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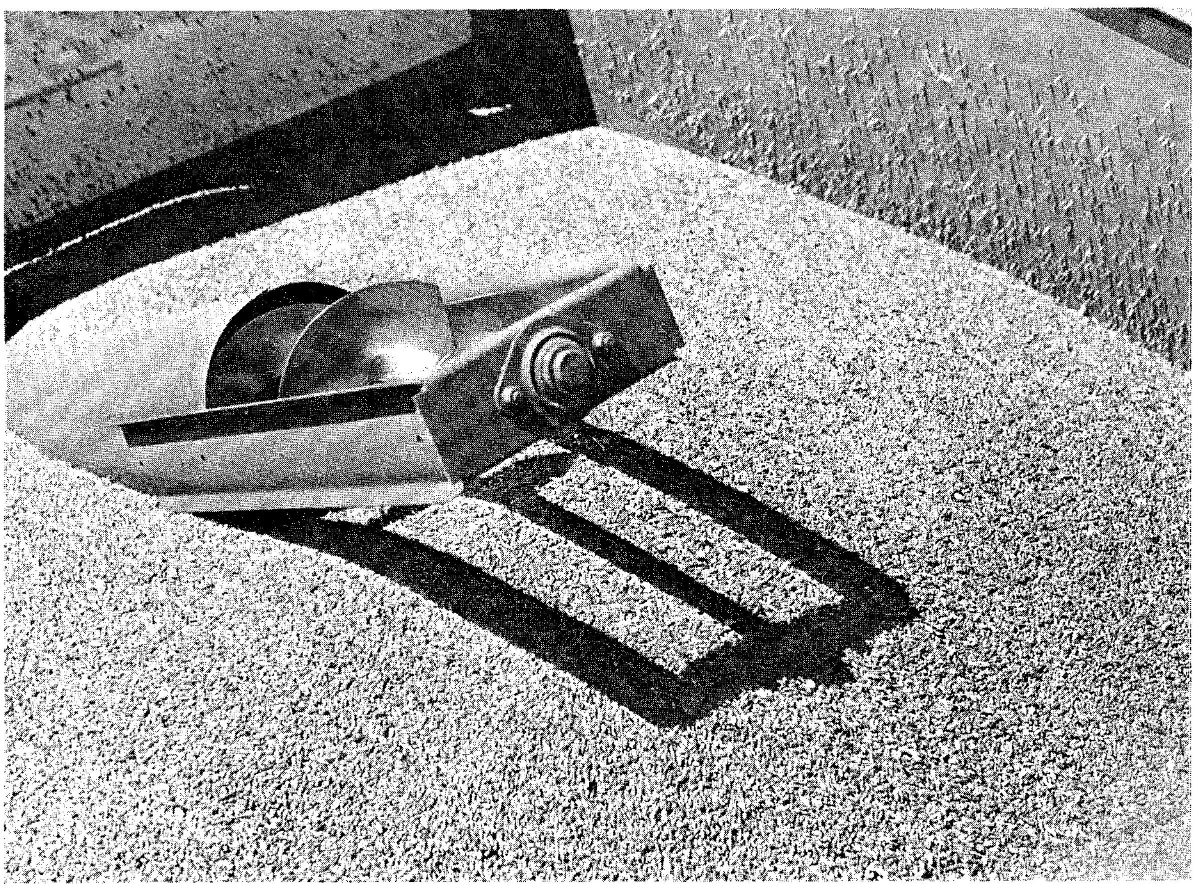
An Analysis Of The Relationships Among Specific Quality Characteristics For Hard Red Spring And Durum Wheat



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FOREWORD

The purpose of this study is to provide information dealing with the specific relationships among various quality characteristics for hard red spring and durum wheat. Grain handlers and users may use these data when actual tests of specific quality relationships are not readily available. The authors wish to extend their graditude to the many individuals who provided information for this publication, especially Mr. Orville J. Banasik and Mr. Leonard D. Sibbitt of the Department of Cereal Chemistry and Technology, North Dakota State University.

The research for this report was conducted under North Dakota Agricultural Experiment Station Project 3314, entitled "Market Development for Hard Red Spring and Durum Wheat."

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Highlights

Data on quality characteristics from the Agricultural Experiment Stations throughout North Dakota show that considerable variation occurred by variety, region, and year for those quality relationships studied, both in hard red spring and durum wheat. Although an estimate of one unknown quality factor on the basis of a known quality factor would have been of little predictive value, a general relationship existed between many of the quality factors.

Protein content and test weight were generally associated on a statewide basis and by variety and region for hard red spring and durum wheat. Only a nominal relationship existed between test weight and protein content on a yearly basis. Test weight and protein content were more highly associated in semidwarf than conventional varieties. Variation in the correlation coefficients on a yearly and regional basis indicated time and geographic location have a significant effect on the relationship between test weight and protein content.

Test weight and flour or semolina yield were nominally associated on a statewide basis. Considerable variation occurred in the association between test weight and flour or semolina yield on a regional and yearly basis. Test weight is generally associated with flour yield in the southern part of the state and is associated with semolina yield in the northern part of the state. The association between test weight and flour yield in semidwarf wheat varieties was considerably higher than that found for conventional hard red spring wheat varieties.

Test weight is generally associated with flour and semolina ash, but is more highly associated in hard red spring wheat than in durum wheat. Significant variation occurred on a varietal and regional basis between test weight and flour or semolina ash.

Loaf volume and protein content are generally related on a statewide basis and highly associated on a regional basis. Climatic conditions did not have a major effect on the association between loaf volume and protein content. A general relationship existed between protein content and loaf volume for both semidwarf and conventional hard red spring wheat varieties.

Protein content and flour or semolina yield are nominally associated on a statewide basis. Protein content and semolina yield are generally associated in all parts of the state except the southwestern and central areas. Protein content and flour yield are highly associated within regions but only generally associated on a yearly basis, thus indicating a strong environmental influence.

Kernel vitreousness and protein content are generally associated in hard red spring wheat, but little relationship exists in durum wheat on a statewide basis. Kernel vitreousness is generally associated with protein content on a regional, yearly, and varietal basis in hard red spring wheat. Generally, kernel vitreousness is not associated with protein content on a varietal, yearly, or regional basis in durum wheat.

