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Consistency of Quality Characteristics in Hard Red Spring Wheats

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Results reported in this study is part of a major project conducted on the topic of demand and competition in the international hard wheat market. Other papers completed include AE Report No. 348. *Grades/Classes of Hard Wheats Exported from North America: Analysis of Demand and Trends*, and AE Report No. 374. *Factors Affecting the Supply of Quality Characteristics in Spring Wheats: Comparisons Between the United States and Canada*. These are available from the authors upon request.

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ABSTRACT

Greater sophistication of buyers in the wheat market has increased demands for higher quality wheats and focused attention on the consistency of the quality of wheat purchased. In this study, the variability of wheat quality characteristics was examined at different stages of the marketing chain. Variability was measured by variety and at farm and export levels. Comparisons were made with Canada where similar data were available. Different measures of variability were utilized where data were available.

Inter-year variability, intra-year variability, and within-lot variability of wheat quality characteristics were measured at different points in the wheat marketing chain in the United States and Canada. Variability of many characteristics was similar between Canada and the United States for changes in annual average levels between years and for within year variability. In both Canada and the United States, higher grades exhibited lower variability than lower grades. In addition, the within-year variability of protein and dockage declined from farm level to export levels for the United States. The variability of average levels for grade and protein segregations between sampling periods in Canada was similar at both the farm production and export levels.

Key Words: Quality, Consistency, Quality Variability, Wheat Export Quality, Farm Production Quality, Wheat Variety Quality, Canada, United States

HIGHLIGHTS

Greater sophistication of buyers in the wheat market has increased demands for higher quality wheats. Increased demands have in turn focused attention on the consistency of the quality of wheat purchased. Several studies have indicated that many importers perceive U.S. wheat as having less consistent quality than either Australian or Canadian wheat. Variability of quality can be affected by many factors (environment, marketing systems, grading systems, etc.) and can be measured in a number of different ways (within shipments, between shipments, across years, etc.). In this study, the variability of wheat quality characteristics was examined at different stages of the marketing chain. Variability was measured for different varieties, and at farm and export levels. Comparisons were made with Canada where similar data were available. Different measures of variability were utilized where possible.

Significant findings are highlighted below:

U.S. Findings

1) The level of variability of selected quality characteristics was similar across varieties. However, the effects of location, variety, and year had different impacts on the levels of quality characteristics. Wet gluten and MTI were most affected by location and variety, whereas, variability in loaf volumes was most affected by annual (yearly) events. Wheat characteristics were affected most by year-to-year variability followed by the variability due to where the wheat was grown (location effects) and finally variability due to variety.

2) Variability in quality was reduced as spring wheats moved from farm level production to U.S. exports. Variability of protein, dockage, test weights, shrunken and broken kernels, and total defects were lower for U.S. exports than at the farm production level. Average within-year variability of protein at the production level had standard deviations of 1.0 to 1.7 percent in the northern production regions while exports of No. 1 and No. 2 OB HRS had average standard deviations of .15 percent to .39 percent and .41 percent to .70 percent, respectively. For dockage, production levels had average standard deviations of 1.28 percent to 2.32 percent, and exports of No. 1 and No. 2 OB HRS had standard deviations for dockage that ranged from .11 percent to .33 percent and .12 percent to .41 percent, respectively. Similar results were found for the test weights, shrunken and broken kernels, and total defects.

3) Higher grades at the export level exhibited lower variability than did lower grades.

4) Variability of protein and dockage levels for selected importing countries importing No. 1 and No. 2 HRS was similar, suggesting that specifications for these parameters by the importing countries were similar for both grades.

5) The range of within-shipment variability of exports (high sublot - low sublot) was lower than the variation indicated between export shipments (represented by standard deviations) for both protein and dockage for individual importing countries. This result was not as prevalent for total exports of HRS when segmented by marketing year and

grade, especially when comparing the within-shipment and between-shipment variability of protein for exports of No. 1 HRS.

Canadian Findings

1) Higher grades had less variability than lower grades. No. 1 CWRS was less variable than No. 2 and No. 3 CWRS.

2) The between-year variability of average protein levels for Canadian protein segregations was similar at both the production and export levels.

Comparisons between the United States and Canada

1) Protein levels were highest in Manitoba and North Dakota and lowest in Alberta and Saskatchewan. The variability of protein at the production level measured as the between-year variability of annual average levels and the within-year variability of protein was similar between the United States and Canada.

2) Higher grades were less variable than lower grades in both countries especially at the export level.

Implications

A couple of implications can be drawn from these results. First, since variability for many quality characteristics was lower for higher grades than for lower grades and Canada exports a higher proportion of CWRS as No. 1 than the United States exports of No. 1 HRS, it is expected that consistency should be less of a problem in Canadian wheat exports. Further, an effective way for importers to reduce variability is to either specify No. 1 versus No. 2OB, and/or limits on specific quality factors. Second, since both between-year variation in average protein levels and within-year variation of protein levels were similar in Canada and the United States at the farm production level, differences in consistency of protein quantities may be more related to differences in marketing systems between the two countries and protein levels. Third, an increased emphasis on variety and location could aid in controlling quality variability in some end-use characteristics.

CONSISTENCY OF QUALITY CHARACTERISTICS IN HARD RED SPRING WHEATS

Bruce L. Dahl and William W. Wilson*

INTRODUCTION

Greater sophistication among buyers in the wheat market has increased demands for higher quality wheats. As demand for higher quality wheats has increased, attention has focused on quality variability or consistency of wheat purchased. Concerns over the quality consistency of hard wheats have been voiced in both domestic (Minnesota Association of Wheat Growers and Minnesota Wheat Research & Promotion Council) and export markets (United States Congress - OTA, Stevens and Rowan, Mercier, Prairie Grains, June 1997). Several studies have examined quality concerns of wheat importers and made comparisons across major exporting countries (United States Congress OTA, Mercier, Stevens and Rowan). These studies have indicated that importers perceive United States imports as less consistent than Australian and Canadian wheat imports.

Many factors affect the variability of wheat produced and exported. These include differences in varietal development and release mechanisms, marketing practices, handling practices, grading systems, and environmental effects which can in turn affect the quality of wheats produced (Dahl and Wilson 1997). Changes in grades and classes imported have also been identified (Dahl and Wilson, 1996). Changes are occurring in how importers purchase wheats. Many importers are increasing the specificity of characteristics in import tenders. For example, Japan and Taiwan have been lowering the maximum dockage allowable in import tenders over time. Finally, wheat purchases are generally made based on protein levels, as protein is related to many end-use quality parameters that are subject to some uncertainty. This study examines variability of wheat at different points in the wheat marketing chain (variety, farm production, and export levels). Comparisons are made with Canada, a competitor country where data are available. Then, effects of environment on end-use quality are reviewed.

BACKGROUND

What is Quality Uncertainty (Consistency)?

Quality consistency has been used with increased frequency, without a strict definition. To define it further, three important aspects of quality variability or consistency must be distinguished. The first is variability in quality due to sampling and grading errors. This has been a major concern for exports, domestic shipments, and farmer deliveries (Hill). Errors in measurement can occur throughout the marketing system due to changes in the condition of the grain, errors in sampling, errors in testing equipment, etc. These errors affect variability in quality by increasing risks to both buyers and sellers that the product will not meet specifications when delivered.

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The second aspect is the intrinsic variability in the level of grain characteristics. These are reflected in interregional (location-to-location) and inter-temporal (year-to-year) differences in characteristic levels. Some of these characteristics are easily measurable (e.g., damage, protein) while others are susceptible to greater measurement error (e.g., vomitoxin). In the former case, the principal implications of variability are the need for segregation and blending activities (by handlers) in order to serve customers with heterogenous demands. In the latter case, increased variability is compounded by measurement error, resulting in greater uncertainty and risk for traders. Much of this type of variability can be controlled with grade specifications and factor limits.

The third aspect refers to the lack of consistency in end-use performance (i.e., mixing characteristics). This is a concern among end users and is reflected in the relationship between end-use performance and measurable quality characteristics. For technological reasons, wheat buyers normally specify easily measurable characteristics (e.g., protein, test weight, etc.) which are correlated with desirable end-use characteristics (e.g., wet gluten, loaf volume, mix tolerance, etc.) that are not quickly measurable. A poor correlation between easily measurable quality characteristics (protein) and end-use characteristics results in greater uncertainty in end-use performance. Allegedly, there is a more consistent relationship between wheat and mixing characteristics for competitors' wheat than for wheat from the United States.

Economics of Quality, Grades, and Brands

Issues related to the role of quality in grades and brands have begun to be addressed in the literature. Bowbrick examined the issue of uniformity or quality consistency. He indicates that issues of quality uniformity deal primarily with inadequate levels and consistency. Inadequate quality levels have been identified as a problem in United States wheat trade for protein (Prairie Grains, p. 15). However, much of the recent debate on uniformity has focused on consistency. Bowbrick identifies three main types of consistency: 1) within a package, lot, or shipload; 2) across packages; and 3) over time. For example, if a country buys United States No. 2 or better DNS, its consistency over time would be determined by the variability of protein, test weight, and end-use quality characteristics in shipments of that grade over time.

