among other other things have an impact on spaghetti quality. The D.H.V. count could not explain all that happens in such a complex food system.

Since spaghetti made from H.R.W. (5) was considered to be the best of the hard wheat samples, a batch of H.R.W. (5) farina was processed with F.D. & C. yellow # 5 - 89% pure at a concentration of 62 X 10^{-3} mg/ml. of added water. At this concentration, the color of the spaghetti seemed to be quite similar to the durum spaghetti color (plate III). Furthermore, upon cooking most of the coloring agent was washed out of the product by the cooking water, and the cooked spaghetti looked as white as the non colored samples.

Table 16 - Analysis of the mixed product for spaghetti processing

Products	Speck	Color	Pgmts ppm	M.C.	Pn.*	Ash *	Granulation				
							Over 30	Over 42	Over 60	Over100	Thru100
H.A.D. Semolina	46	57.0	7.67	14.8	13.3	.79	.9	40.5	47.6	8.7	2.3
Durum Semolina	42	52.0	7.40	15.0	13.6	.73	.1	41.7	46.6	9.2	2.4
H.R.W. (1) Farina	45	34.0	3.80	15.0	11.4	.59	Trace	43.6	44.8	9.3	2.3
H.R.W. (2) Farina	43	32.5	3.53	15.1	10.9	.55	Trace	41.4	46.7	9.5	2.4
H.R.W. (3) Farina	41	33.0	4.07	13.4	10.0	.54	Trace	41.8	45.0	11.1	2.1
H.R.W. (4) Farina	38	35.0	4.40	14.3	10.6	.49	Trace	41.6	45.0	10.7	2.7
H.R.W. (5) Farina	40	38.0	4.83	14.1	10.8	.50	Trace	41.8	44.5	10.9	2.8

* 14 % Moisture Basis.

Table 17 - Spaghetti Processing data

Wheats	Absorption %	Mixing time (min)		Opt. Cook. time (min)
		Speed 1	Speed 2	
Hard Amber Durum	30.0	3.0	1.5	16
Durum	31.0	3.0	1.5	15
Hard Red Winter # 1	32.5	2.5	1.5	14
Hard Red Winter # 2	32.5	2.5	1.5	14
Hard Red Winter # 3	32.5	2.5	1.5	15
Hard Red Winter # 4	32.5	2.5	1.5	15
Hard Red Winter # 5	32.5	2.5	1.5	15

Table 18 - Spaghetti Quality Data

Wheats	Color			Optimum Cook. time			Overcooked 10 min.		
	l (%)	b (%)	Color score	Cook.Wt. g/ 10 g	Loss %	Firmness g	Cook.Wt. g/10 g	Loss %	Firmness g
Hard Amber Durum	65.6	15.5	7.5	33.2	5.5	192	36.1	9.0	148
Durum	63.2	14.4	6.5	33.6	6.1	186	36.4	9.3	138
Hard Red Winter # 1	71.6	11.5	5.0	30.7	7.0	184	38.0	10.6	149
Hard Red Winter # 2	70.8	11.4	5.0	29.5	7.5	183	37.8	12.7	130
Hard Red Winter # 3	72.4	11.9	5.0	30.5	6.9	179	37.7	11.8	128
Hard Red Winter # 4	68.2	12.7	6.0	29.9	6.5	178	38.0	13.2	142
Hard Red Winter # 5	75.9	13.4	6.0	29.6	6.3	210	37.1	11.2	139

Table 19- Analysis of Variance for the Spaghetti cooking Caracteristics

Source of Variation	d.f.	Mean Square Significance					
		Optimum Cooking time			Overcooked 10 min.		
		Cook.Wt.	Loss	Firmness	Cook.Wt.	Loss	Firmness
Between classes	6	9.3706 *	1.5629 *	131.6296 *	2.4751 *	10.4512 *	244.3334 *
Within classes	21	0.2816	0.1609	18.0952	0.2881	0.4377	19.3809
Total	27						

* Significant at the 0.05 level of significance.

Table 20 - Ordered array of means for cooking weight at optimum cooking time.

Classes	$\bar{X}$	L.S.D.
Durum	33.6	0.552
H.A.Durum	33.2	
H.R.W. # 1	30.7	
H.R.W. # 3	30.5	
H.R.W. # 4	29.9	
H.R.W. # 5	29.6	
H.R.W. # 2	29.5	

Table 21 -Ordered array of means for cooking weight after overcooking

Classes	$\bar{X}$	L.S.D.
H.R.W. # 1	38.0	0.558
H.R.W. # 4	38.0	
H.R.W. # 2	37.8	
H.R.W. # 3	37.7	
H.R.W. # 5	37.1	
Durum	36.4	
H.A.Durum	36.1	

* Lines join difference between means lower than L.S.D.

Table 22 -Ordered array of means for cooking losses at optimum cooking time.

Classes	$\bar{X}$	L.S.D.
H.R.W. # 2	7.5	0.417
H.R.W. # 1	7.0	
H.R.W. # 3	6.9	
H.R.W. # 4	6.5	
H.R.W. # 5	6.3	
Durum	6.1	
H.A.Durum	5.5	

Table 23 - Ordered array of means for cooking losses after overcooking.

Classes	$\bar{X}$	L.S.D.
H.R.W. # 4	13.2	0.688
H.R.W. # 2	12.7	
H.R.W. # 3	11.8	
H.R.W. # 5	11.2	
H.R.W. # 1	10.6	
Durum	9.3	
H.A.Durum	9.0	

* Lines join difference between mean lower than L.S.D.

Table 24 - Ordered array of means for firmness at optimum cooking time.

Classes	$\bar{X}$	L.S.D.
H.R.W. # 5	210	4.424
H.A.Durum	192	
Durum	186	
H.R.W. # 1	184	
H.R.W. # 2	183	
H.R.W. # 4	178	
H.R.W. # 3	170	