The low coefficients found in this study may be due to the narrow range of values and the relatively small sample sizes used in this study. The variation in the correlation coefficients on a varietal, regional, and yearly basis indicates the magnitude of varietal and environmental influences on the association among quality factors. Caution must be exercised in applying rules of thumb regarding quality relations. Varietal and environmental influences must be considered for each year when applying quality relationships.

AN ANALYSIS OF THE RELATIONSHIPS AMONG SPECIFIC QUALITY CHARACTERISTICS FOR HARD RED SPRING AND DURUM WHEAT

by

John F. Mittleider and Donald E. Anderson*

Numerous new wheat varieties have been released in recent years. Millers and bakers are concerned with the dough properties and milling and baking quality of these varieties. These data may be used to estimate the association between specific quality relationships when actual tests are not readily available.

Kernel Parts

The wheat kernel consists basically of three parts--the germ, the endosperm, and the bran. Breakdown by percentage of these parts is:

1. Endosperm, 83.0 percent;
2. Bran, 14.5 percent; and
3. Germ, 2.5 percent.[1]

Endosperm is the source of white flour. The primary aim of the miller is to separate the endosperm from the other structures and to grind it into a fine powder. The endosperm contains about 75 percent of the protein found in wheat.

Bran is the protective coat of the seed. It is removed and often used for animal or poultry feed.

Germ is the embryo or sprouting section of the seed. It is usually separated in the milling process because it contains fat, which limits the keeping quality of flours.

Shorts consists of fine particles of bran, germ, and flour left after the flour is milled. Feed, also known as bran or shorts, is not pure bran and germ since bran contains some endosperm and shorts contains a considerable amount of endosperm.

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*Mittleider is Research Assistant and Anderson is Professor, Agricultural Economics.

[1]Wheat Flour Institute, From Wheat to Flour, Chicago, Illinois, 1966, p. 38.

Grading Factors

Weight per unit volume is an important factor in wheat grading. It is considered to be a rough index of the yield of flour that can be obtained from hard red spring wheat, or the semolina yield that can be obtained from durum wheat.

Differences in test weight due to inherent varietal differences are often not reflected by corresponding differences in flour yield. Frequent handling and moving of wheat may polish the bran coat and increase test weight without influencing flour yield. Evidence seems to show that test weight above 57 pounds per bushel has relatively little influence on flour milling yield.[2] At lower weights, the milling yield usually falls off rather rapidly with decreasing test weights. Immature wheat or wheat that is badly shriveled as a result of disease or drought is usually low in test weight and gives correspondingly poor flour yields.

The protein content of hard red spring wheat varies from about 11 percent to 20 percent, depending in part on the variety and class, but more largely on environmental factors during growth. Abundant rainfall during the period of kernel development usually results in a lower protein content; whereas, dry conditions during that period favor higher protein content.

The percent of protein in wheat and flour is a measure of the amount of nitrogen in the wheat kernel or flour. The procedure used to measure the protein content takes into consideration only the total quantity of protein and not the quality of protein.[3]

The amount of protein in flour is often considered as a measure of dough strength. The amount of gluten in dough is positively correlated with protein content. Thus, more gluten strands are contained in a dough made from high protein flour than are contained in a low protein flour. The quality of these strands is also important as they, too, help to determine the strength of dough.

Protein content of wheat is generally considered to be inversely related to flour yield and, hence, test weight. An inverse relationship reportedly exists between flour ash and test weight. Both crude fiber

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[2]Inglett, George E., Wheat: Production and Utilization, The AUI Publishing Company, Inc., 1974, p. 101.

[3]Swanson, C. O., Wheat and Flour Quality, Burgess Publishing Company, Minneapolis, Minnesota, 1941, p. 138.

and the ash content of wheat are thought to be related to the amount of bran in the wheat and, hence, have rough inverse relationships to flour or semolina yield.

"Ash is the residue left after heating a small amount of wheat or flour under such conditions that all organic material is destroyed and that none of the noncombustible constituents are volatilized or expelled."[4] The ash contains most of the elements which the wheat plant obtained from the soil, although the compounds of these elements are changed or destroyed.

Most of the ash contained in a wheat seed is in the bran. The percentage of ash in feed is about 13.5 times greater than that in flour. As there is a great difference in ash percentage by lot of grain, the ash determination in flour has become one of the more important measures of a grade of flour.

Vitreous kernels are reportedly associated with kernel hardness for grading purposes. Vitreousness is considered to be associated with high protein content.

Loaf volume is considered to be directly associated with protein content. Loaf volume, which is usually determined in cubic centimeters, is the size of a loaf of baked bread.

Procedures and Methods

Data on quality were obtained from North Dakota's Agricultural Experiment Stations for hard red spring and durum wheat for the years 1970 through 1975. Data were not available for Fargo in 1974, for Langdon in 1973, and for Williston in 1971 due to crop losses in those years.

A correlation procedure was utilized to estimate the linear relationship between quality variables. The correlation coefficient (p) lies between +1 and -1. If p = -1 or +1, then the variables in question have a perfectly linear relationship. A negative value implies as one variable increases, the other decreases; while a positive value indicates as one variable increases, the other also increases. If p = 0, then no relationship exists between the variables in question.

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[4] Ibid., p. 13.

The significance level of a correlation coefficient is the probability that a correlation coefficient of that magnitude or larger in absolute value will arise by chance alone if the random variables were truly independent.

Correlation coefficients were calculated on a statewide, varietal, regional, and yearly basis for the following quality characteristics:

1. Test weight,
2. Protein content,
3. Flour or semolina yield,
4. Flour or semolina ash,
5. Kernel vitreousness, and
6. Loaf volume.

Protein content will refer to that of wheat throughout this study. Correlations computed of main interest were:

1. Test weight vs. protein content,
2. Test weight vs. flour or semolina yield,
3. Test weight vs. flour or semolina ash,
4. Protein content vs. loaf volume,
5. Protein content vs. flour or semolina yield, and
6. Protein content vs. kernel vitreousness

The association between two quality characteristics was considered high if the correlation coefficient had a value of .70 or higher. A general relationship existed if the correlation coefficient had a value from .30 through .69. The association between two quality characteristics was considered nominal if the correlation coefficient had a value of less than .30.