Many trading and handling practices are undertaken among exporting countries and firms that influence quality. These include contract limits, premiums/discounts, procurement strategies, blending, site-specific purchases, and loading plans. Grain handlers, exporters, processors, and end users routinely blend different lots to meet specific requirements.

Role of Quality Variability in Export Competition

A number of studies have examined issues related to wheat quality. There have been two major studies in the United States and one each in Australia (GRDC) and Canada (Stevens and Rowan, 1996). The first was by the Office of Technology Assessment (US-Congress OTA). The OTA surveyed domestic and overseas millers about their views toward United States wheat. A major concern of overseas respondents was an apparent increase in the lack of uniformity in end-use quality, baking absorption, and dough-handling properties. When examining wheat characteristics used for grade standards, overseas millers identified moisture, test weight, dockage, and insect levels as those parameters most affected by lack of uniformity among shipments. Domestic millers identified the same parameters except for dockage.

The Economic Research Service of USDA conducted a comprehensive analysis of issues related to wheat quality. One major component of that study was a series of in-country interviews of buyers in major wheat-importing countries to determine effects of cleaner United States wheat on sales in these markets. In the analysis, importers identified several factors influencing the choice of supplier country. These included the role of quality factors in import purchases and importers' perception of wheat purchased from their suppliers, details of preferences as revealed by contract specifications, level of dockage in import shipments and the cost of removal, and sensitivity of import purchases to cleanliness and the willingness of importers to pay a premium for a cleaner wheat from the United States. In many cases, quality variability (primarily protein content and gluten quality) was listed as a concern in supplier choice, especially for specific higher income importers.

A common theme in these two studies (OTA, USDA) is a growing concern about quality variability. Important conclusions of the OTA study were that buyers wanted to have more information on end-use performance and that they had major concerns about the lack of uniformity in quality. The USDA survey of buyers indicated that wheat from both Australia and Canada was viewed as superior to that from the United States in terms of quality variability. Concerns were raised about quality variability both within and among shipments. Importers indicated that in some cases, variability in protein quantity was a concern both within shipments and across shipments for HRS and white wheat grown in the Pacific Northwest. Gluten quality was identified as a problem for HRS in markets serviced through Great Lakes ports and the Gulf of Mexico, primarily for wheat grown in Minnesota; however, other importers rated gluten quality of HRS as equal to or superior to CWRS.

The Grain Research and Development Corporation of Australia (GRDC) study interviewed numerous importers. This survey had three important conclusions: 1) Canada and Australia were recognized as "quality" suppliers and the United States as a "price" supplier (p. 4), 2) buyers identified "consistency" as an important quality characteristic affecting purchases, and 3) Canada and Australia were recognized as delivering a product of better quality than specified in contracts.

Stevens and Rowan (1996, 1997) found similar results in their studies for Canada's Western Grain Marketing Panel. They surveyed importers about their impressions of quality specifically, the intrinsic quality of the commodity, cleanliness, and consistency of quality from shipment to shipment. Importers ranked exporters on a 5-point scale for intrinsic quality, cleanliness, and quality consistency. They found Canada and Australia ranked first and second for all three quality parameters and were considered preferred quality suppliers. The United States ranked third for intrinsic quality and consistency while ranking fourth in cleanliness. The European Union (EU) ranked fourth for intrinsic quality and consistency while ranking third in cleanliness. Argentina ranked last in all quality parameters. Importers viewed Argentina, EU, and the United States as price suppliers.

Overseas staff for United States Wheat Associates have also indicated that their customers have seen a drop in protein quality over the last five years and that CWRS has better protein quality than DNS (Prairie Grains, p. 15). Overseas staff indicated issues that limit competitiveness of United States wheats in world markets in the following order of priority: 1) cleanliness, 2) quality uniformity, and 3) protein content disparities (need to compete with CWB, AWB practice of exceeding protein specifications[1]) (Prairie Grains, P. 16). Furthermore, within the United States, much of the research on wheat quality has focused on quality levels, rather than on quality variability, even though both the level and variability are critical in commercial processing.[2,3]

Effects of Environment[4]

The effects of environment on wheat quantities and qualities have been examined extensively in the agronomy and cereal chemistry literature. Much of the effects of climate on yields are known, and mechanistic descriptions exist (e.g., crop growth models such as Godwin et al.). In addition, climate has been known to affect end-use quality for some time.

In general, production in moister, cooler environments tends to produce lower protein wheats with lower dough strength than dryer regions with higher temperatures during the latter stages of production. Studies of the effects of temperatures on end-use quality have indicated that high and low temperatures affect protein levels and dough strengths (Waldron et al., Harris et al., Finney and Fryer, Randall and Moss, Blumenthal et al., and Preston et al. 1991). Higher temperatures in the earlier portions of head filling have been found to increase protein levels and dough strengths. However, temperatures over 35 degrees C in the latest stages of head filling (last 15 days), even for extremely short periods, have been found to reduce dough strengths. The extent of high temperature effects on quality has varied by variety, with some varieties more/less heat tolerant than others. Similarly, low temperatures (below -3 degrees C) have been shown to affect end-use quality of wheat. Effects were least when plants were closest to maturity.

Another focus of studies examining the effects of environment on quality has been the effects of variety, location, and their interaction. Much of the research has tended to indicate that environmental effects are the predominant factor affecting agronomic parameters such as protein and test weights. However, for technical characteristics, genotype effects are predominant, and genotype X environment (GE) effects are small (Mariani et al., McGuire and McNeal).

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[1] Carter and Loyns indicated that protein content in shipments of Canadian and Australian grain to Japan are routinely higher than specifications and Canadian exports generally averaged .6 percent higher than specifications. They estimated the value of protein giveaways for Canadian wheat exports amounted to $CA1.25/MT.

[2] In particular, large deviations in quality potentially interrupt production schedules, increase processing costs, require additional storage, and reduce product quality.

[3] One objective of *total quality management* is to reduce quality variability.

[4] For a broader examination of the effects of the environment on quality, see the Appendix.

Prior Research on Quality Variability

A number of studies have estimated the variability of quality parameters for hard red spring and hard red winter wheats. Most of these studies have focused on estimating cultivar by environment interactions. Some have examined quality at the variety level (Busch, Shuey, and Frohberg and Peterson, Graybosch, Baenzinger, and Grombacher) Others have examined it on a production quality level (Slaughter, Norris, and Hruschka) and at the export level (Preston, Morgan, and Tipples (1988).

U.S. Studies

Busch et al. (1969) estimated means and ranges (minimums and maximums) for six quality parameters for hard red spring wheats grown from 1964 to 1967 in Minnesota, Montana, North Dakota, South Dakota, Wisconsin, and Wyoming. For the eight varieties tested, they estimated means and ranges for wheat protein, flour yields, flour ash, absorption, mixograms, and loaf volumes. They reported average protein across all varieties and trials of 15.3 percent with the variety Polk having the smallest range of protein (11.5 to 17.7 percent) and Thatcher having the largest range (10.0 to 18.7 percent). Flour yields, flour ash, and flour absorption averaged 59.2 percent, .47 percent, and 64.2 percent for all varieties and trials. The spread between high and low values ranged between 8.9 percent to 10.9 percent, .2 percent to .43 percent, and 6.6 percent to 16.3 percent, for flour yields, flour ash, and absorption, respectively. Mixogram scores averaged 5.1 with the spread between high and low values ranging from a score of 4 to 9. Loaf volumes averaged 185 cc with the spread between high and low values ranging from 50 cc to 84 cc.

A more recent examination of wheat variability on a variety level was done by Peterson et al. They evaluated 18 hard red winter wheat varieties for six quality parameters (flour protein, mixing time, mix tolerance, sedimentation, kernel hardness, and kernel weights) and yields. They estimated variability of quality characteristics and yields for 1988 and 1989. Standard deviations of flour protein by variety ranged from 18 to 33 grams/kg protein on dry moisture basis (1.6 percent to 2.8 percent protein on 14 percent moisture basis). Mix time and mix tolerance variability ranged from standard deviations of 0.75 to 1.78 minutes and .61 to 1.71 scale points, respectively. Kernel hardness and kernel weights had standard deviations of .34 to .65 scale points and .27 to .54 grams, respectively.