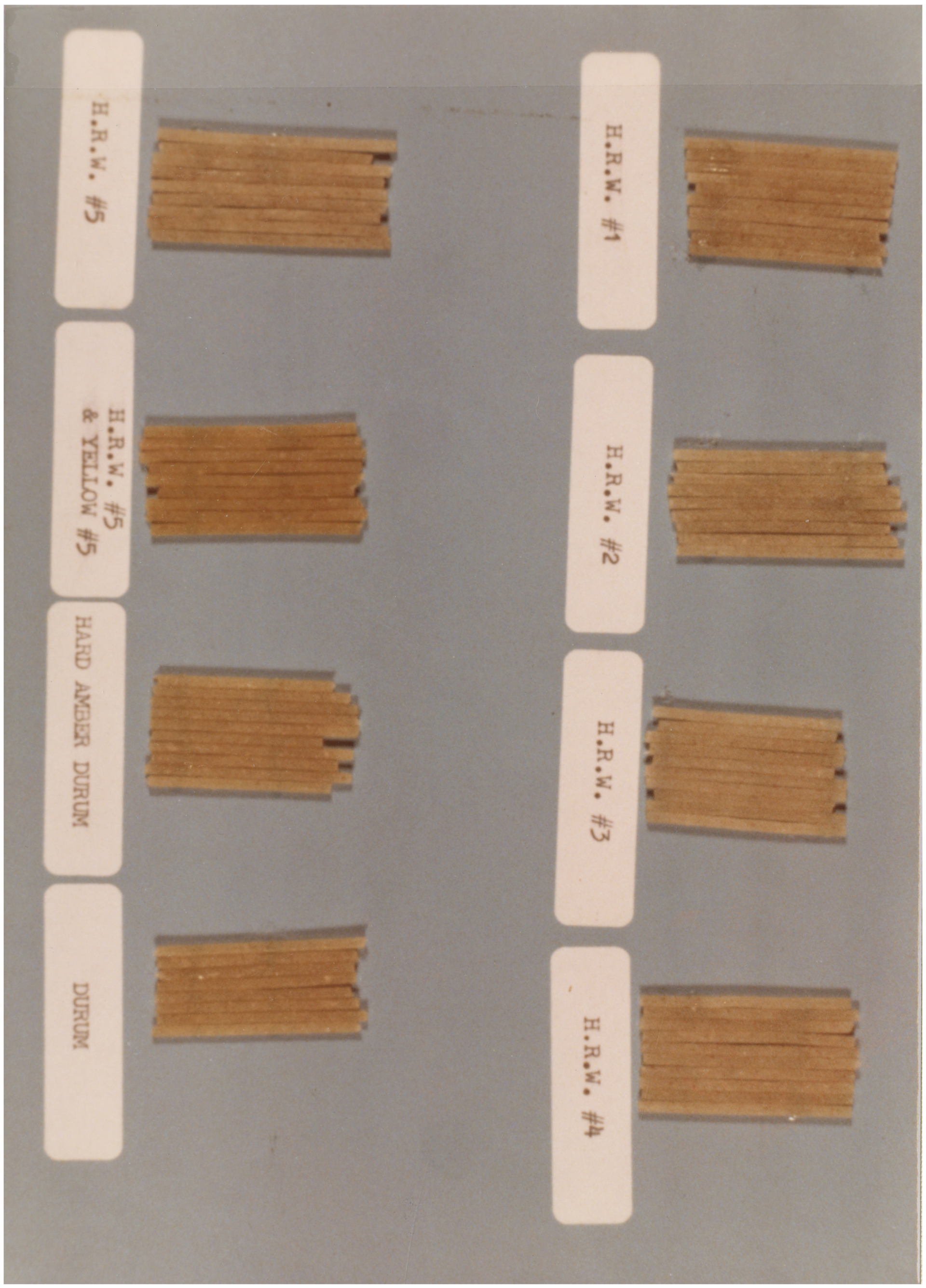
Table 25 - Ordered array of means for firmness after overcooking

Classes	$\bar{X}$	L.S.D.
H.R.W. # 1	149	4.578
H.A.Durum	148	
H.R.W. # 4	142	
H.R.W # 5	139	
Durum	138	
H.R.W. # 2	130	
H.R.W. # 3	128	

* Lines join difference between means lower than L.S.D.

EXPLANATION OF PLATE III

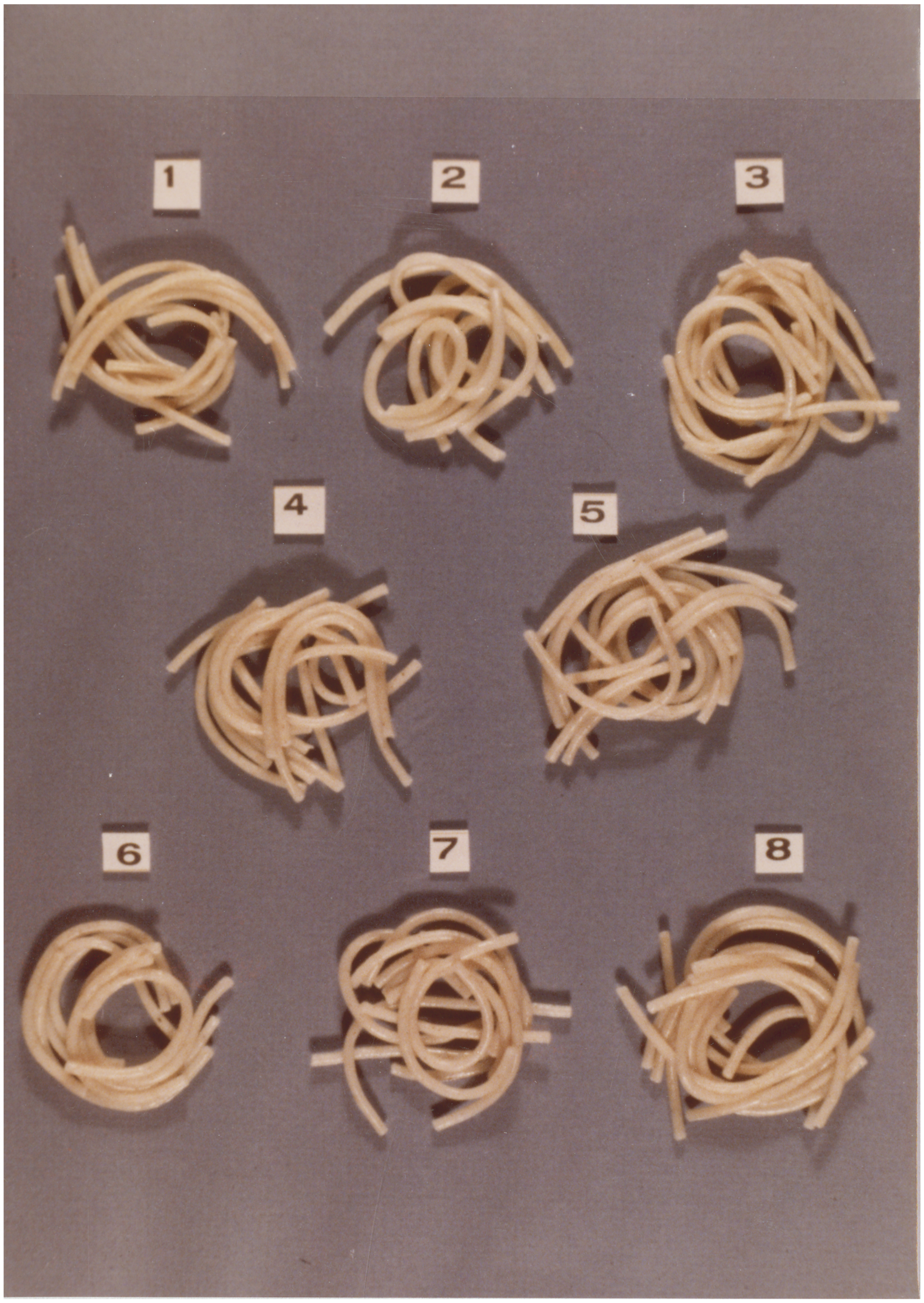
Photograph of the spaghetti made from the different kinds of semolina and farina.


H.R.W. #5
H.R.W. #5 & YELLOW #5
HARD AMBER DURUM
DURUM
H.R.W. #1
H.R.W. #2
H.R.W. #3
H.R.W. #4

EXPLANATION OF PLATE IV

Photograph of the cooked spaghetti made from the different kinds of semolina and farina at optimum cooking time.

1 : Commercial spaghetti
2 : Hard amber durum spaghetti
3 : Durum spaghetti
4 : H.R.W. # 1 spaghetti
5 : H.R.W. # 2 spaghetti
6 : H.R.W. # 3 spaghetti
7 : H.R.W. # 4 spaghetti
8 : H.R.W. # 5 spaghetti


1
2
3
4
5
6
7
8

Short extraction and spaghetti quality assessment :

Since our primary purpose was to optimize the yields, farina and semolina samples were speckier than the recommanded norms. For that, we further purified these samples using the KICE aspirator. The machine also removed the finest fractions and the flour. 20 percent of the initial product weight was removed this way. The previous farina and semolina yields were corrected on the basis of the amount of product recovered and called short extractions.