Quality Relationships For Hard Red Spring Wheat

Statewide Quality Relationships

The analysis of quality characteristics in hard red spring wheat consisted of 765 observations (Table 1).

The correlation of -.59 between test weight and protein content indicated test weight could not be used as a reliable estimator of protein content, but a relatively high level of association existed between the two variables.

Little relationship existed between test weight and flour yield. The correlation coefficient was computed to be .21.

TABLE 1. CORRELATION COEFFICIENTS OF QUALITY FACTORS FOR HARD RED SPRING WHEAT, NORTH DAKOTA, CROP YEARS 1970 THROUGH 1975

Quality Factor	Protein Content	Flour Yield	Flour Ash	Vitreous Kernels	Loaf Volume
Test Weight	-.59[a] (.01)[b]	.21 (.01)	-.49 (.01)	.01 (.81)	-.22 (.01)
Protein Content		-.34 (.01)	.21 (.01)	.37 (.01)	.49 (.01)
Flour Yield			-.06 (.12)	-.26 (.01)	-.01 (.82)
Flour Ash				-.08 (.03)	.11 (.01)
Vitreous Kernels					.17 .01

[a]Denotes the correlation coefficient.
[b]Denotes the significance level.

SOURCE: Quality data provided by Department of Cereal Chemistry and Technology at North Dakota State University.

The correlation coefficient of -.49 indicated test weight was generally associated with flour ash.

Although protein content was not a good estimator of loaf volume, the coefficient of .49 indicated a general association existed.

Protein content was generally associated with flour yield, as indicated in the coefficient of -.34.

The correlation coefficient of .37 between protein content and kernel vitreousness indicated that, although kernel vitreousness was not a reliable estimator of protein content, a basic association existed between the two variables.

Summary

No single quality characteristics is capable of estimating the value of a second, although several quality characteristics are closely associated with each other.

Quality Relationships By Variety

Twenty-five varieties were considered in the analysis of quality characteristics on a varietal basis for hard red spring wheat (Table 2). Numerous varieties that were included in the analysis by region, year, and on a statewide basis were not included in the varietal analysis since many, such as Thatcher and Red River 68, are no longer grown.

The correlation coefficient between test weight and protein content generally indicated a high inverse relationship existed on a varietal basis, suggesting test weight and protein content were highly associated in many varieties. However, the high correlation did not exist for all varieties. For example, the correlation coefficient for Protor was -.16, indicating very little relationship between test weight and protein content.

Test weight and protein content were more highly associated in semidwarf varieties than in conventional varieties. The coefficients were -.63 and -.55 for semidwarf and conventional varieties, respectively.

Test weight was highly associated with flour yield for Norana and Prodax. Many varieties were found to have little or no relationship between test weight and flour yield. For example, Chris had a correlation coefficient of -.02 between these two variables.

The coefficient of .09 for conventional varieties indicated little relationship existed between test weight and flour yield. Semidwarf varieties were found to have a coefficient of .39 between the two variables.

Test weight appeared to be highly associated with flour ash for some varieties. Numerous coefficients were found which ranged from -.45 to -.65 indicating a general association between the two variables.

Little difference existed in the coefficients of -.50 and -.53 between test weight and flour ash for semidwarf and conventional varieties, respectively.

The correlation coefficients between protein content and flour yield varied from .01 to -.78. Norana, Protor, and WS 1812 indicated the highest association between protein content and flour yield with coefficients of -.78, -.77, and -.74, respectively. A general relationship existed between protein content and flour yield for most other varieties.

TABLE 2. CORRELATION COEFFICIENTS OF QUALTIY FACTORS FOR HARD RED SPRING WHEAT, BY VARIETY, NORTH DAKOTA, CROP YEARS 1970 THROUGH 1975