An examination of wheat quality variability on the farm production level was done by Slaughter et al. (1992). They examined quality of both hard red winter and hard red spring wheat samples for 1987-1989 from ten states from Texas to Montana. They calculated distributions for quality characteristics by year and found annual standard deviations for wheat protein varied by year from 1.0 to 1.4 percent protein for spring wheat and winter wheat. Standard deviations for test weights ranged from 1.8 to 2.7 lbs/bu for spring wheat and 1.8 to 2.3 lbs/bu for winter wheat. Variability of kernel weights ranged from standard deviations of 3.5 to 4.1 percent for spring wheat and 2.6 to 3.0 percent for winter wheat. Variability of dough properties measured by absorption, tolerance, and peak times ranged from 2.2 to 2.4 percent, 5.6 to 6.6, and 3.1 to 3.2 minutes for spring wheats, respectively. Variability for winter wheats ranged from 2.4 to 2.7

percent, 2.8 to 3.8, and 1.8 to 1.9 minutes for absorption, tolerance, and peak times. Loaf volumes varied more for hard red winter wheats in 1988 and 1989 than for spring wheats, and levels ranged from 50 cc to 150 cc lower for winter wheats than for spring wheats. Standard deviations for loaf volumes ranged from a low of 67.6 in 1987 to a high of 93.5 in 1989 for winter wheats and from a low of 66.2 to 75.1 for spring wheats.

Slaughter et al., also estimated correlation coefficients for quality parameters and Maholanobis[5] distances to determine which quality factors could best be used to differentiate hard red spring and winter wheats. They found protein was more consistently correlated with a higher number of other quality assessments than other measurements although hardness, sedimentation, loaf volume, absorption, and peak times also correlated well with other quality parameters.

Other studies have measured variability for selected quality dimensions. Wilson and Preszler (1993a,b) and Heilman demonstrated that some variances for flour produced from United States wheat were up to 10 times as great as those from Canada. These results suggested that the standard set of wheat characteristics reflected end-use performance for the United States less than for Canadian wheats. Johnson, Wilson, and Diersen derived standard deviations of wheat characteristics from the 1993 and 1994 HRS crop years. Results demonstrated that standard deviations varied substantially across regions and through time. The effect of this was greater geographical dispersion in flows than otherwise would have been the case.

Canadian Studies

Quality at the export level was examined by Preston, Morgan, and Tipples for Canadian Western Red Spring Wheat. They evaluated quality characteristics of composite samples collected from export shipments from 1973 to 1986. Samples were collected by protein segregation, grade, and port location (Atlantic and Pacific ports). Average variability of protein within segregations increased from CWRS1 (CV=1.0) to CWRS2 (CV=1.4) to CWRS3 (CV=3.3). Significant differences in the distribution of protein between grades were found between CWRS 1 and CWRS2 12.5 percent protein at both ports and 13.5 percent at Pacific ports. Average coefficients of variation for test weight, falling numbers, flour yield, wet gluten, loaf volumes, and absorption also increased as grades decreased from CWRS1 to CWRS3 (Table 1). They indicated that variability for many quality parameters was low (less than 5.0 percent), especially for CWRS1. Higher coefficients of variation for CWRS3 probably resulted because that grade does not have protein segregations.

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[5] Maholanobis distances are a statistical method of comparing the “distance” between mean values adjusted for differences in measurement units and standard deviations. This allows for comparisons of many quality characteristics with dissimilar measurement units and standard deviations among wheat classes.

Table 1. CWRS Export Shipments Within Protein Segregations: Average Coefficients of Variation for Selected Quality Characteristics, by Grade, 1973-1986.

	CWRS 1	CWRS 2	CWRS 3
Wheat protein	1.0	1.4	3.3
Test weight	0.9	1.0	1.5
Kernel weight	5.6	4.7	4.8
Falling number	6.8	12.2	19.0
Flour yield	0.8	0.9	1.2
Flour protein	1.0	1.7	3.7
Wet gluten	2.0	2.6	4.1
Ash	4.8	4.7	6.0
Loaf Volume	2.9	3.2	6.4
Absorption	1.7	2.0	2.4
Development time	8.7	9.8	14.1
MTI	15.3	15.0	21.4
Stability	18.0	17.1	17.8

Source: Preston, Morgan, and Tipples (1988).

DATA SOURCES AND SCOPE OF ANALYSIS

In this study, the quality of United States Hard Red Spring Wheat (HRS) was examined to measure the variability of quality characteristics at different points in the wheat production and marketing system. Quality variability at each stage was documented and comparisons made with Canada where data were available. The examination and comparison of variability was complicated by the differences in types, level of aggregation, and availability of data at different stages of the system and across countries. Much of the Canadian data available were observations for composite samples derived at the country level for grade and protein segregations. However, United States data were less aggregate with much of it representing individual shipments/samples. In cases where Canadian aggregate data existed, United States data were aggregated to a similar level to allow for more representative comparisons.

Data on spring wheat quality parameters were collected from a number of sources and at different places in the wheat production system. Data on quality characteristics at the variety level were collected from North Dakota varietal trials from 1989 to 1995 (Department of Cereal Science). Data for Canada on a variety level exist, but were unavailable for this analysis.

Data on production quality characteristics for Northern Regional hard red spring wheat were collected from Moore et al. and Shelton et al. from 1980-1996. This data set included individual sample data on wheat quality characteristics as well as aggregates for state and regional average characteristics. Data on Canadian production quality characteristics were obtained from annual crop quality reports (CGC-GRL). This data set contained observations for composite samples for protein, by province from 1980 to 1996, and observations for CWRS quality characteristics by grade and protein segregation generated from composite samples for western Canada. Summaries for protein distributions (unaggregated) were also available for 2 years (1996 and 1997) (Williams 1997a,b).

Data on export quality characteristics were obtained from GIPSA-Export Grain Inspection System Data (EGIS) for 1985 to 1997. This data set included observations by shipment for grade and selected non-grade quality characteristics (protein, dockage, and falling number). Canadian export quality characteristics were obtained for CWRS exports by grade and protein segregations (CGC). Data represent composite samples for port location (Atlantic and Pacific) and grade and protein segregations, collected semi-annually and quarterly.

RESULTS

VARIETAL CONSISTENCY: EXPERIMENT STATION DATA

Data on quality for varieties are evaluated annually through crop varietal trials done at state experiment stations. End-use quality parameters are derived for varieties in the trials (Department of Cereal Science). Quality characteristics were evaluated from 1989 to 1995 to estimate annual variability of quality parameters on a variety level. Eight varieties were evaluated that were present in the varietal trials in most years and were adopted by farmers on at least 10 percent of planted acres in one of the years 1989-1995. Therefore, varieties examined represent varieties important for spring wheat production in North Dakota and had higher numbers of observations across years. Similar data on quality characteristics for varieties in Canada exist, but are not publicly available.

Mean values, standard deviations, and coefficient of variation were estimated for selected wheat, dough, and baking characteristics for 1989-1995 (Table 2). Annual wheat protein levels over this period ranged from a low of 14.8 percent for Marshall to a high of 16.3 percent for Gus. Average annual variability for wheat protein on a variety level, measured by standard deviation, ranged from a low of .86 percent protein for Butte 86 to a high of 1.2 percent protein for Marshall. Comparisons of standard deviations for protein by variety indicate that although some varieties had lower standard deviations, the variability for protein did not differ among varieties.

Results were similar for most quality characteristics. Although some varieties had standard deviations that were higher than others, differences in variability for most quality characteristics were not significant. Standard deviations for test weights ranged from 1.54 lbs/bu to 2.81 lbs/bu. Levels for vitreous kernels by variety averaged 84.9 to 92.6 percent and had standard deviations that ranged from 9.23 to 19.06 percent. Gus (2375) had the highest (lowest) average level for vitreous kernels and the lowest (highest) standard deviation. Wet gluten levels ranged from 38.9 percent for Marshall to 45.2 percent for Gus with standard deviations ranging from a low of 3.19 percent for Len to a high of 4.15 percent for Marshall. Absorption levels ranged from a low of 61.5 percent for Marshall to a high of 67.7 percent for Butte 86. Standard deviations for absorption were lowest in Butte 86 (1.92 percent) and highest for Grandin (2.43 percent). Levels for loaf volumes ranged from a low of 864 cc for Marshall to a high of 957 cc for Gus. However, standard deviations for the varieties ranged only from 49 cc for Amidon to a high of 66 cc for Grandin.

For different characteristics, some varieties had the highest average levels while for other characteristics, these varieties had the lowest average levels. For example, Marshall had the lowest average levels for wheat and flour protein, wet gluten, and absorption, yet also had the highest flour extraction levels. In addition, Marshall had the largest standard deviations for all of these characteristics. 2375 had lower levels for wheat protein, flour protein, wet gluten, and flour extraction while levels for Grandin were higher. However, many of the standard deviations for farinograph parameters and baking quality were lower (although not significant) for 2375 than for Grandin.

The effects of location, variety, and year on variability of quality characteristics were then examined by using data from the experiment station varietal trials. An analysis of variance (ANOVA) was conducted for selected quality characteristics from 1989-1995 for the seven varieties across the seven North Dakota experiment stations. Specific effects examined were variety, location, and year. Interaction effects were included, but later dropped due to insignificance for all factors. F-statistics for selected quality characteristics were all statistically significant and are reported in Table 3.