In addition, a sample of hard red winter wheat - "Eagle" variety-, a sample of hard white winter wheat, a sample of soft red winter wheat, and a sample of soft white wheat -"Gaines" variety- were analyzed for moisture, protein and ash. The results of these analyses are shown in table 26. The D.H.V. count was also determined (plates V, VI, VII, and VIII).

The wheats were then tempered and milled according to the procedure previously described, and passed through the KICE aspirator. Semolina and farina color, speck count, moisture, protein, and ash were also determined for all the samples. The results of these analyses are given in table 27.

A batch of spaghetti was then processed from each semolina and farina sample. Durum semolina and H.R.W. farina were processed using the previous absorptions and mixing times. The four other farina samples were processed at 33 percent absorption using the same mixing time - 2 ½ minutes at low speed followed by 1 ½ minute at medium speed-.

The color of the different spaghetti samples was then assessed (table 27). Spaghetti processed from the four latest wheat samples were also cooked and their cooking qualities assessed both at optimum cooking time and after 10 minutes overcooking. The results are shown in table 28.

After purification, semolina and farina speck count and ash were drastically lowered for all the samples. However, the color scores were not affected by the purification because branny particles fluoresce in the green spectrum but do not show up in the blue spectrum.

Spaghetti color also showed an overall improvement in the visual appearance and color scores due mainly to higher yellowness values (plate IX). The visual appearance of the cooked product also improved. After cooking the product was whiter and had less specks (table X)

Both soft wheats had a poor farina yield. This was somewhat expected since their D.H.V. count was relatively low. The farina color scores were also low. However, farina produced from soft red winter wheat had a somewhat higher color score. Hard white winter wheat yielded as much farina as H.R.W. (2) but had lower yellow color. Hard red winter wheat "Eagle" produced about the same amount of farina as H.R.W. (3) . With a somewhat similar color score. So at similar D.H.V. count levels both farina yield and color were comparable. White wheats, being less pigmented, produced a whiter farina. However, these results should be considered with caution since only one milling run was done for each of the four latest wheats.

The same type of trend could be observed for spaghetti color. Spaghetti made from both white wheats were whiter than the spaghetti made from the different types of hard red winter wheats, whose color scores where somewhat similar (Plate IX).

As far as cooking qualities, spaghetti made from both soft wheats had a lower cooking time when compared to spaghetti made from H.R.W. wheats. At optimum cooking time, the cooking qualities of the four different spaghetti samples were very similar. However, spaghetti made from soft white wheat had the highest cooking losses and the lowest firmness values. After overcooking, the quality of spaghetti made from soft wheats deteriorated.

They became sticky, had a high percentage of losses, and were the least firm. The low protein content of both soft wheats might have been one of the reasons for such a susceptibility of these spaghetti to overcooking. Spaghetti made from H.R.W. "Eagle" and hard white wheat were somewhat similar in quality to spaghetti made from the other H.R.W. samples.

Table 26 - Wheats analyses

Wheats	% D.H.V.	M.C.	Pn *	Ash *
Hard Red Winter "Eagle"	54	11.2	12.7	1.45
Hard White Winter	24	11.7	11.2	1.56
Soft Red Winter	16	11.6	10.9	1.65
Soft White "Gaines"	14	8.7	10.5	1.51

* 14 % moisture basis.

Table 27 - Semolina and farina analyses and spaghetti color

Products	% Extraction	Speck count	% Yellow	M.C.	Pn *	Ash *	Spaghetti color		
							b %	1 %	color score
Hard Amber Durum	42.9	9	56	10.9	12.0	0.67	19.1	66.7	8.5
Durum	38.0	11	51	10.6	12.9	0.65	17.2	73.9	7.5
H.R.W. # 1	30.0	10	33	12.9	10.0	0.44	13.7	63.2	6.5
H.R.W. # 2	29.4	14	28	14.0	11.2	0.46	12.7	63.2	6.5
H.R.W. # 3	33.8	10	35	12.9	10.6	0.40	13.7	63.2	6.5
H.R.W. # 4	35.0	12	38	11.9	10.6	0.40	14.8	63.2	6.5
H.R.W. # 5	35.9	14	37	13.1	10.8	0.42	15.1	64.6	7.5
H.R.W. "Eagle"	32.5	13	37	15.2	11.0	0.42	14.7	63.2	6.5
Soft Red Winter	24.6	11	27	15.2	9.7	0.50	12.7	63.2	6.5
Hard White Winter	29.5	11	21	14.7	9.0	0.46	13.4	63.9	6.5
Soft White Wheat "Gaines"	25.2	14	20	15.5	9.9	0.47	14.7	63.2	6.5

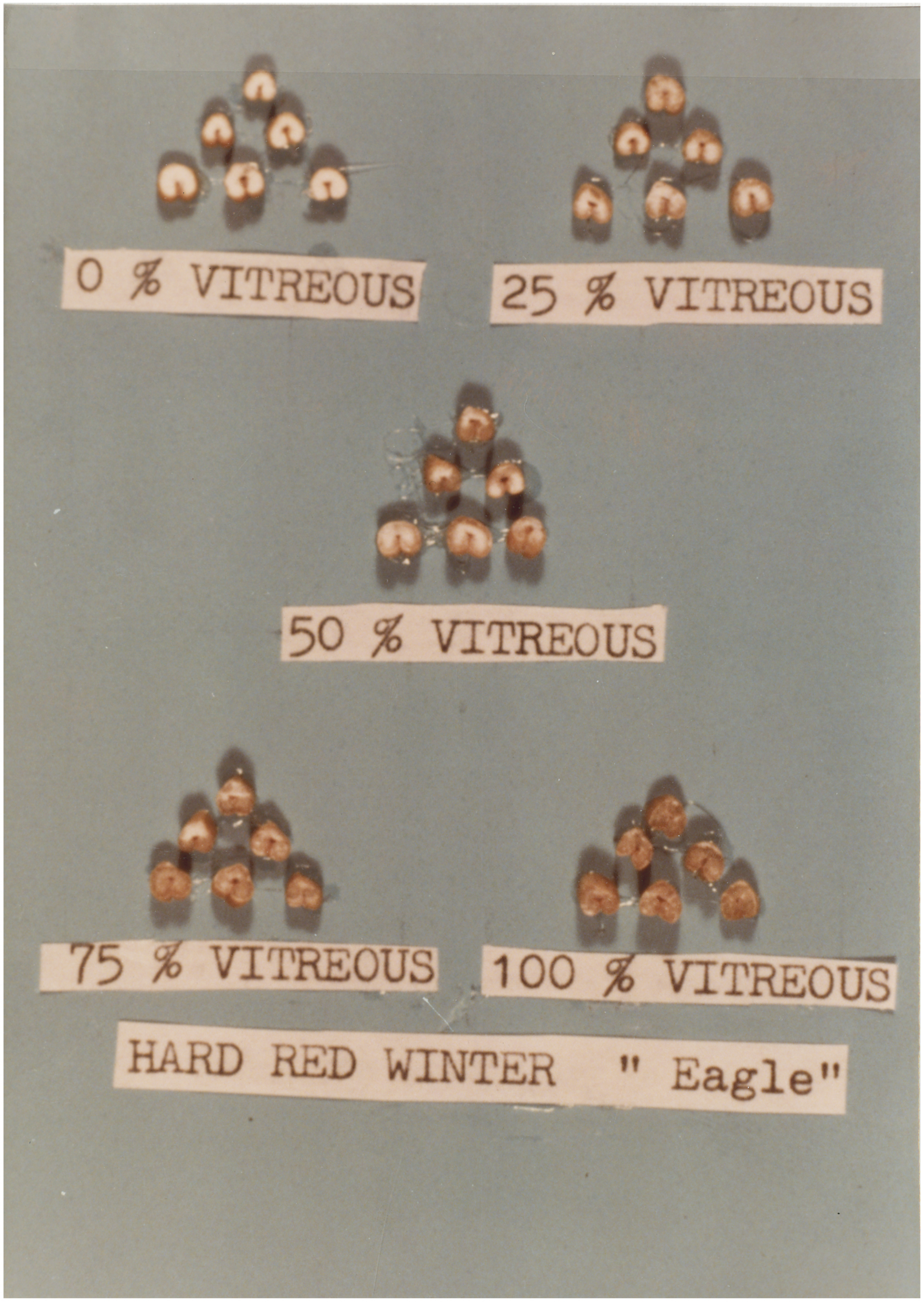
* 14 % moisture basis.