Variety	No. of Obs.	Test Weight vs. Protein Content	Test Weight vs. Flour Yield	Test Weight vs. Flour Ash	Test Weight vs. Vitreous Kernels	Test Weight vs. Loaf Volume	Protein Content vs. Flour Yield	Protein Content vs. Flour Ash	Protein Content vs. Vitreous Kernels	Protein Content vs. Loaf Volume	Flour Yield vs. Flour Ash	Flour Yield vs. Vitreous Kernels	Flour Yield vs. Loaf Volume	Flour Ash vs. Vitreous Kernels	Flour Ash vs. Loaf Volume	Vitreous Kernels vs. Loaf Volume
Bonanza	32	-.72 (.01)	.43 (.01)	-.50 (.01)	.11 (.54)	-.37 (.04)	-.45 (.01)	.26 (.14)	.34 (.05)	.52 (.01)	-.15 (.57)	-.34 (.05)	-.24 (.18)	-.14 (.54)	.15 (.57)	.29 (.11)
Bounty 208	36	-.43 (.01)	.43 (.01)	-.45 (.01)	.15 (.61)	.00 (1.00)	-.53 (.01)	.07 (.69)	.54 (.01)	.54 (.01)	.01 (.93)	-.32 (.06)	.02 (.91)	-.10 (.58)	.02 (.92)	.36 (.03)
Bounty 309	8	.46 (.25)	.21 (.63)	-.78 (.02)	.45 (.26)	.17 (.69)	-.04 (.92)	-.16 (.70)	.26 (.54)	.54 (.17)	-.39 (.34)	.45 (.26)	-.44 (.28)	-.25 (.56)	.04 (.92)	.03 (.95)
Chris	29	-.69 (.01)	-.02 (.88)	-.53 (.01)	.08 (.63)	-.09 (.58)	.01 (.95)	.34 (.03)	.40 (.10)	.37 (.02)	-.12 (.54)	-.09 (.53)	.14 (.60)	-.13 (.56)	.15 (.63)	.15 (.63)
Ellar	39	-.66 (.01)	-.06 (.71)	-.53 (.01)	-.28 (.09)	-.30 (.06)	-.20 (.23)	.21 (.20)	.43 (.01)	.46 (.01)	.01 (.95)	-.15 (.64)	.33 (.04)	-.11 (.51)	.11 (.51)	.10 (.55)
Era	39	-.68 (.01)	.33 (.04)	-.48 (.01)	-.05 (.76)	-.54 (.01)	-.26 (.10)	-.33 (.04)	.26 (.11)	.60 (.01)	-.08 (.62)	-.12 (.54)	.05 (.75)	-.23 (.16)	.34 (.03)	.26 (.08)
Fortuna	17	-.60 (.01)	.43 (.08)	-.63 (.01)	-.09 (.72)	-.10 (.71)	-.39 (.12)	.19 (.53)	.37 (.14)	.54 (.03)	-.33 (.19)	.23 (.63)	-.32 (.21)	-.09 (.73)	.06 (.82)	.40 (.10)
Glenlea	20	-.82 (.01)	.42 (.07)	-.54 (.01)	-.14 (.55)	-.48 (.03)	-.32 (.16)	.27 (.24)	.20 (.59)	.67 (.01)	-.53 (.01)	-.09 (.72)	.07 (.76)	-.02 (.93)	-.02 (.93)	-.27 (.25)
Justin	37	-.60 (.01)	.03 (.86)	-.48 (.01)	.06 (.73)	-.14 (.58)	-.03 (.88)	.20 (.24)	.27 (.10)	.47 (.01)	-.05 (.78)	-.02 (.91)	-.06 (.73)	-.31 (.06)	.14 (.58)	.08 (.65)
Kitt	19	-.77 (.01)	.39 (.10)	-.42 (.07)	-.31 (.20)	-.13 (.59)	-.20 (.57)	.57 (.01)	.51 (.02)	.41 (.08)	-.02 (.92)	-.12 (.62)	-.48 (.04)	.27 (.26)	.05 (.80)	.26 (.28)
Lark	31	-.73 (.01)	.66 (.01)	-.56 (.01)	.19 (.30)	-.34 (.05)	-.53 (.01)	.33 (.07)	.20 (.27)	.63 (.01)	-.34 (.06)	-.12 (.53)	-.09 (.62)	.07 (.71)	.18 (.32)	.21 (.25)
Manitou	37	-.72 (.01)	.06 (.74)	-.49 (.01)	.05 (.79)	-.28 (.08)	-.17 (.30)	.25 (.13)	.24 (.15)	.46 (.01)	-.23 (.17)	-.22 (.18)	.19 (.25)	.04 (.80)	.05 (.75)	.06 (.72)
Napayo	12	-.87 (.01)	.24 (.55)	-.43 (.16)	-.21 (.52)	-.26 (.59)	-.42 (.18)	.14 (.66)	.57 (.05)	.21 (.52)	.14 (.67)	-.62 (.03)	.42 (.17)	-.01 (.98)	.33 (.29)	-.20 (.54)
Norana	8	-.66 (.07)	.83 (.01)	-.82 (.01)	.05 (.89)	.31 (.54)	-.78 (.02)	.43 (.29)	-.05 (.89)	-.36 (.62)	-.73 (.04)	.14 (.74)	.65 (.08)	.15 (.72)	-.34 (.59)	.31 (.53)
Nordak	19	-.75 (.01)	.46 (.05)	-.57 (.01)	-.12 (.64)	.25 (.30)	-.54 (.01)	.26 (.29)	.52 (.02)	.23 (.65)	-.05 (.84)	-.51 (.02)	.12 (.63)	-.21 (.60)	-.12 (.62)	.27 (.27)
Nowesta	19	-.58 (.01)	.27 (.27)	-.54 (.02)	-.21 (.61)	-.09 (.70)	-.61 (.01)	.29 (.23)	.60 (.01)	.47 (.04)	-.39 (.10)	-.38 (.11)	-.14 (.57)	.16 (.52)	-.06 (.81)	.15 (.56)
Olaf	37	-.66 (.01)	.15 (.62)	-.64 (.01)	-.19 (.26)	-.59 (.01)	-.29 (.07)	.32 (.05)	.60 (.01)	.69 (.01)	-.18 (.29)	-.18 (.27)	.06 (.71)	-.01 (.93)	.41 (.01)	.34 (.04)
Prodox	13	-.56 (.05)	.80 (.01)	-.42 (.16)	.19 (.53)	-.60 (.03)	-.45 (.12)	.05 (.86)	.34 (.26)	.91 (.01)	-.29 (.34)	.35 (.24)	-.60 (.03)	-.46 (.11)	.14 (.66)	.23 (.55)
Profit 75	7	-.68 (.09)	.53 (.22)	-.17 (.72)	.71 (.07)	-.43 (.34)	-.06 (.89)	.52 (.23)	-.50 (.25)	-.03 (.95)	-.39 (.61)	.02 (.97)	-.58 (.17)	.09 (.84)	.14 (.75)	-.54 (.21)
Protor	13	-.16 (.61)	.42 (.15)	-.26 (.60)	-.08 (.79)	.05 (.86)	-.77 (.01)	.49 (.08)	.65 (.02)	.09 (.76)	-.12 (.69)	-.64 (.02)	.17 (.60)	.06 (.85)	.42 (.15)	-.28 (.65)
Tioga	26	-.77 (.01)	.42 (.03)	-.38 (.05)	-.36 (.07)	-.39 (.04)	-.45 (.02)	-.02 (.93)	.64 (.01)	-.09 (.66)	.01 (.99)	-.51 (.01)	.05 (.80)	-.32 (.11)	.05 (.80)	.30 (.13)
Waldron	39	.62 (.01)	.18 (.27)	-.55 (.01)	.01 (.96)	-.20 (.23)	-.36 (.02)	.31 (.05)	.27 (.09)	.55 (.01)	-.11 (.52)	-.16 (.66)	-.05 (.77)	-.21 (.20)	.12 (.54)	.05 (.76)
Wared	13	-.58 (.04)	.63 (.02)	-.41 (.15)	.05 (.87)	-.47 (.11)	-.44 (.13)	.11 (.72)	.14 (.66)	.80 (.01)	-.06 (.84)	.02 (.93)	-.32 (.28)	-.15 (.63)	.04 (.89)	.09 (.77)
WS 1809	35	-.56 (.01)	.26 (.12)	-.60 (.01)	.23 (.17)	-.07 (.71)	-.53 (.01)	.42 (.01)	.43 (.01)	.42 (.01)	-.23 (.18)	-.21 (.22)	-.42 (.01)	-.06 (.73)	-.01 (.95)	.16 (.65)
WS 1812	15	-.67 (.01)	.55 (.03)	-.75 (.01)	-.17 (.55)	-.40 (.14)	-.74 (.01)	.23 (.59)	.59 (.02)	.55 (.03)	-.10 (.73)	-.55 (.03)	-.40 (.14)	-.02 (.97)	.15 (.59)	.33 (.23)
Semidwarf		-.63 (.01)	.39 (.01)	-.50 (.01)	.03 (.60)	-.33 (.01)	-.43 (.01)	.26 (.01)	.34 (.01)	.55 (.01)	-.04 (.51)	-.21 (.01)	-.11 (.05)	-.05 (.59)	.15 (.01)	.21 (.01)
Conventional		-.55 (.01)	.09 (.09)	-.53 (.01)	-.02 (.67	-.16 (.01)	-.28 (.01)	.17 (.01)	.40 (.01)	.49 (.01)	-.08 (.11)	.25 (.01)	.08 (.13)	-.11 (.03)	.07 (.18)	.10 (.06)