F-statistics indicate that many of the quality characteristics are affected most by year-to-year variations. This agrees with the results of earlier studies (Harris, et al.). For example, most of the variability in the level of wheat protein can be explained by year-to-year variations due to climatic conditions. The effect of year on wheat protein has about twice the impact of location and about 4 times the impact of variety. The effect of year-to-year variations were larger than the effects of location and variety for many of the wheat quality characteristics and some of the flour and end-use characteristics. However, for some of the flour and baking quality characteristics, the importance of the effects location, variety, and year were different. For wet gluten and Mix Tolerance Index (MTI), the effects of location and variety exceeded the effects of annual variability. For absorption and loaf volumes, the effects of year were largest followed by variety and location. These results suggest that procurement strategies that focus on variety and location may be appropriate if targeting wet gluten or MTI. However, if absorption or mix time are critical, location has a lesser impact than variety or year to year variability. Finally, if the quality parameter targeted is loaf volume, the effect of year to year variability largely determines the level of loaf volume.

Table 2. Means and Standard Deviations for Variety Level Characteristics, 1989-1995.

	Wheat Protein	Test Weight	Vitreous Kernels	Falling Number	Flour Protein	Flour Extract.	Ash	Wet Gluten
Mean								
2375	15.2	60.7	84.9	440	13.9	68.8	0.42	40.6
Amidon	15.3	60.1	92.1	419	14.1	68.8	0.41	42.4
Butte 86	15.6	60.1	88.7	427	14.3	68.0	0.41	42.8
Grandin	15.6	60.1	88.5	418	14.5	69.4	0.43	40.7
Gus	16.3	59.3	92.6	407	15.2	68.5	0.44	45.2
Len	15.5	59.2	88.3	420	14.4	69.2	0.43	39.4
Marshall	14.8	59.3	89.9	421	13.8	70.4	0.41	38.9
Stoa	15.5	59.1	90.4	420	14.5	68.5	0.41	41.2
Standard Deviation								
2375	0.92	1.54	19.06	38	0.97	1.93	0.040	3.29
Amidon	0.98	1.70	10.03	35	1.04	1.56	0.036	3.84
Butte 86	0.86	1.89	14.28	36	0.98	1.40	0.042	3.85
Grandin	0.93	2.28	15.13	39	1.00	1.60	0.040	3.39
Gus	0.91	2.14	9.43	50	0.92	1.53	0.047	4.08
Len	0.91	2.35	14.38	32	0.95	2.00	0.041	3.19
Marshall	1.19	2.81	12.37	53	1.24	2.00	0.047	4.15
Stoa	0.94	2.22	10.05	45	0.96	1.79	0.034	3.36
Coefficient of Variation								
2375	6.05	2.54	22.45	8.64	6.98	2.81	9.52	8.10
Amidon	6.41	2.83	10.89	8.35	7.38	2.27	8.78	9.06
Butte 86	5.51	3.14	16.10	8.43	6.85	2.06	10.24	9.00
Grandin	5.96	3.79	17.10	9.33	6.90	2.31	9.30	8.33
Gus	5.58	3.61	10.18	12.29	6.05	2.23	10.68	9.03
Len	5.87	3.97	16.29	7.62	6.60	2.89	9.53	8.10
Marshall	8.04	4.74	13.76	12.59	8.99	2.84	11.46	10.67
Stoa	6.06	3.76	11.12	10.71	6.62	2.61	8.29	8.16

Table 2. (Continued)

	Absorption	Peak Time	Mix Tolerance	MTI	Mix Time	DO	Loaf Volume	Granularity	Crumb	Symmetry
Mean										
2375	65.9	12.9	17.5	23.1	1.9	9.8	903	8.0	8.4	9.8
Amidon	65.1	9.8	14.4	27.7	2.0	9.8	909	8.0	8.2	9.7
Butte 86	67.7	11.5	13.5	25.2	1.9	9.9	922	8.2	8.4	9.8
Grandin	67.0	15.5	20.6	17.9	2.5	9.9	940	8.1	8.2	9.8
Gus	66.4	14.0	17.2	23.2	2.1	9.7	957	8.0	8.2	9.7
Len	65.5	16.9	22.9	16.9	2.8	10.0	949	8.1	7.7	9.9
Marshall	61.5	11.9	17.5	24.5	1.8	9.9	864	8.0	8.2	9.8
Stoa	64.7	17.2	21.3	19.3	2.4	9.9	934	8.0	8.5	9.8
Standard Deviation										
2375	2.07	7.23	7.0	11.7	0.36	0.68	50	0.37	0.37	0.40
Amidon	2.07	4.13	5.4	11.8	0.27	0.48	49	0.44	0.34	0.52
Butte 86	1.92	5.45	6.4	15.0	0.30	0.28	65	0.40	0.30	0.69
Grandin	2.43	8.16	8.0	7.6	0.43	0.41	66	0.45	0.36	0.54
Gus	2.09	5.92	6.8	14.1	0.31	0.90	60	0.62	0.60	0.65
Len	2.25	9.25	8.9	6.5	0.53	0.15	61	0.49	0.42	0.37
Marshall	2.34	8.17	6.8	10.2	0.31	0.29	60	0.53	0.43	0.64
Stoa	2.18	7.59	6.9	11.7	0.32	0.37	63	0.44	0.40	0.52
Coefficient of Variation										
2375	3.14	56.05	40.00	50.65	18.95	6.95	5.54	4.63	4.40	4.08
Amidon	3.18	42.14	37.50	42.60	13.50	4.89	5.39	5.50	4.15	5.36
Butte 86	2.84	47.39	47.41	59.52	15.79	2.83	7.05	4.88	3.57	7.04
Grandin	3.63	52.65	38.84	42.46	17.20	4.16	7.02	5.56	4.39	5.51
Gus	3.15	42.29	39.53	60.78	14.76	9.28	6.27	7.75	7.32	6.70
Len	3.44	54.73	38.86	38.46	18.93	1.50	6.43	6.05	5.45	3.74
Marshall	3.80	68.66	38.86	41.63	17.22	2.94	6.94	6.63	5.24	6.53
Stoa	3.37	44.13	32.39	60.62	13.33	3.74	6.75	5.50	4.71	5.31

Table 3. Effect of Variety, Location, and Year on Selected Quality Characteristics, 1989-1995.

Factor	Variety	Location	Year	R - Square
	---------------------- F Statistic -----------------------			
Wheat Protein	12.23	24.77	59.52	0.64
Test Weight	5.13	19.83	26.48	0.49
Vitreous Kernels	3.03	42.49	32.54	0.59
Falling Number	3.62	20.59	29.46	0.50
Flour Protein	13.46	31.79	59.21	0.66
Flour Extraction	9.22	20.14	29.98	0.52
Wet Gluten	19.82	23.60	12.29	0.52
Ash	6.08	51.05	42.57	0.65
Absorption	40.80	36.57	81.58	0.75
Peak Time	9.67	31.21	44.58	0.61
Mix Tolerance	13.93	19.82	19.46	0.50
MTI	5.88	9.94	4.76	0.28
Mix Time	37.67	4.21	53.94	0.65
DO	1.44	7.40	8.18	0.24
Loaf Volume	10.66	6.90	122.18	0.72
Granularity	1.81	6.39	9.12	0.24
Crumb	16.85	9.52	16.52	0.45
Symmetry	0.64	2.20	26.51	0.35

NDWC Data

Another source of data on quality at the variety level is from a 1996 survey conducted by the North Dakota Wheat Commission. It conducted a survey of farm production quality and collected samples of specific varieties across the state. Wheat, flour, dough, and baking quality characteristics were determined for each sample. This survey was also conducted for 1997; however, results of this survey are not available.

Samples were segregated based on variety, protein level, and location, and their quality characteristics were examined. They found qualities such as absorption, loaf volume, and overall bread texture and color appeared to be more correlated to protein than did dough strength and mixing properties (Table 4). Dough strength and mixing properties were more correlated to location and variety. Since United States wheat is not typically purchased on variety specifications, increasing protein levels of wheat purchases could increase wet gluten, absorption, and loaf volumes due to the correlation of these quality parameters to protein. However, purchasing by location could increase peak times and mixing tolerance due to a slight correlation between dough strength and location that may be related to the higher percentages of stronger type varieties planted in western North Dakota or lower disease pressures.

Using this data, relationships between protein content of wheat and absorption were estimated for 4 of the varieties sampled (2375, Grandin, Amidon, and Butte 86). Relationships suggest a lower increase in absorption as protein levels increase. Absorption levels for lower protein samples were higher in the data from 1996 than for the variety trial data. However, this represents only one year, whereas the variety trial data represent a 7-year time frame.

Data from this survey were obtained, and variability of quality characteristics were estimated (Table 5). However, results from these comparisons should be interpreted with caution because of the low number of observations (8 observations or less per variety) and data were not collected to represent state production patterns (a higher proportion of samples were collected in western North Dakota than would be representative of average production patterns).

Table 4. Average Quality Characteristics for Protein and Location Segregations, NDWC Survey, 1996.