Table 28 - Spaghetti cooking qualities

Products	Optimum cooking time	Opt. cooking time			10 min. overcooked		
		cook.wt. g/10 g	cook. losses%	firmness g	cook. wt. g/ 10 g	cook. losses %	firmness g
Hard Red Winter "Eagle"	14	29.8	6.2	150	35.8	10.5	136
Hard White Wheat	14	30.2	6.5	156	35.1	11.2	121
Soft Red Winter	10	31.5	6.6	141	38.2	11.8	105
Soft White "Gaines"	10	32.5	7.9	136	40.9	12.2	98

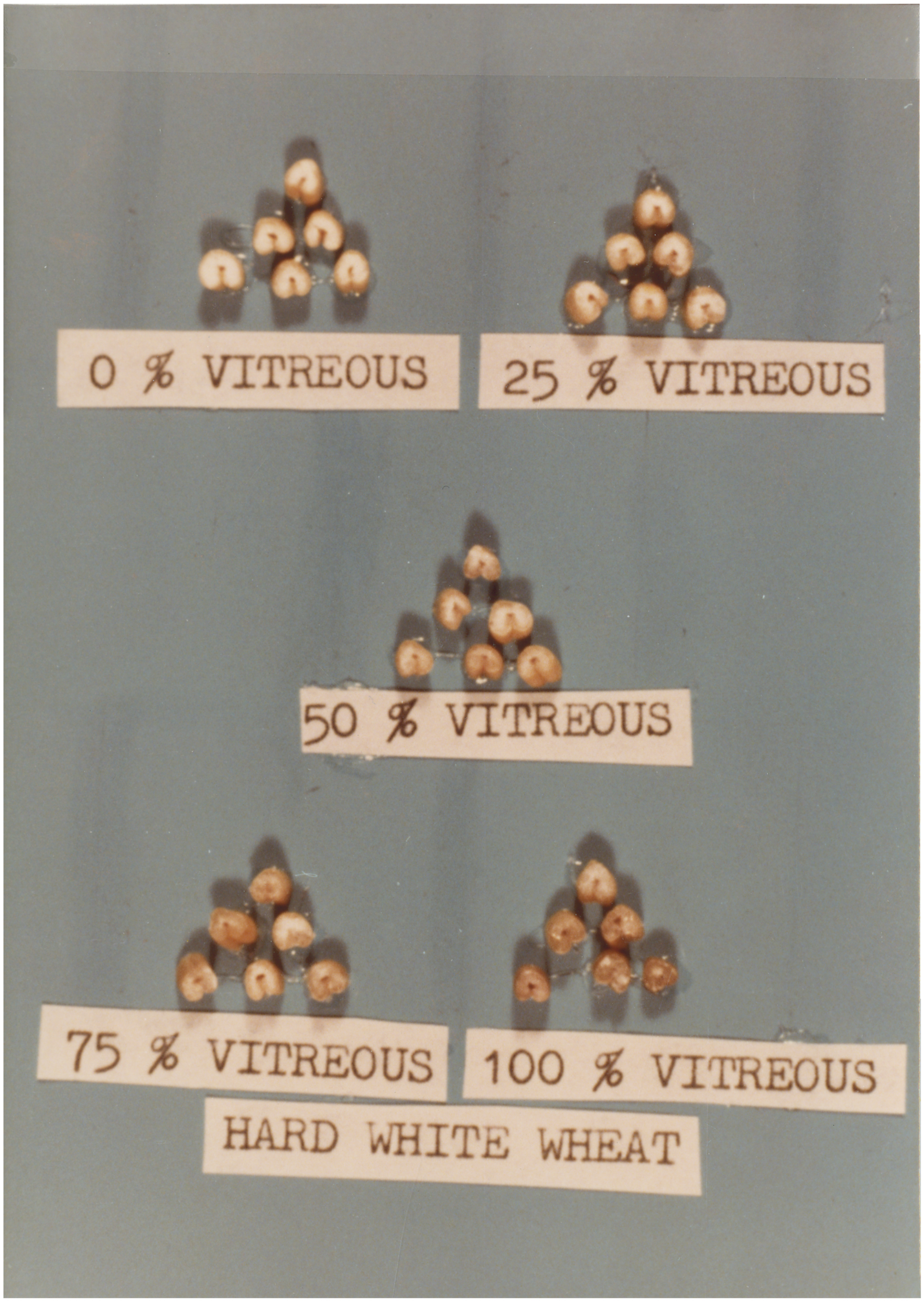
EXPLANATION OF PLATE V

Transection of hard red winter "Eagle" kernels.
White endosperm : Chalky
Dark endosperm : Vitreous


0 % VITREOUS
25 % VITREOUS
50 % VITREOUS
75 % VITREOUS
100 % VITREOUS
HARD RED WINTER " Eagle"