[a]Denotes the correlation coefficient.
[b]Denotes the significance level.

SOURCE: Quality data provided by Department of Cereal Chemistry and Technology at North Dakota State University.

Semidwarf varieties indicated higher correlation coefficients between protein content and flour yield than did conventional varieties with coefficients of -.43 and -.28, respectively.

Protein content was often not highly associated with loaf volume, although a positive relationship normally existed. The majority of the coefficients ranged from .40 to .70. The coefficient of .91 for Prodax was the highest obtained.

Little difference existed in the coefficients of .55 and .49 for semidwarf and conventional varieties, respectively.

The correlation coefficients between protein content and kernel vitreousness ranged from .65 for Protor to -.50 for Profit 75. Protein content and kernel vitreousness were nominally associated in many varieties and generally related in all others.

The relationship between protein content and kernel vitreousness was nearly the same for semidwarf and conventional varieties with coefficients of .34 and .40, respectively.

<u>Summary</u>

Generally, test weight was highly associated with protein content on a varietal basis. Test weight was generally not highly associated with flour yield. Test weight appeared to be highly associated with flour ash. Flour yield and loaf volume were not highly associated with protein content. Kernel vitreousness was generally associated with protein content. Variety has an important influence on the relationships between quality factors.

Test weight and protein content were more highly associated in semidwarf varieties than in conventional varieties. Flour yield and test weight were nominally related in semidwarf varieties, but little relationship existed in conventional varieties. Test weight and flour ash were generally related in both semidwarf and conventional varieties. Protein content was more highly associated with loaf volume and flour yield in semidwarf varieties than conventional varieties but was not as highly associated with kernel vitreousness.

Quality Relationships By Region

The correlation coefficients between test weight and protein content ranged from -.75 for the Carrington (Dryland) Station to -.26 for the Minot

Station (Table 3). A general association between protein content and test weight existed for all other stations.

Test weight was not a highly accurate or reliable index of flour yield at any station. Correlation coefficients of .01, -.01, and .09 indicated virtually no relationship existed between test weight and flour yield at the Langdon, Minot, and Williston stations, respectively.

Test weight and flour ash were highly inversely related at the Carrington (Dryland) and Williston stations with coefficients of -.73 and -.79, respectively. The coefficients at all other stations indicated test weight was generally associated with flour ash. The Minot data indicated a comparatively weak relationship between these two quality factors with a coefficient of -.31.

Protein content was generally associated with flour yield at all stations except the Minot and Williston stations. The coefficient of -.04 indicated a very low relationship existed between protein content and flour yield at the Williston Station.

Kernel vitreousness was generally associated with protein content at all stations except the Carrington (Dryland and Irrigated) stations, where the coefficients of .14 and -.01, respectively, were obtained.

Protein content and loaf volume were generally related at all stations.

<u>Summary</u>

Protein content and test weight were highly associated at the Carrington (Dryland) Station. Virtually no relationship existed by station between test weight and flour yield at the Langdon, Minot, and Williston stations. Flour ash and test weight were highly associated at the Carrington (Dryland) and Williston stations. Protein content is usually highly associated with flour yield and loaf volume. Protein content is generally associated with kernel vitreousness. Geographic location tends to have a distinct bearing on the quality relationships.

Quality Relationships By Year

Protein content was highly associated with test weight for the 1973 crop year with a coefficient of -.85 (Table 4). Virtually no relationship was found between the two variables for the 1972 and 1975 crop.

TABLE 3. CORRELATION COEFFICIENTS OF QUALITY FACTORS FOR HARD RED SPRING WHEAT, BY REGION, NORTH DAKOTA, CROP YEARS 1970 THROUGH 1975

Region	No. of Obs.	Test Weight vs. Protein Content	Test Weight vs. Flour Yield	Test Weight vs. Flour Ash	Test Weight vs. Vitreous Kernels	Test Weight vs. Loaf Volume	Protein Content vs. Flour Yield	Protein Content vs. Flour Ash	Protein Content vs. Vitreous Kernels	Protein Content vs. Loaf Volume	Flour Yield vs. Flour Ash	Flour Yield vs. Vitreous Kernels	Flour Yield vs. Loaf Volume	Flour Ash vs. Vitreous Kernels	Flour Ash vs. Loaf Volume	Vitreous Kernels vs. Loaf Volume
Carrington Dryland	119	-.75[a] (.01)[b]	.34 (.01)	-.73 (.01)	.03 (.77)	-.11 (.22)	-.36 (.01)	.66 (.01)	.14 (.14)	.42 (.01)	-.36 (.01)	-.26 (.01)	-.07 (.55)	.12 (.21)	.11 (.22)	.13 (.16)
Carrington Irrigated	118	-.49 (.01)	.23 (.01)	-.43 (.01)	.50 (.01)	-.20 (.03)	-.41 (.01)	.05 (.59)	-.01 (.95)	.58 (.01)	.16 (.07)	-.09 (.32)	-.05 (.59)	-.12 (.20)	.23 (.01)	.04 (.65)
Dickinson	115	-.31 (.01)	.36 (.01)	-.53 (.01)	-.01 (.91)	-.12 (.18)	-.39 (.01)	.10 (.29)	.48 (.01)	.68 (.01)	-.20 (.03)	.07 (.54)	-.13 (.17)	-.31 (.01)	-.04 (.70)	.35 (.01)
Fargo	92	-.45 (.01)	.30 (.01)	-.67 (.01)	-.14 (.19)	-.42 (.01)	-.48 (.01)	.39 (.01)	.54 (.01)	.49 (.01)	-.19 (.06)	-.52 (.01)	-.02 (.82)	.06 (.56)	.37 (.01)	.03 (.57)
Langdon	98	-.31 (.01)	.01 (.88)	-.36 (.01)	-.15 (.12)	-.12 (.24)	-.44 (.01)	.25 (.01)	.39 (.01)	.33 (.01)	-.09 (.60)	-.42 (.01)	-.14 (.17)	.26 (.01)	.32 (.01)	.10 (.65)
Minot	122	-.26 (.01)	-.01 (.93)	-.31 (.01)	.16 (.07)	.10 (.25)	-.20 (.03)	-.45 (.01)	.44 (.01)	.46 (.01)	.09 (.66)	-.11 (.23)	.17 (.06)	-.28 (.01)	-.36 (.01)	.38 (.01)
Williston	101	-.65 (.01)	.09 (.64)	-.79 (.01)	-.41 (.01)	-.43 (.01)	-.04 (.69)	.59 (.01)	.56 (.01)	.57 (.01)	.08 (.57)	.01 (.88)	.03 (.79)	.52 (.01)	.44 (.01)	.35 (.01)