Protein Level	Greater than 14.5%	13.5 to 14.5%	Less than 13.5%
Protein	15.2	14.1	13.2
Vit. Kernels	91	85	90
Wet Gluten	40.7	37.5	35.1
Absorption	65.6	65.1	64
Peak Time	7.3	6.8	7
Mix Tolerance	13.4	12.1	12.7
Loaf Volume	1122	1056	1000
Location	**West**	**Central**	**East**
Protein	14.1	14.4	14
Vit. Kernels	93	88	76
Test Wt.	61.9	61	61.3
Extraction	69.9	70.1	70.5
Absorption	65.2	64.7	64.7
Peak Time	7.8	6.4	6
Mix Tolerance	14.8	9.2	12.1
Loaf Volume	1053	1078	1061

Table 5. Parameters for Quality Characteristics From North Dakota Wheat Commission Variety Quality Survey Data, 1996.

	Wheat Protein	Test Weight	Vitreous Kernels	Kernel Weight	Flour Extraction	Ash	Wet Gluten
Mean							
2375	13.7	61.7	84	34.8	71.0	0.42	36.4
Grandin	14.4	61.7	86	33.1	70.2	0.40	36.3
Amidon	13.9	61.6	93	30.2	69.6	0.41	38.4
Butte 86	14.0	61.6	89	32.8	69.3	0.42	37.5
Standard Deviation							
2375	0.51	0.96	12.6	2.45	0.66	0.04	1.88
Grandin	0.90	1.03	12.4	3.45	1.29	0.02	2.52
Amidon	0.62	1.48	4.2	1.93	2.22	0.05	2.21
Butte 86	0.85	1.53	9.3	2.43	0.79	0.06	2.48
Coefficient of Variation							
2375	3.73	1.56	15.0	7.02	0.93	9.88	5.17
Grandin	6.27	1.66	14.3	10.4	1.84	6.18	6.93
Amidon	4.43	2.40	4.5	6.39	3.18	11.09	5.76
Butte 86	6.03	2.48	10.4	7.41	1.14	14.83	6.61

Table 5. (Continued)

	Absorption	Peak Time	Mix Tolerance	Class	Bake Absorption	Mix Time	Loaf Volume
Mean							
2375	63.9	6.7	13.3	5.6	62.4	2.5	1035
Grandin	65.8	8.9	17.3	7.0	64.3	3.2	1103
Amidon	64.5	6.4	9.9	5.0	63.0	2.5	1071
Butte 86	65.9	6.7	9.9	4.7	64.4	2.4	1017
Standard Deviation							
2375	0.8	1.0	3.0	0.48	0.78	0.22	48
Grandin	1.3	1.9	7.5	0.71	1.31	0.49	59
Amidon	1.4	1.0	1.2	0.71	1.40	0.22	51
Butte 86	1.3	2.9	3.4	1.62	1.34	0.36	63
Coefficient of Variation							
2375	1.22	15.39	22.37	8.61	1.25	8.66	4.68
Grandin	1.99	21.38	43.65	10.10	2.04	15.26	5.33
Amidon	2.17	15.06	12.44	14.14	2.22	8.66	4.73
Butte 86	2.03	43.54	34.68	34.37	2.08	15.19	5.23

FARM PRODUCTION QUALITY

Quality of wheat at the farm level is estimated for both Canada and the United States through established production surveys (Moore et al., Canadian Grain Commission-GRL, Williams 1997a,b). Survey methods differ between the two countries. In the northern region of the United States, individual samples are collected and analyzed for grade and selected non-grade parameters with end-use quality tests done on composite samples (samples are aggregated to a crop reporting district level). In contrast, Canada conducts analysis on individual samples only for test weights, protein, and moisture. Composite samples are collected by grade and protein segregation, and estimates for other grain and end-use characteristics are derived from these composite samples. Composite samples for these grade and protein segregations are collected for western Canada.

To examine variability of quality characteristics, data from these farm quality surveys were gathered. Variability of quality parameters from annual crop production surveys were compared.[6]

Protein Variability

Observations on protein are measured for both the Canadian and United States samples submitted/gathered for their respective quality of production surveys. In 1996 and 1997, Canada released distributions of protein observations. In prior years, only mean values by province were released. These distributions were reported by grade and province for all milling grades. These are compared to distributions for protein in the northern regions of the United States. Two distinct comparisons are made. First, variability of annual average levels for protein are compared. Then, comparisons are made for yearly protein distributions.

Average annual levels of protein for CWRS and HRS were gathered and converted to a 12 percent moisture basis for 1980 to 1996. Average annual protein levels were evaluated over three periods: 1980-1996, 1980-1986, and 1990-1996, by state/province and region. Within Canada, protein was also segregated by grade. Average annual levels of protein from 1980-1996 were highest in North Dakota and South Dakota and lowest in Alberta, Saskatchewan, and Minnesota (Tables 6-7). Between-year variability of annual average levels from 1980 to 1996 ranged from a low standard deviation of .6-.61 percent protein in Manitoba and North Dakota to a high of .88-.90 percent in Montana and South Dakota. Variability of annual averages was lower for Northern Regional HRS production (Standard deviation=0.59 percent) than for western Canada (Standard deviation=0.66 percent), however, differences were not significant. This indicates that variation of state/provincial/regional annual protein levels from year to year are similar in Canada and the northern United States.

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[6] Dahl and Wilson (1996, 1997) examined the distribution of grades at the farm production level and export level. Results indicated that the percentage of HRS and CWRS production grading No.1 or No. 2 was similar in both the northern United States and western Canada. However, a distinct difference exists between the two countries for export grades. Canada routinely ships over 40 percent of CWRS exports as No. 1 whereas less than 15 percent of HRS exports are shipped as No. 1.

Table 6. Variability of Annual Average Protein* Levels by Grade/Area for Selected Periods, Canada.**

Grade/Area	1980-1996			1980-1986			1990-1996		
	Mean	**Std. Dev.**	**C.V.**	**Mean**	**Std. Dev.**	**C.V.**	**Mean**	**Std. Dev.**	**C.V.**
CWRS 1									
Manitoba	14.2	0.68	4.79	14.4	0.69	4.79	13.9	0.53	3.81
Saskatchewan	14.0	0.83	5.93	14.3	0.38	2.66	13.2	0.44	3.33
Alberta	13.9	0.72	5.18	14.2	0.45	3.17	13.3	0.48	3.61
Canada	13.8	0.72	5.22	14.3	0.36	2.52	13.3	0.41	3.08
CWRS 2									
Manitoba	14.1	0.55	3.90	14.3	0.52	3.64	13.8	0.52	3.77
Saskatchewan	13.7	0.84	6.13	14.0	0.45	3.21	12.9	0.39	3.02
Alberta	13.4	0.67	5.00	13.6	0.44	3.24	12.9	0.55	4.26
Canada	13.8	0.69	5.00	14.0	0.32	2.29	13.1	0.39	2.98
All Grades									
Manitoba	14.1	0.60	4.26	14.2	0.62	4.37	13.9	0.53	3.81
Saskatchewan	13.8	0.82	5.94	14.0	0.51	3.64	13.0	0.42	3.23
Alberta	13.7	0.64	4.67	14.0	0.33	2.36	13.1	0.51	3.89
Canada	13.8	0.66	4.78	14.0	0.40	2.86	13.2	0.40	3.03

* 12% Moisture Basis.
** One observation per year per grade/location.
Source: Canada Grain Commission (Various Issues,a).

Table 7. Variability of Annual Average Protein* Levels by Grade/Area for Selected Periods, Northern Regional United States.**

State	1980-1996			1980-1986			1990-1996		
	Mean	**Std. Dev.**	**C.V.**	**Mean**	**Std. Dev.**	**C.V.**	**Mean**	**Std. Dev.**	**C.V.**
Minnesota	13.9	0.76	5.47	13.3	0.52	3.91	14.1	0.49	3.48
Montana	14.3	0.88	6.15	14.3	0.82	5.73	13.9	0.64	4.60
North Dakota	14.5	0.61	4.21	14.5	0.25	1.72	14.1	0.27	1.91
South Dakota	14.5	0.90	6.21	14.5	0.39	2.69	14.0	0.47	3.36
Region	14.3	0.59	4.13	14.1	0.22	1.56	14.0	0.25	1.79

* 12% Moisture Basis.
** One observation per location per year.
Source: Moore et al. (Various Issues).

Variability of the distribution of protein levels within years were compared for 1996 and 1997 between the United States and Canada. Average levels of protein in Canada for all grades in 1996 declined from Manitoba to Saskatchewan to Alberta, and as protein levels declined, standard deviations increased (Table 8). Average standard deviations of protein levels ranged from 1.0 percent protein in Manitoba for CWRS1, CWRS2, and all grades of CWRS to a high of 1.7 percent protein for CWRS2 in Alberta. Results for 1997 indicate higher variability of protein levels than in 1996 (Table 9). Standard deviations ranged from a low of 1.1 percent for all grades of CWRS in Manitoba to a high of 1.9 percent for CWRS3 in Saskatchewan. Standard deviations of protein in Canada in 1997 were lowest in Manitoba and higher in both Saskatchewan and Alberta.