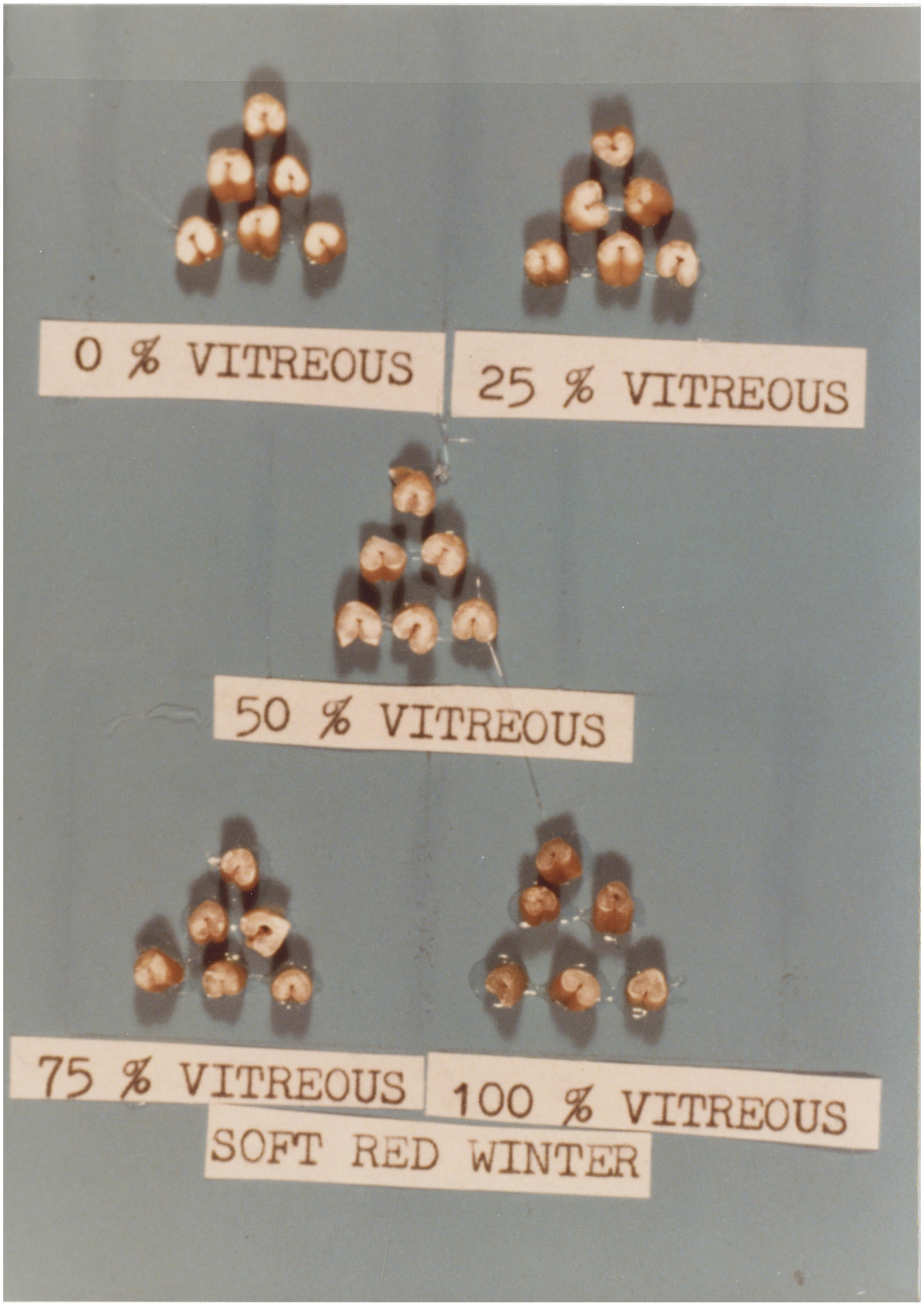
EXPLANATION OF PLATE VI

Transection of hard white winter wheat kernels.
White endosperm : Chalky
Dark endosperm : Vitreous


0 % VITREOUS
25 % VITREOUS
50 % VITREOUS
75 % VITREOUS
100 % VITREOUS
HARD WHITE WHEAT

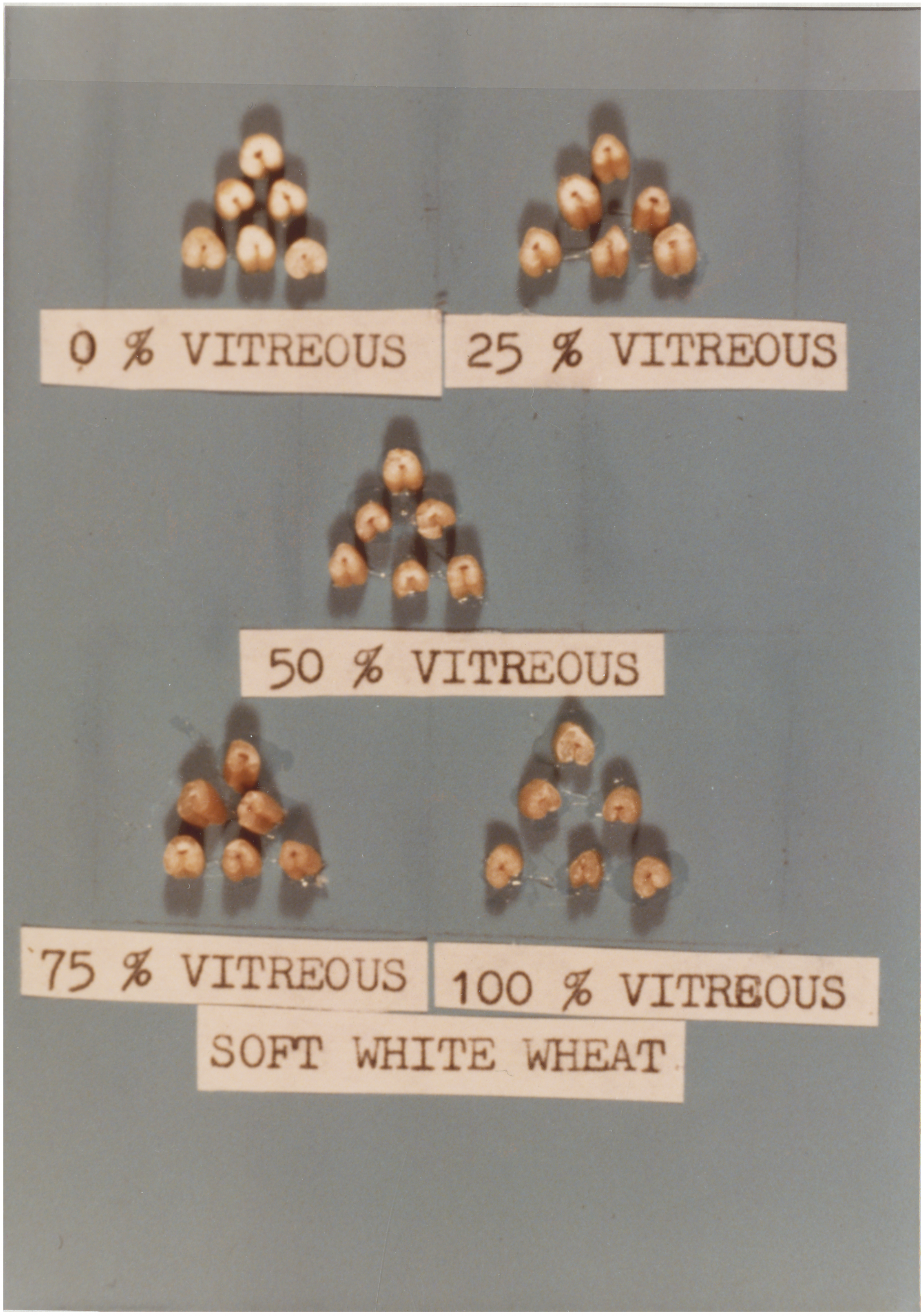
EXPLANATION OF PLATE VII

Transection of soft red winter wheat kernels.
White endosperm : Chalky
Dark endosperm : Vitreous