[a]Denotes the correlation coefficient.
[b]Denotes the significance level.

SOURCE: Quality data provided by Department of Cereal Chemistry and Technology at North Dakota State University.

TABLE 4. CORRELATION COEFFICIENTS OF QUALITY FACTORS FOR HARD RED SPRING WHEAT, BY YEAR, NORTH DAKOTA, CROP YEARS 1970 THROUGH 1975

Year	No. of Obs.	Test Weight vs. Protein Content	Test Weight vs. Flour Yield	Test Weight vs. Flour Ash	Test Weight vs. Vitreous Kernels	Test Weight vs. Loaf Volume	Protein Content vs. Flour Yield	Protein Content vs. Flour Ash	Protein Content vs. Vitreous Kernels	Protein Content vs. Loaf Volume	Flour Yield vs. Flour Ash	Flour Yield vs. Vitreous Kernels	Flour Yield vs. Loaf Volume	Flour Ash vs. Vitreous Kernels	Flour Ash vs. Loaf Volume	Vitreous Kernels vs. Loaf Volume
1970	140	-.34[a] (.01)[b]	.18 (.02)	-.35 (.01)	-.08 (.68)	-.38 (.01)	-.33 (.01)	.08 (.67)	.14 (.11)	.62 (.01)	-.02 (.84)	-.09 (.27)	-.07 (.61)	-.14 (.09)	.06 (.55)	.06 (.53)
1971	130	-.57 (.01)	.28 (.01)	-.55 (.01)	.18 (.04)	-.33 (.01)	-.34 (.01)	.38 (.01)	-.01 (.90)	.49 (.01)	-.16 (.07)	-.42 (.01)	.23 (.01)	-.10 (.24)	.17 (.04)	-.26 (.10)
1972	121	-.19 (.04)	.08 (.58)	-.64 (.01)	-.09 (.65)	-.14 (.11)	-.20 (.02)	-.05 (.60)	.57 (.01)	.43 (.01)	.28 (.01)	-.40 (.01)	.39 (.01)	-.25 (.01)	.17 (.06)	.16 (.08)
1973	120	-.85 (.01)	.30 (.01)	-.56 (.01)	-.16 (.08)	-.02 (.83)	-.31 (.01)	.34 (.01)	.42 (.01)	.30 (.01)	-.02 (.79)	-.11 (.21)	.09 (.67)	-.10 (.26)	.07 (.54)	.37 (.01)
1974	123	-.44 (.01)	.48 (.01)	-.66 (.01)	.30 (.01)	.30 (.01)	-.61 (.01)	.39 (.01)	.43 (.01)	.60 (.01)	-.29 (.01)	-.15 (.10)	-.37 (.01)	-.11 .23	.18 .05	.27 .01
1975	131	-.14 (.11)	.37 (.01)	-.37 (.01)	-.04 (.63)	.02 (.82)	-.05 (.01)	.27 (.01)	.30 (.01)	.42 (.01)	-.35 (.01)	-.17 (.06)	-.18 (.03)	.07 (.54)	.18 (.04)	.11 (.20)

[a] Denotes the correlation coefficient.
[b] Denotes the significance level.

SOURCE: Quality data provided by Department of Cereal Chemistry and Technology at North Dakota State University.

A general association existed between test weight and flour yield for all years, except the 1970 and 1972 crop years. The correlation coefficients for these years were .18 and .08, respectively.

A general association existed between flour ash and test weight for all years.

Protein content was generally associated with flour yield except for the 1972 and 1975 crop years. Little or no relationship existed between the variables for these years. The highest coefficient found was -.61 for the year 1974.

Virtually no relationship was found between protein content and kernel vitreousness for the years 1970 and 1971. Protein content and kernel vitreousness were generally associated for all other years.

Loaf volume was generally related to protein content for all years.

<u>Summary</u>

Test weight was highly associated with protein content for the 1973 crop year. Test weight was generally associated with flour yield for most years. Flour ash and test weight were generally associated for all years. Protein content was generally associated with flour yield, kernel vitreousness, and loaf volume for most years.

<u>Quality Relationships For Durum Wheat</u>

Statewide Quality Relationships

The analysis of quality relationships in durum wheat consisted of 221 observations.

The correlation coefficient of -.25 between test weight and protein content indicated a nominal association existed between the two variables (Table 5).

Semolina yield was found to be generally associated with test weight, as indicated by the correlation coefficient of .32.

The correlation coefficient of -.29 between semolina ash and test weight indicated a nominal relationship existed between the two variables.

Protein content and semolina yield were found to have a correlation coefficient of -.31, indicating a general relationship between the two variables.

The coefficient between protein content and kernel vitreousness was .18, suggesting a nominal relationship between the two variables.