Table 8. Distribution of Protein in CWRS Wheat, 1996.*

Location	Samples	Mean	Std. Dev.	Min	Max	C.V.
CWRS 1						
Manitoba	1192	14.4	1.0	9.6	17.4	6.9
Saskatchewan	4798	13.1	1.3	9.3	18.0	9.9
Alberta	1518	13.0	1.5	9.3	18.1	11.5
Canada	7508	13.3	1.4	9.3	18.1	10.5
CWRS 2						
Manitoba	1498	14.5	1.0	10.5	18.2	6.9
Saskatchewan	2209	13.1	1.4	8.7	17.4	10.7
Alberta	549	12.3	1.7	8.7	17.5	13.8
Canada	4256	13.5	1.5	8.7	18.2	11.1
CWRS 3						
Manitoba	221	13.9	1.2	10.8	17.0	8.6
Saskatchewan	1625	12.2	1.4	8.6	17.5	11.5
Alberta	1312	12.1	1.4	8.1	16.5	11.6
Canada	3158	12.3	1.4	8.1	17.5	11.4
All Grades						
Manitoba	2978	14.4	1.0	9.6	18.2	6.9
Saskatchewan	8736	12.9	1.4	8.6	18.0	10.9
Alberta	3625	12.5	1.5	8.1	18.1	12.0
Canada	15339	13.1	1.5	8.1	18.2	11.5

* Values converted from 13.5% Moisture Basis to 12% Moisture Basis.
Source: Williams, 1997a.

Table 9. Distribution of Protein in CWRS Wheat, 1997.*

Location	Samples	Mean	Std. Dev.	Min	Max	C.V.
CWRS 1						
Manitoba	886	15.0	1.2	10.8	18.0	8.0
Saskatchewan	3816	13.5	1.6	9.1	19.0	11.9
Alberta	1645	13.2	1.6	9.2	18.6	12.1
Canada	6347	13.6	1.6	9.1	19.0	11.8
CWRS 2						
Manitoba	1296	15.3	1.1	10.8	19.0	7.2
Saskatchewan	1461	13.8	1.7	9.4	19.4	12.3
Alberta	1062	12.9	1.5	8.9	20.0	11.6
Canada	3819	14.0	1.8	8.9	20.0	12.9
CWRS 3						
Manitoba	150	15.0	1.5	10.3	18.0	10.0
Saskatchewan	259	13.3	1.9	8.6	18.0	14.3
Alberta	545	12.2	1.5	8.4	20.0	12.3
Canada	954	12.9	1.9	8.4	20.0	14.7
All Grades						
Manitoba	2473	15.2	1.1	10.3	19.0	7.2
Saskatchewan	5542	13.5	1.6	8.6	19.4	11.9
Alberta	3270	12.9	1.6	8.4	20.0	12.4
Canada	11285	13.7	1.7	8.4	20.0	12.4

* Values converted from 13.5% Moisture Basis to 12% Moisture Basis.
Source: Williams, Dec 4, 1997b.

Average levels for protein by state in the northern United States were higher than in Alberta and Saskatchewan, with North Dakota having the highest average level of protein in both 1996 and 1997 (Tables 10-11). Standard deviations of protein by state range from a low of 1.0 percent in North Dakota and South Dakota to a high of 1.7 percent in Montana in 1996. In 1997, Minnesota was the state with the least variability in protein levels (Standard Deviation=0.8 percent) with Montana again having the most variability (Standard deviation=1.7 percent). Comparisons of within-year variability measured in the northern United States and Canadian provinces indicates that within-year variability of wheat protein levels was similar in 1996 and 1997.

Table 10. Northern Regional HRS Protein Distribution, 1996.

Location	Mean	Std. Dev.	Min	Max	C.V.
Minnesota	13.5	1.1	10.3	16.2	8.1
Montana	14.2	1.7	9.9	19.0	12.0
North Dakota	14.0	1.0	10.4	17.2	7.1
South Dakota	13.4	1.0	10.7	16.3	7.5
Region	13.9	1.2	9.9	19.0	8.6

Table 11. Northern Regional HRS Protein Distribution, 1997.

Location	Mean	Std. Dev.	Min	Max	C.V.
Minnesota	14.3	0.8	12.0	15.6	5.7
Montana	14.0	1.7	10.2	18.2	12.0
North Dakota	14.7	1.0	11.6	17.4	6.6
South Dakota	14.3	1.0	11.9	16.2	6.6
Region	14.4	1.1	10.2	18.2	7.9

Data on protein distributions by year were not available for Canada other than for 1996 and 1997; however, data were available to estimate annual distributions for the northern United States from 1987 to 1996. Average annual protein levels averaged 14.4 percent for the northern United States region from 1987 to 1996 and ranged from a low of 13.7 percent to a high of 16.1 percent (Tables 12-13). Average protein levels were highest in North Dakota and South Dakota during this period. Standard deviations for within-year protein levels from 1987 to 1996 varied most in Montana, averaged 1.33 percent for the period, and ranged from a low .84 percent protein to a high of 1.7 percent protein in 1996. Standard deviations for within-year variability were lowest in Minnesota, averaging 1.02 percent protein from 1987 to 1996, while North Dakota and South Dakota had standard deviations for within-year variability of 1.18 percent and 1.17 percent protein. These results suggest that if samples represented quality at the state level during this period, 95 percent of protein levels for state production should have been within an average of +/- 2 percent to 2.7 percent of the state level average protein level.

Table 12. Characteristics of Annual Northern Regional HRS Protein Distribution Parameters, 1987-1996.

Location	Average Protein Level			Standard Deviation		
	Mean	Min	Max	Mean	Min	Max
Minnesota	14.3	13.5	15.4	1.02	0.74	1.49
Montana	14.3	13.0	16.3	1.33	0.84	1.67
North Dakota	14.6	13.7	16.3	1.17	0.94	1.48
South Dakota	14.6	13.4	17.0	1.18	1.01	1.44
Region	14.4	13.7	16.1			

Table 13. Results for Analysis of Variance for Wheat Protein, 1987-1996.

Location	Mean	Root MSE	C.V.	R-Square
Minnesota	14.3	1.07	7.50	.34
Montana	14.1	1.40	9.92	.38
North Dakota	14.5	1.18	8.12	.38
South Dakota	14.5	1.19	8.17	.45
Region	14.4	1.25	8.67	.33

* Indicates Minnesota and Montana are from different distributions than North Dakota and South Dakota.

Dockage

Variability of dockage levels were examined for Northern Regional HRS production. Observations for dockage from samples were examined by estimating crop year means and standard deviations of dockage levels from data collected in the quality surveys. Annual dockage levels were lowest in Montana and highest in North Dakota and South Dakota from 1987 to 1996 (Table 14). Average within-year variability of dockage (standard deviations) during this period was higher than average dockage levels. Average annual variability, like average dockage levels, was lowest for Montana (1.28 percent) and highest for North Dakota and South Dakota (2.32 percent and 2.14 percent, respectively).

Table 14. Characteristics of Annual Northern Regional HRS Dockage Distribution Parameters, 1987-1996.

Location	Average Dockage Level			Standard Deviation		
	Mean	Min	Max	Mean	Min	Max
Minnesota	1.73	0.85	2.96	1.94	0.74	3.60
Montana	1.00	0.31	2.50	1.28	0.32	4.12
North Dakota	1.86	0.72	3.75	2.32	0.99	4.93
South Dakota	1.92	1.15	4.10	2.14	1.06	4.95

Test Weight

Test weights of farm production were available for both regional United States production of HRS and Canadian CWRS. Data on CWRS were only available on a provincial level by grade. Data on HRS were obtained from observations from the regional quality survey. Annual average test weights for HRS ranged from a low average of 58.4 lbs/bu for Minnesota to a high of 60.6 lbs/bu for Montana from 1987-1996 (Table 15). However, average annual standard deviations for test weights were highest for Minnesota and lowest for Montana (2.3 lbs/bu and 1.7 lbs/bu, respectively).

Table 15. Characteristics of Annual Northern Regional HRS Test Weight Distribution Parameters, 1987-1996.

Location	Average Test Weight Level			Standard Deviation		
	Mean	Min	Max	Mean	Min	Max
Minnesota	58.4	55.4	61.6	2.3	1.4	3.4
Montana	60.6	59.0	61.4	1.7	1.4	2.0
North Dakota	59.8	58.2	61.0	2.1	1.6	3.1
South Dakota	58.9	56.7	61.4	2.1	1.5	2.8

Vitreous Kernels

Levels of vitreous kernels are assessed in the United States Northern Regional crop surveys and not in the Canadian survey. Average levels for vitreous kernels were highest in Montana (87 percent for 1987-1996) and lowest in Minnesota (67 percent from 1987 to 1996) (Table 16). Variability of vitreous kernels levels followed a pattern where lowest standard deviations were associated with regions with the highest average levels. From 1987 to 1996, variability of vitreous kernels was lowest in Montana (Standard deviation of 14.2 percent) and highest in Minnesota (Standard deviation of 23.1 percent). Minimum and maximum annual standard deviations for vitreous kernels suggest that variability within and across years can be substantial. For example, the minimum 3.4 percent standard deviation for Montana implies that 95 percent of observations should be within +- 7 percent of average levels for vitreous kernels; however, the maximum of 24.6 percent implies a range of +-50 percent.