0 % VITREOUS
25 % VITREOUS
50 % VITREOUS
75 % VITREOUS
100 % VITREOUS
SOFT RED WINTER

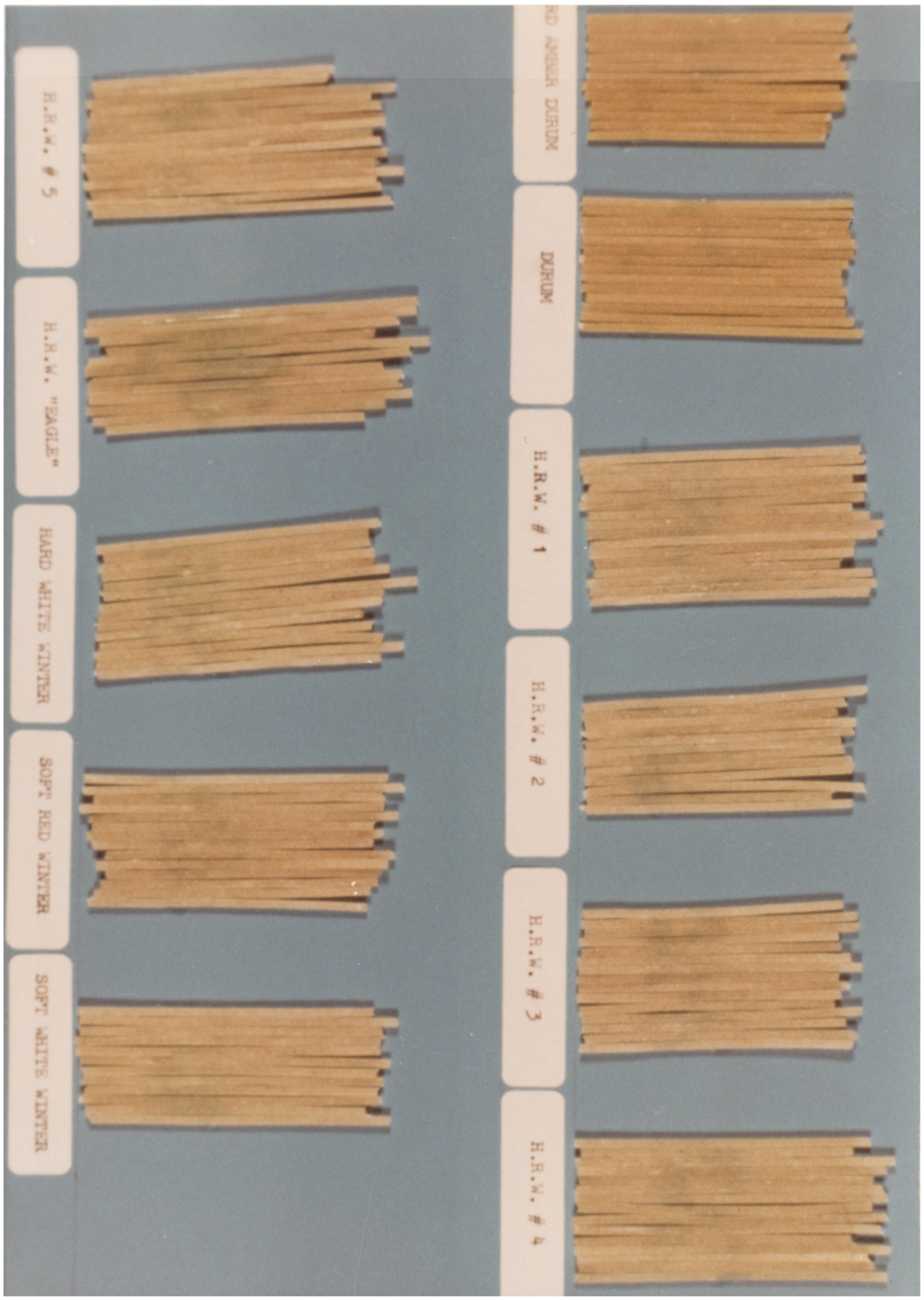
EXPLANATION OF PLATE VIII

Transection of soft white wheat "Gaines" kernels.
White endosperm ; Chalky
Dark endosperm : Vitreous


0 % VITREOUS
25 % VITREOUS
50 % VITREOUS
75 % VITREOUS
100 % VITREOUS
SOFT WHITE WHEAT

EXPLANATION OF PLATE IX

Photograph of the uncooked spaghetti made from the different kinds of semolina and farina after purification.


H.R.W. # 5
H.R.W. "EAGLE"
HARD WHITE WINTER
SOFT RED WINTER
SOFT WHITE WINTER
AMBER DURUM
DURUM
H.R.W. # 1
H.R.W. # 2
H.R.W. # 3
H.R.W. # 4

EXPLANATION OF PLATE X

Photograph of the cooked spaghetti made from the different kinds of farina and semolina after purification.

SUMMARY AND CONCLUSIONS

From this study, it has been observed that the dark hard and vitreous count as determined by our method, seemed to have a significant impact both on the farina yield and spaghetti quality of hard red winter wheats.

First of all, as the dark hard and vitreous count was increased, farina yield improved linearly ; with the sample having the highest dark hard and vitreous count yielding almost as mush farina as the durum subclass. Also farina color improved and flour yield decreased both linearly as the dark hard and vitreous count was increased. However, as it was pointed out earlier, these results might not be totally reliable since the dark hard and vitreous count was not increased in regular increment, but rather to accomodate the former hard red winter wheat subclasses. Wheat grades and protein content did not seem to have a great impact on the farina yield.

Second, as far as spaghetti quality, the same type of trend has been observed. As the dark hard and vitreous count increased, spaghetti color improved. The cooking qualities of the spaghetti also seemed to get better. Spaghetti processed from hard red winter farina having the highest dark hard and vitreous count had the best color score and cooking quality. However, this improvement was not quite as remarkable as the improvement observed for the milling yield, since the best of the hard red winter spaghetti samples were significantly lower in quality than spaghetti processed from durum subclass. Also it must be pointed out that the firmness results were quite controversial, with some hard red winter spaghetti samples scoring better tham durum. Besides, there was no definite relationship between farina protein content and spaghetti quality. Consequently, it seems that beside the dark hard and vitreous count, a whole set of other factors have an impact on the spaghetti quality. One parameter could not explain all that happens in such a complex food system.

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A P P E N D I C E S

Table 29 - Milling results for hard amber durum (76 % vitreous)

Test #	% Extraction	% Semolina	% Flour	% Feed	% Loss	Speck/ 10sq.in	% Yellow	Granulation				
								over 30	over 42	over 60	over 100	Thru 100
1	69.7	55.9	13.8	29.3	1.0	43	59.0	.5	42.5	46.3	8.4	2.3
2	67.7	52.8	14.9	31.2	1.1	44	56.0	.7	42.9	44.7	9.4	2.3
3	66.4	53.0	13.4	30.2	3.4	40	55.0	.7	43.0	44.8	9.1	2.4
4	67.7	52.7	15.0	31.2	1.1	45	55.0	.9	42.1	44.5	10.4	2.1
5	68.7	52.9	15.8	28.7	2.6	40	57.0	.7	41.7	44.9	10.6	2.1
6	69.6	54.0	15.6	17.7	2.7	41	59.5	.8	41.1	45.6	9.9	2.6

Table 30 - Milling results for durum (54 % vitreous)

Test #	% Extraction	% Semolina	% Flour	% Feed	% Loss	Speck/ 10 sq In	% Yellow	Granulation				
								Over 30	Over 42	Over 60	Over 100	Thru 100
1	66.4	50.0	16.4	31.2	2.8	40	52.5	.2	43.2	46.0	8.2	2.4
2	66.8	47.9	18.9	30.4	2.8	41	54.0	trace	42.3	45.8	9.5	2.4
3	65.2.	44.5	20.7	32.2	2.8	43	54.0	trace	41.9	46.5	9.3	2.3
4	69.2	49.6	19.6	28.1	2.7	43	55.0	trace	42.5	45.8	9.2	2.5
5	66.9	45.1	21.8	30.4	2.7	40	54.5	trace	42.4	45.6	9.1	2.9
6	67.8	46.0	21.8	29.5	2.7	41	52.0	trace	42.8	46.1	8.5	2.6

Table 31—Milling results for Hard Red Winter # 1 (18 % D.H.V.*)

Test #	% Extraction	% Farina	% Flour	% Feed	% Loss	Speck/ 10sq.In	% Yellow	Granulation				
								Over 30	Over 42	Over 60	Over 100	Thru. 100
1	68.3	38.1	30.2	28.4	3.3	42	36.0	Trace	42.8	44.7	9.9	2.6
2	66.7	36.8	29.9	28.9	4.4	42	36.0	Trace	44.2	45.4	7.9	2.5
3	68.0	37.7	30.3	28.2	3.8	45	35.5	Trace	42.1	44.3	10.8	2.8
4	69.9	37.5	32.4	27.3	2.8	37	35.0	Trace	41.2	46.8	9.4	2.6
5	70.2	37.8	32.4	28.3	1.5	45	37.0	Trace	40.5	46.7	9.7	3.1
6	68.0	37.4	30.6	29.6	2.4	35	33.0	Trace	41.9	46.9	8.7	2.5

* D.H.V stands for Dark Hard vitreous Count.