TABLE 5. CORRELATION COEFFICIENTS OF QUALITY FACTORS FOR DURUM WHEAT, NORTH DAKOTA, CROP YEARS 1970 THROUGH 1975

Quality Factor	Protein Content	Semolina Yield	Semolina Ash	Vitreous Kernels
Test Weight	-.25[a] (.01)[b]	.32 (.01)	-.29 (.01)	.01 (.91)
Protein Content		-.31 (.01)	.07 (.30)	.18 (.01)
Semolina Yield			.28 (.01)	.03 (.62)
Semolina Ash				-.07 (.68)

[a]Denotes the correlation coefficient.
[b]Denotes the significance level.

SOURCE: Quality data provided by Department of Cereal Chemistry and Technology at North Dakota State University.

Summary

Test weight was nominally associated with semolina ash and protein content and generally associated with semolina yield. Protein content was generally associated with semolina yield. Kernel vitreousness and protein content were nominally associated.

Quality Relationships By Variety

Twelve durum varieties entered into the analysis of quality factors by variety (Table 6).

The correlation coefficient between test weight and protein content varied from -.88 for Wascana to -.19 for Ward. A high association frequently existed between the variables on a varietal basis.

The correlation coefficients between test weight and semolina yield varied from -.08 for Ward to .84. Test weight and semolina yield were highly associated in varieties, such as Crosby, Mindum, and Wascana, and were generally associated in all other varieties, except Ward. Virtually no relationship existed between the two variables for Ward.

TABLE 6. CORRELATION COEFFICIENTS OF QUALITY FACTORS FOR DURUM, BY VARIETY, NORTH DAKOTA, CROP YEARS 1970 THROUGH 1975

Variety	No. of Obs.	Test Weight vs. Protein Content	Test Weight vs. Semolina Yield	Test Weight vs. Semolina Ash	Test Weight vs. Vitreous Kernels	Protein Content vs. Semolina Yield	Protein Content vs. Semolina Ash	Protein Content vs. Vitreous Kernels	Semolina Yield vs. Semolina Ash	Semolina Yield vs. Vitreous Kernels	Semolina Ash vs. Vitreous Kernels
Botno	11	-.81[a] (.01)[b]	.45 (.16)	-.64 (.03)	.09 (.80)	-.60 (.05)	.48 (.13)	.02 (.95)	.01 (.98)	.09 (.80)	.42 (.19)
Crosby	11	-.77 (.01)	.84 (.01)	-.70 (.02)	.24 (.52)	-.72 (.01)	.25 (.53)	-.16 (.64)	-.41 (.21)	.30 (.63)	.06 (.85)
Hercules	20	-.24 (.30)	.33 (.15)	-.31 (.18)	.31 (.18)	-.48 (.03)	.15 (.53)	.11 (.64)	.42 (.06)	.10 (.56)	-.11 (.65)
Leeds	32	-.56 (.01)	.55 (.01)	-.35 (.05)	.34 (.06)	-.53 (.02)	.03 (.87)	.09 (.64)	.23 (.19)	-.04 (.81)	-.01 (.98)
Macoun	11	-.76 (.01)	.62 (.04)	-.53 (.09)	.13 (.70)	-.80 (.01)	.15 (.66)	-.23 (.50)	-.04 (.89)	.37 (.27)	.32 (.34)
Mindum	5	-.52 (.37)	.80 (.10)	-.15 (.80)	-.51 (.38)	-.29 (.64)	-.67 (.22)	.33 (.59)	.02 (.97)	.05 (.94)	.38 (.53)
Rollette	32	-.57 (.01)	.38 (.03)	-.41 (.02)	.02 (.93)	-.31 (.08)	.02 (.91)	.45 (.01)	.47 (.01)	.10 (.60)	-.06 (.75)
Rugby	11	-.80 (.01)	.45 (.17)	-.51 (.11)	.03 (.94)	-.65 (.03)	.40 (.22)	-.05 (.88)	-.04 (.91)	.15 (.66)	.24 (.52)
Wakooma	17	-.58 (.01)	.55 (.02)	-.47 (.05)	.05 (.84)	-.73 (.01)	-.10 (.71)	.06 (.81)	.01 (.98)	-.12 (.95)	.14 (.61)
Ward	29	-.19 (.67)	-.08 (.67)	-.37 (.05)	-.05 (.80)	-.42 (.02)	-.07 (.73)	-.55 (.01)	.25 (.20)	.12 (.55)	-.18 (.65)
Wascana	7	-.88 (.01)	.75 (.05)	-.30 (.51)	.13 (.77)	-.73 (.06)	.13 (.78)	.18 (.70)	.01 (.99)	-.04 (.93)	.01 (.98)
Wells	33	-.62 (.01)	.47 (.01)	-.30 (.09)	.04 (.83)	-.37 (.03)	.01 (.94)	.40 (.02)	.39 (.02)	.08 (.65)	-.25 (.15)

[a]Denotes the correlation coefficient.
[b]Denotes the significance level.

SOURCE: Quality data provided by the Department of Cereal Chemistry and Technology at North Dakota State University.

The correlation coefficients between test weight and semolina ash ranged from -.70 for Crosby to -.15 for Mindum. Test weight and semolina ash were highly associated in Crosby and were generally related in most other varieties.

Crosby, Macoun, Wakoma, and Wascana indicated a high association between protein content and semolina yield. A significant relationship did not exist between the two variables in Mindum.

The coefficients between protein content and kernel vitreousness ranged from -.55 for Ward to .45 for Rollette. The two variables were generally related in Rollette, Ward, and Wells, while virtually no relationship existed for all other varieties.

Summary

Protein content and test weight were generally highly associated. Test weight and semolina yield were highly associated in Crosby, Mindum, and Wascana, and were generally related in all other varieties, except Ward. Test weight and semolina ash were highly associated in Crosby and generally related in most other varieties. Protein content was highly associated with semolina yield in numerous varieties. Kernel vitreousness was generally not associated with protein content. The variation in the coefficients from one variety to another indicated variety has an important influence on the relationships between the quality factors.

Quality Relationships By Region

A high inverse relationship existed between test weight and protein content for the Williston Station with a coefficient of -.79 (Table 7). The two variables were generally associated for the Carrington and Fargo stations while virtually no association existed for the Dickinson, Langdon, and Minot stations.

Test weight and semolina yield were highly related for the Williston Station, were generally related for the Carrington and Langdon stations. and were unrelated for the remaining stations.