Table 16. Characteristics of Annual Northern Regional HRS Vitreous Kernels Distribution Parameters, 1987-1996.

Location	Average Vitreous Kernels Level			Standard Deviation		
	Mean	Min	Max	Mean	Min	Max
Minnesota	67.1	47.9	88.4	23.1	12.3	30.7
Montana	87.0	70.8	97.2	14.2	3.4	24.6
North Dakota	82.7	68.8	94.0	18.3	10.2	31.0
South Dakota	76.5	54.6	94.9	19.3	8.4	29.0

Falling Numbers

Farm production surveys for both the United States and Canada were available for falling numbers. In Canada, only average levels were reported by grade. Average annual levels for falling numbers from 1987 to 1996 were lowest in Minnesota (373) and highest in South Dakota (395) (Table 17). Average annual variability again was highest in the state with the lowest average annual levels (Minnesota - Standard deviation = 81). However annual variability in falling numbers was lowest in Montana (31), ranging from annual standard deviations of 16 to 54 from 1987 to 1996.

Table 17. Characteristics of Annual Northern Regional HRS Falling Numbers Distribution Parameters, 1987-1996.

Location	Average Falling Numbers Level			Standard Deviation		
	Mean	Min	Max	Mean	Min	Max
Minnesota	373	332	413	81	52	130
Montana	390	360	441	31	16	54
North Dakota	388	349	431	51	30	102
South Dakota	395	343	428	53	30	95

Damaged Kernels, Shrunken and Broken, Foreign Material, and Total Defects

Observations were only available for the United States Northern Regional HRS production for damaged kernels, shrunken and broken, foreign material, and total defects. Average annual damaged kernel levels were lowest in Montana from 1987-1996 and highest in Minnesota (Table 18). Annual variability of damaged kernels was also lowest in Montana (0.2 percent) where levels were lowest, and variability was highest in Minnesota (2.1 percent).

Variability for shrunken and broken kernels followed that for damaged kernels since the state with the lowest variability was also the state with the lowest average levels from 1987-1996 (Table 19). However, Minnesota had the lowest level of shrunken and broken kernels (1.1 percent) and the lowest variability (0.7 percent), whereas South Dakota had the highest levels (1.4 percent) and standard deviations (1.1 percent).

Levels of foreign material and variability were low compared to other parameters (Table 20). Average annual levels of foreign material for all four states averaged 0.1 percent. However, standard deviations were highest on average in South Dakota (0.4 percent) and lowest in Montana (0.1 percent) from 1987 to 1996.

Distributions for total defects were similar to that for damaged kernels. Minnesota had the highest average levels (3.0 percent) and standard deviations (2.6 percent) for total defects from 1987-1996 (Table 21). Meanwhile, Montana had the lowest average levels (1.4 percent) and the lowest variability (1.1 percent).

Table 18. Characteristics of Annual Northern Regional HRS Damaged Kernels Distribution Parameters, 1987-1996.

Location	Average Damaged Kernels Level			Standard Deviation		
	Mean	Min	Max	Mean	Min	Max
Minnesota	1.8	0.2	4.6	2.1	0.3	5.0
Montana	0.1	0.1	0.3	0.2	0.1	0.5
North Dakota	0.8	0.1	2.0	1.5	0.1	3.0
South Dakota	1.0	0.1	4.3	1.3	0.2	4.2

Table 19. Characteristics of Annual Northern Regional HRS Shrunken and Broken Kernels Distribution Parameters, 1987-1996.

Location	Average Shrunken and Broken Kernels Level			Standard Deviation		
	Mean	Min	Max	Mean	Min	Max
Minnesota	1.1	0.5	1.5	0.7	0.5	1.0
Montana	1.3	0.8	2.2	1.0	0.6	1.6
North Dakota	1.3	0.6	1.7	1.0	0.6	1.5
South Dakota	1.4	0.7	2.1	1.1	0.6	1.7

Table 20. Characteristics of Annual Northern Regional HRS Foreign Material Distribution Parameters, 1987-1996.

Location	Average Foreign Material Level			Standard Deviation		
	Mean	Min	Max	Mean	Min	Max
Minnesota	0.1	0.1	0.2	0.2	0.1	0.6
Montana	0.1	0.0	0.1	0.1	0.0	0.2
North Dakota	0.1	0.1	0.3	0.3	0.1	0.7
South Dakota	0.1	0.1	0.4	0.4	0.1	1.2

Table 21. Characteristics of Annual Northern Regional HRS Total Defects Distribution Parameters, 1987-1996.

Location	Average Total Defects Level			Standard Deviation		
	Mean	Min	Max	Mean	Min	Max
Minnesota	3.0	1.6	5.7	2.6	1.1	5.2
Montana	1.4	0.6	2.3	1.1	0.8	1.7
North Dakota	2.2	1.3	3.4	2.1	0.9	3.5
South Dakota	2.5	1.6	5.6	2.0	1.1	4.6

Average State Level Statistics for Flour and Baking Characteristics

Observations for flour and baking quality are only established for composite samples for crop reporting districts in the regional crop quality surveys. These are weighted according to production levels to establish state level values. Similarly, in Canada, flour and baking characteristics are established from composite samples. However, in Canada, composite samples are only generated by grade and protein level for Canada.

Average annual characteristics for flour, dough, and baking properties were evaluated from 1980-1996 by state. Average flour protein during this period ranged from a low of 12.7 percent for Minnesota to a high of 13.4 percent protein for North Dakota (Table 22). Variability of annual flour protein levels ranged from a standard deviation of .62 percent for North Dakota to a high of .9 percent for South Dakota. As one would expect, characteristics for average annual flour protein levels and variability of annual protein levels from 1980-1996 were similar to annual wheat protein distributions although average flour proteins were 1.0-1.2 percent lower than wheat protein levels.

Flour extraction rates from 1980-1996 were highest in Minnesota (69.2 percent) and lowest in South Dakota (67.9 percent). Annual averages were most variable in Minnesota (Standard deviations=1.1 percent) and lowest in North Dakota (Standard deviations=0.6 percent). Flour ash percentages ranged from highs for Minnesota and South Dakota (0.46 percent) to a low for Montana (0.43 percent). Annual averages for flour ash in all four states had standard deviations of 0.03-0.04 percent.

Annual levels of wet gluten were lowest in Minnesota (34.3 percent) with the highest variability from 1980-1996 (3.0 percent). North Dakota had the highest average annual levels for wet gluten (36.5 percent), and annual levels changed the least from year to year (Standard deviation=1.9 percent).

Comparisons of state level dough characteristics indicate that Minnesota had the lowest average absorption levels (62.8 percent) while Montana had the highest (66 percent) (Table 23). However, absorption varied most for Montana (Standard deviation=2.5 percent) while absorption levels for North Dakota, which had average levels slightly lower than Montana (65.3 percent), were the least variable (Standard deviation=1.5 percent). For the other dough characteristics listed, Montana had the highest levels of the states, yet South Dakota varied the most.

Loaf volumes where highest for North Dakota (906 cc) while Minnesota had the lowest (853 cc) (Table 24). North Dakota was also the least variable for state average loaf volume levels (Standard deviation=50 cc) while annual loaf volumes for Minnesota and Montana varied the most (Standard deviation= 68 cc).

Table 22. Average Annual Flour Characteristics, by State, 1980-1996.

	Mean	Std. Dev.	Min	Max	C.V.
Flour Protein					
Minnesota	12.7	0.73	11.1	14.4	5.75
Montana	13.2	0.85	11.8	15.2	6.44
North Dakota	13.4	0.62	12.6	15.2	4.63
South Dakota	13.3	0.90	12.2	15.8	6.77
Region	13.2	0.60	12.5	15.0	4.55
Flour Extraction					
Minnesota	69.2	1.1	67.4	71.2	1.59
Montana	68.4	1.0	66.7	70.3	1.46
North Dakota	68.9	0.6	68.0	70.1	0.87
South Dakota	67.9	1.0	65.9	69.6	1.47
Region	68.8	0.6	67.9	69.9	0.87
Ash					
Minnesota	0.46	0.03	0.40	0.52	6.52
Montana	0.43	0.04	0.39	0.52	9.30
North Dakota	0.45	0.03	0.40	0.49	6.67
South Dakota	0.46	0.04	0.41	0.53	8.70
Region	0.45	0.03	0.41	0.49	6.67
Wet Gluten					
Minnesota	34.3	3.0	29.0	39.4	8.75
Montana	36.1	2.5	32.8	42.5	6.93
North Dakota	36.5	1.9	33.5	41.4	5.21
South Dakota	35.9	2.7	31.8	42.5	7.52
Region	35.7	2.1	32.6	41.1	5.88

* Represents Average of State/Region Annual Observations.