Table 32 - Milling results for Hard Red Winter # 2 (12 % D.H.V.)

Test #	% Extraction	% Farina	% Flour	% Feed	% Loss	Speck/ 10 sq.In	% Yellow	Granulation				
								Over 30	Over 42	Over 60	Over 100	Thru. 100
1	69.0	37.0	32.0	29.4	1.6	37	35.0	Trace	42.6	45.6	8.8	3.0
2	68.7	35.8	32.9	29.4	1.4	31	32.5	Trace	41.2	45.3	10.8	3.1
3	70.4	36.3	34.1	26.8	2.8	35	33.0	Trace	42.4	44.0	10.7	2.9
4	71.0	36.9	34.1	26.4	2.6	33	34.0	Trace	43.1	46.1	8.3	2.5
5	70.3	37.7	32.6	27.0	2.7	42	32.0	Trace	42.7	45.7	8.7	2.9
6	69.0	36.7	32.3	29.4	1.6	45	34.5	Trace	44.9	43.3	9.5	2.3

Table 33 - Milling results for Hard Red Winter # 3 (60 % D.H.V.)

Test #	% Extraction	% Farina	% Flour	% Feed	% Loss	Speck/ 10 sq.In	% Yellow	Granulation				
								Over 30	Over 42	Over 60	Over 100	Thru 100
1	70.3	41.7	28.6	26.0	3.7	46	36.5	Trace	44.4	45.5	8.1	2.0
2	71.2	42.2	29.0	27.8	1,0	37	37.0	Trace	42.7	44.6	9.8	2.9
3	70.3	43.2	27.1	26.5	3.2	41	32.5	Trace	44.1	45.0	8.6	2.3
4	69.8	42.2	27.6	26.4	3.8	34	34.5	Trace	41.9	44.5	10.7	2.9
5	70.0	42.6	27.4	27.4	2.6	48	37.0	Trace	43.6	45.7	8.5	2.2
6	69.0	42.1	26.9	28.0	3.0	49	35.5	Trace	41.5	45.7	9.8	3.0

Table 34 - Milling results for Hard Red Winter # 4 (64 % D.H.V.)

Test #	% Extra-ction	% Farina	% Flour	% Fedd	% Loss	Speck/ 10 sq.In.	Color	Granulation				
								Over 30	Over 42	Over 60	Over 100	Thru 100
1	71.8	44.7	27.1	25.4	2.8	37	38.5	Trace	43.7	44.5	8.9	2.9
2	70.9	43.9	27.0	25.9	3.2	43	36.0	Trace	42.0	46.0	9.6	2.4
3	70.7	43.5	27.2	26.2	3.1	42	36.0	Trace	42.5	44.3	10.4	2.8
4	70.2	43.0	27.2	26.9	2.9	40	37.0	Trace	41.4	46.2	9.6	2.8
5	69.5	43.3	26.2	26.8	3.7	38	37.0	Trace	42.3	45.4	9.7	2.6
6	70.2	44.3	25.9	26.5	3.3	43	38.0	Trace	43.6	45.8	8.6	2.0

Table 35 - Milling results for Hard Red Winter # 5 (78 % D.H.V.)

Test #	% Extraction	% Farina	% Flour	% Feed	% Loss	Speck/ 10 sq.In	% Yellow	Granulation Over 30	Over 42	Over 60	Over 100	Thru 100
1	71.3	44.7	26.6	25.4	3.3	39	38.0	Trace	43.1	44.9	9.7	2.3
2	70.4	44.8	25.6	25.6	3.7	41	36.5	Trace	42.8	45.1	9.8	2.3
3	70.1	44.9	25.2	27.5	2.7	42	37.0	Trace	42.9	44.1	10.1	2.9
4	71.9	45.0	26.9	24.2	3.9	41	37.0	Trace	43.6	44.7	8.9	2.8
5	69.3	44.1	25.2	27.5	3.2	36	36.0	Trace	42.5	46.9	8.4	2.2
6	70.7	45.8	24.9	26.4	2.9	44	35.5	Trace	42.7	45.8	8.6	2.9

Table 36 - Moisture, Protein, and Ash analyses for Farina and Semolina

Test #	H.R.Durum			Durum			H.R.W. # 1			H.R.W. # 2			H.R.W # 3			H.R.W. # 4			H.R.W. # 5		
	M.C.	Pn.	Ash	M.C.	Pn.	Ash	M.C.	Pn.	Ash	M.C.	Pn.	Ash	M.C.	Pn.	Ash	M.C.	Pn.	Ash	M.C.	Pn.	Ash
1	15.1	11.8	.77	15.3	12.3	.73	15.3	11.6	.59	16.0	11.0	.53	14.1	10.8	.50	14.1	10.7	.53	14.2	10.8	.48
2	15.1	12.0	.77	15.6	12.4	.74	15.1	11.5	.56	15.8	10.8	.54	15.3	9.8	.59	14.3	10.8	.51	14.3	10.9	.49
3	15.1	11.9	.80	15.2	12.4	.74	14.9	11.6	.60	15.2	10.8	.57	14.5	10.6	.56	14.4	10.5	.50	14.6	10.9	.49
4	14.9	12.3	.74	15.0	12.3	.75	15.9	11.7	.56	14.1	10.9	.59	15.1	9.9	.56	14.4	10.8	.49	14.0	10.9	.52
5	15.0	11.8	.80	14.6	12.1	.76	14.8	11.7	.62	15.2	10.6	.56	14.0	9.9	.58	14.7	10.6	.47	13.6	10.8	.48
6	14.8	11.8	.81	15.3	12.3	.75	16.2	11.6	.56	15.2	10.7	.59	14.2	10.0	.56	13.5	10.6	.46	14.3	10.8	.49

Protein and Ash are expressed on 14 % moisture basis.