Test weight and semolina ash were generally related for the Carrington, Dickinson, and Fargo stations, but were unrelated for the remaining stations.

Protein content was highly associated with semolina yield for the Williston Station. The two variables were generally associated for the Carrington and Dickinson stations.

TABLE 7. CORRELATION COEFFICIENTS OF QUALITY FACTORS FOR DURUM, BY REGION, NORTH DAKOTA, CROP YEARS 1970 THROUGH 1975

Region	No. of Obs.	Test Weight vs. Protein Content	Test Weight vs. Semolina Yield	Test Weight vs. Semolina Ash	Test Weight vs. Vitreous Kernels	Protein Content vs. Semolina Yield	Protein Content vs. Semolina Ash	Protein Content vs. Vitreous Kernels	Semolina Yield vs. Semolina Ash	Semolina Yield vs. Vitreous Kernels	Semonina Ash vs. Vitreous Kernels
Carrington	39	-.50[a] (.01)[b]	.55 (.01)	.30 (.06)	.26 (.10)	-.36 (.02)	-.22 (.17)	-.24 (.14)	.61 (.01)	.42 (.01)	.64 (.01)
Dickinson	37	-.05 (.77)	.15 (.61)	-.65 (.01)	.22 (.19)	-.32 (.05)	.19 (.27)	-.10 (.56)	-.22 (.19)	-.20 (.24)	-.37 (.02)
Fargo	30	-.61 (.01)	.14 (.53)	-.55 (.01)	-.17 (.64)	-.04 (.83)	.65 (.01)	.67 (.01)	.26 (.17)	.24 (.20)	.54 (.01)
Langdon	36	-.25 (.15)	.50 (.01)	.23 (.87)	.53 (.01)	.16 (.64)	.48 (.01)	-.22 (.20)	.61 (.01)	.33 (.05)	-.05 (.76)
Minot	45	-.07 (.64)	-.13 (.59)	-.18 (.23)	-.09 (.54)	-.24 (.11)	-.31 (.04)	.30 (.04)	.80 (.01)	-.12 (.35)	-.13 (.60)
Williston	34	-.79 (.01)	.76 (.01)	-.12 (.50)	.49 (.01)	-.71 (.01)	.35 (.04)	-.44 (.01)	-.08 (.65)	.40 (.02)	.02 (.89)

[a]Denotes the correlation coefficient.
[b]Denotes the significance level.

SOURCE: Quality data provided by the Department of Cereal Chemistry and Technology at North Dakota State University.

Kernel vitreousness was generally associated with protein content for the Fargo, Minot, and Williston stations, but was unrelated at all other stations.

Summary

Protein content and test weight were associated for the Carrington, Fargo, and Williston stations. Test weight was associated with semolina yield for the Carrington, Langdon, and Williston stations. Test weight was generally associated with semolina ash for the Carrington, Dickinson, and Fargo stations. Semolina yield and protein content were associated for the Carrington, Dickinson, and Williston stations. Kernel vitreousness was generally associated with protein content for the Fargo, Minot, and Williston stations.

Quality Relationships By Year

The value of the correlation coefficients between test weight and protein content varied considerably from year to year (Table 8). The two variables were only associated for the years 1971 and 1974.

The correlation coefficients of .69 and .51 for the years 1971 and 1973, respectively, indicate test weight and semolina yield were generally associated. The two variables were highly associated for the year 1974.

Virtually no relationship existed between test weight and semolina ash for the year 1970, but a general or high association existed for all other years.

Semolina yield was highly associated with protein content for the year 1974 and was generally associated for the years 1971 and 1973.

Protein content was generally associated with kernel vitreousness for the years 1972 and 1973. Virtually no relationship existed between the two variables for all other years.

Summary

Protein content and semolina yield were highly associated with test weight for the year 1974. Test weight was associated with semolina ash in all years, except 1970. Kernel vitreousness was associated with protein content for the years 1972 and 1973. Semolina yield was associated with protein content for the years 1971 through 1974. A significant variation occurred in the relationships between the quality factors from year to year.

TABLE 8. CORRELATION COEFFICIENTS OF QUALITY FACTORS FOR DURUM, BY YEAR, NORTH DAKOTA, CROP YEARS 1970 THROUGH 1975

Year	No. of Obs.	Test Weight vs. Protein Content	Test Weight vs. Semolina Yield	Test Weight vs. Semolina Ash	Test Weight vs. Vitreous Kernels	Protein Content vs. Semolina Yield	Protein Content vs. Semolina Ash	Protein Content vs. Vitreous Kernels	Semolina Yield vs. Semolina Ash	Semolina Yield vs. Vitreous Kernels	Semolina Ash vs. Vitreous Kernels
1970	31	-.06[a] (.76)[b]	.24 (.19)	-.07 (.69)	.13 (.52)	-.26 (.16)	-.26 (.15)	-.06 (.76)	-.05 (.78)	.49 (.01)	-.44 (.01)
1971	26	-.53 (.01)	.69 (.01)	-.68 (.01)	-.08 (.71)	-.50 (.01)	.39 (.04)	.14 (.51)	-.22 (.29)	.25 (.22)	.21 (.30)
1972	34	-.19 (.28)	-.28 (.10)	-.85 (.01)	.19 (.29)	-.29 (.10)	.37 (.03)	.58 (.01)	.15 (.60)	-.47 (.01)	-.06 (.74)
1973	29	-.24 (.21)	.51 (.01)	-.31 (.10)	.23 (.24)	-.41 (.02)	-.42 (.02)	.65 (.01)	-.09 (.66)	.12 (.55)	-.73 (.01)
1974	47	-.82 (.01)	.78 (.01)	-.64 (.01)	-.07 (.62)	-.74 (.01)	.62 (.01)	.14 (.65)	-.41 (.01)	.02 (.87)	.56 (.01)
1975	54	-.10 (.52)	-.12 (.61)	-.45 (.01)	.29 (.03)	-.15 (.27)	.13 (.65)	.16 (.25)	.01 (.97)	.18 (.20)	-.34 (.01)

[a] Denotes the correlation coefficient.
[b] Denotes the significance level.

SOURCE: Quality data provided by the Department of Cereal Chemistry and Technology at North Dakota State University.

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