Table 37 - Moisture Protein, and Ash analyses for flour

Test #	H.A.Durum			Durum			H.R.W. # 1			H.R.W. # 2			H.R.W. # 3			H.R.W. # 4			H.R.W. # 5		
	M.C.	Pn.	Ash	M.C	Pn.	Ash	M.C.	Pn.	Ash	M.C.	Pn.	Ash	M.C.	Pn.	Ash	M.C.	Pn.	Ash	M.C.	Pn.	Ash
1	15.1	13.8	.99	15.7	14.2	.89	15.4	12.9	.63	16.5	11.7	.58	14.8	12.6	.65	14.6	13.0	.63	14.7	13.2	.68
2	15.2	14.2	1.02	16.0	14.1	.83	14.9	12.7	.62	16.4	11.7	.58	16.2	11.3	.69	15.0	13.2	.66	14.6	13.2	.66
3	14.8	14.2	1.01	15.4	13.8	.84	15.1	12.9	.64	15.9	11.9	.60	15.2	11.4	.66	15.1	13.0	.63	14.6	13.2	.63
4	14.8	14.2	.98	15.1	14.0	.87	16.1	12.7	.59	15.5	11.8	.61	14.8	11.5	.67	14.8	13.2	.64	14.5	13.4	.66
5	15.1	13.7	.90	15.1	14.2	.99	16.1	12.8	.64	15.9	11.9	.61	15.2	11.6	.71	15.2	12.8	.59	14.3	13.9	.64
6	15.3	13.9	.99	15.2	14.0	.92	13.8	12.9	.63	15.3	11.6	.60	15.2	11.1	.70	15.2	13.1	.63	15.0	13.4	.66

Protein and Ash are expressed on 14 % moisture basis.

Table 38 - Wet Gluten Analysis on flour

Test #	Hard Amber Durum	Durum	H.R.W # 1	H.R.W # 2	H.R.W # 3	H.R.W. # 4	H.R.W. # 5
1	31.1	33.9	33.8	30.0	33.2	35.9	36.4
2	33.6	33.4	34.1	32.1	28.8	35.2	35.9
3	35.0	31.0	34.9	32.7	31.7	35.8	34.6
4	35.2	33.1	33.1	31.0	29.8	35.7	36.9
5	32.2	33.4	33.0	32.3	32.1	35.1	35.1
6	31.2	31.2	32.3	30.4	30.1	35.0	35.0

Table 39 - Test results for the cooking losses

Test #	H.A.Durum		Durum		H.R.W. # 1		H.R.W. # 2		H.R.W. # 3		H.R.W. # 4		H.R.W. # 5	
	Opt. Cook.T	Over cook.	Opt. cook.T	Over cook.	Opt. cook.T	Over cook.	Opt. cook.T	Over cook.	Opt. cook.T	Over cook.	Opt. cook.T.	Over cook.	Opt. cook.T	Over cook.
1	5.2	9.5	6.3	9.5	7.7	10.1	7.6	12.9	6.1	12.5	6.1	13.1	6.3	11.0
2	5.7	9.3	6.0	9.2	6.9	10.3	7.7	12.7	6.7	10.9	6.5	12.7	6.7	10.6
3	5.4	8.8	5.9	9.7	6.8	10.8	7.9	12.6	6.3	12.8	7.2	14.2	5.9	11.7
4	5.8	8.4	6.3	8.9	6.7	11.5	6.6	12.8	5.9	11.3	6.4	13.0	6.6	11.5

Table 40 - Test results for firmness

Test #	H.A.Durum		Durum		H.R.W.# 1		H.R.W. # 2		H.R.W. # 3		H.R.W. # 4		H.R.W. # 5	
	Opt. cook.T	Over cook.	Opt. cook.T	Over cook.	Opt. cook.T.	Over cook.	Opt. cook.T.	Over cook.	Opt. cook.T	Over cook.	Opt. cook.T	Over cook.	Opt. cook.T	Over cook.
1	194	149	186	137	186	150	175	124	170	135	183	139	208	136
2	189	149	179	140	182	150	181	122	171	121	171	140	214	140
3	192	146	191	137	188	146	188	136	170	132	182	144	209	138
4	192	147	188	141	182	150	188	139	169	127	173	145	207	142

Table 41 - Test results for the cooking weight

Test #	H.A.Durum		Durum		H.R.W. # 1		H.R.W. # 2		H.R.W. # 3		H.R.W. # 4		H.R.W. # 5	
	Opt. cook.T	Over cook.	Opt. cook.T.	Over cook.	Opt. cook.T	Over cook.	Opt. cook.T	Over cook.	Opt. cook.T	Over cook.	Opt. cook.T	Over cook.	Opt. cook.T	Over cook.
1	32.66	35.72	32.18	36.68	30.83	38.76	29.21	37.95	30.27	37.70	29.81	38.03	29.46	37.67
2	31.57	35.94	34.90	36.24	30.89	37.20	29.41	37.23	30.35	37.10	29.95	37.41	29.92	37.15
3	32.88	36.78	33.36	36.63	30.70	37.36	29.55	37.63	30,70	38.41	29.83	38.13	29.50	36.53
4	31.91	36.10	34.03	36.15	30.36	38.83	29.91	38.44	30.76	37.87	30.06	38.56	29.39	37.12

QUALITY EVALUATION OF SPAGHETTI MADE FROM TWO SUBCLASSES OF DURUM WHEAT AND FROM HARD WINTER WHEATS OF DIFFERENT DARK HARD AND VITREOUS COUNT

by

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The objective of this study was to find out the influence of the dark hard and vitreous (D.H.V.) count on the farina yield and the spaghetti quality of hard red winter wheat. Two subclasses of durum were utilized as standard of comparison.

To do so, in the first step a method was devised to evaluate the dark hard and vitreous count. After slicing the wheat kernels, we visually assessed the percentage of vitreousness for each kernel. On this basis, kernels were classified as 0 %, 25 %, 50 %, 75 %, and 100 % vitreous. 50 % vitreous was considered as an arbitrary cut off point between starchy and vitreous endosperm.

On this basis, five different samples of hard red winter wheat were selected to accomodate the former hard red winter wheat subclasses. The first two samples had a low D.H.V. count corresponding to the former subclass "Yellow Hard Winter Wheat". The following two samples had an intermediate D.H.V. count corresponding to the former subclass "Hard Winter Wheat". One of each set of samples had a low protein content. The other had a protein content as high as the durum wheat sample. The fifth sample had a high D.H.V. count corresponding to the former subclass "Dark Hard Winter Wheat", and a high protein content. Two durum wheat samples corresponding to subclasses "Hard Amber Durum Wheat" and "Durum wheat" were also selected.

The different wheats were cleaned and analyzed prior to experimentation then tempered and milled in the same manner. Six duplicates were run for each type of wheat. Protein, moisture, ash, color, speck count, and granulation were determined for semolina and farina. For the flour, protein, moisture, ash, and wet gluten tests were also performed before discarding the sample.

The six batches previously milled were them blended, and spaghetti was processed in duplicate from each semolina and farina mix. The quality of spaghetti was evaluated in terms of color, cooking weight, cooking losses, and firmness both at optimum cooking time and after overcooking.

Findings from the results indicated : (1) at comparable extractions rates, as the D.H.V. count was increased farina yield improved linearly ; with the sample having the highest D.H.V. count yielding almost as much farina as the durum subclass. Farina color also improved and flour yield decreased both linearly as the D.H.V. count was increased. Wheat grades and protein content did not seem to have any influence on farina yield. (2) Spaghetti color and cooking qualities also improved as the D.H.V. count increased. Spaghetti processed from hard red winter farina having the highest D.H.V. count had the best overall quality. However, this improvement was not quite as remarkable as the improvement observed for the milling yields ; since the best hard red winter spaghetti had a significantly lower quality than durum spaghetti. Also, there was no definite relationship between farina protein content and spaghetti quality. (3) After purification semolina and farina speck count and ash were considerably reduced. The visual appearance and the color score of the different spaghetti samples also improved. (4) Spaghetti made from white wheats were somewhat less yellow. (5) At optimum cooking time, the cooking qualities of spaghetti made from soft wheats were quite comparable to spaghetti made from hard wheats. However, they were the most susceptible to disintegration after overcooking.