Table 23. Average Annual Dough Characteristics, by State, 1980-1996.

	Mean	Std. Dev.	Min	Max	C.V.
Absorption - %					
Minnesota	62.8	1.8	58.6	66.4	2.87
Montana	66.0	2.5	62.6	70.3	3.79
North Dakota	65.3	1.5	63.0	68.9	2.30
South Dakota	64.8	2.1	61.4	69.2	3.24
Region	64.7	1.6	61.8	68.3	2.47
Peak Time - Minutes					
Minnesota	7.9	2.3	5.5	15.4	29.11
Montana	13.7	4.5	8.4	21.0	32.85
North Dakota	10.3	3.6	6.8	20.3	34.95
South Dakota	12.5	6.5	5.9	26.6	52.00
Region	10.5	3.3	7.2	18.6	31.43
Mix Tolerance - Minutes					
Minnesota	12.2	4.4	6.8	22.8	36.07
Montana	17.7	4.3	8.1	24.1	24.29
North Dakota	14.7	4.3	9.8	22.9	29.25
South Dakota	17.0	6.4	7.4	30.9	37.65
Region	14.9	4.1	10.3	23.5	27.52
Classification - Ranking (1-8)					
Minnesota	5.2	1.0	4.0	7.3	19.23
Montana	6.9	0.8	5.1	8.0	11.59
North Dakota	6.1	0.9	4.7	8.0	14.75
South Dakota	6.4	1.3	3.7	8.0	20.31
Region	6.0	0.8	4.8	7.8	13.33

* Represents Average of State/Region Annual Observations.

Table 24. Average Annual Baking Characteristics by State, 1980-1996.

Loaf Volume	Mean	Std. Dev.	Min	Max	C.V.
Minnesota	863	68	710	998	7.88
Montana	870	68	776	1041	7.82
North Dakota	906	50	840	1062	5.52
South Dakota	871	55	788	997	6.31
Region	883	52	817	1039	5.89

* Represents Average of State/Region Annual Observations.

Canadian Production Quality

Canada reports values for farm level wheat quality by grade and protein segregation for western Canada. Up to 1990, observations were reported for both western and eastern prairie production regions. However, after that time, observations were only reported for all of western Canada. Observations from annual crop quality reports were collected from 1981 to 1996 (less 1986 and 1988 when reports were unavailable). Observations for all protein segregations were not available in all years.

Average levels of protein for No. 1 and No. 2 CWRS were .4 percent to .5 percent over minimum protein levels for each segregation (Tables 25-27). Average coefficients of variation within protein segregations for production quality of CWRS No. 1 and No. 2 were .8 percent to .74 percent. This compares to the 1.0 percent and 1.4 percent average coefficient of variation reported for protein segregations of export shipments of No. 1 and No. 2 CWRS from 1973-1986 (Preston et al. 1988). Similarly, coefficients of variation for most other parameters for production quality protein segregations except falling numbers were similar to average coefficients of variation from export shipment protein segregations for both CWRS 1 and CWRS2.

Average levels for many quality characteristics increased for higher protein segregations. For example, falling numbers, wet gluten, loaf volumes, and absorption levels were generally higher for the higher protein segregations for both CWRS 1 and CWRS 2. However, other quality characteristics were lower for the higher protein segregations. This includes flour extraction, test weights, and kernel weights.

Table 25. Mean Quality Characteristics and Average Coefficients of Variation for Protein Segregations of CWRS 1, Production Quality Surveys, 1981-1996.

	CWRS 1 12.5%	CWRS 1 13.5%	CWRS 1 14.5%	Average CV
Observations	14	12	9	
Protein 12% MB	12.9	13.9	15	0.8
Test Weight	62.1	61.8	61.5	0.83
Kernel Weight	31.3	31.1	30.2	6.55
Falling Number	397	404	407	3.13
Extraction	75.6	75.5	75.3	0.86
Flour Protein	12.1	13.2	14.1	0.89
Wet Gluten	35.3	39.2	42.3	2.27
Ash	0.49	0.49	0.48	3.33
Loaf Volume	786	871	947	2.73
Absorption	64.7	65.2	65.4	1.72

Table 26. Mean Quality Characteristics and Average Coefficients of Variation for Protein Segregations of CWRS 2, Production Quality Surveys, 1981-1996.

	CWRS 2 12.5%	CWRS 2 13.5%	CWRS 2 14.5%	Average CV
Observations	13	11	6	
Protein 12% MB	12.9	13.9	15	0.74
Test Weight	60.8	60.6	60.3	1.1
Kernel Weight	31.2	31.2	29.9	6.43
Falling Number	385	384	386	6.72
Extraction	75.2	75.6	74.9	1.12
Flour Protein	12.1	13.1	14.1	0.88
Wet Gluten	35.1	38.8	42	2.37
Ash	0.5	0.49	0.49	4.36
Loaf Volume	798	876	958	2.49
Absorption	64.3	64.8	64.9	1.64

Table 27. Mean Quality Characteristics and Average Coefficients of Variation for Protein Segregations of CWRS 3, Production Quality Surveys, 1981-1996.

	CWRS3	Std. Dev.	CV
Observations	12		
Protein 12% MB	13.2	0.62	4.72
Test Weight	59.7	0.57	0.95
Kernel Weight	31.2	1.84	5.88
Falling Number	320	50.5	15.8
Extraction	74.9	0.59	0.79
Flour Protein	12.4	0.59	4.78
Wet Gluten	35.8	2.92	8.16
Ash	0.5	0.016	3.28
Loaf Volume	813	50	6.12
Absorption	64.5	1.24	1.92

EXPORT LEVEL QUALITY

Quality characteristics for United States exports of spring wheat were examined to measure the extent of quality variability of wheat exports. Export data available included information on average, high, and low protein, dockage, and moisture levels for United States wheat export shipments and average levels for other grade/non-grade characteristics (test weight, vitreous kernels, total damage, foreign material, shrunken and broken kernels, and total defects) (USDA-GIPSA). Variability of wheat quality characteristics was estimated by marketing year and grade to determine the extent of quality variability in United States HRS exports. Then shipments were examined for a number of large HRS importers to determine variability in quality characteristics for individual importing countries. Quality characteristics are contrasted to Canadian exports where Canadian data were available.

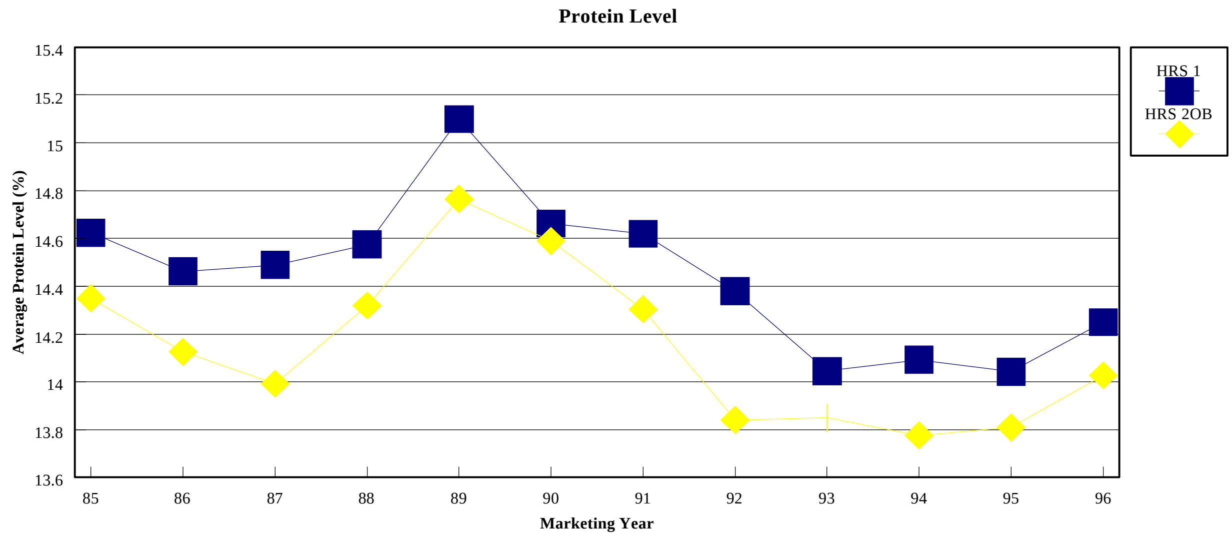
Average protein levels, variability of average protein levels, and the range of protein samples within shipments were examined to establish the variability of protein in United States wheat exports. Average protein levels for United States exports of No.1 HRS within marketing years have varied from a high of 15.1 percent in 1989 to a low of 14.0 percent in 1993 and 1995 (Table 28, Figure 1). Average protein levels for shipments of No. 2 or better HRS have generally been lower than those for No. 1 HRS, ranging between a high of 14.8 percent in 1989 to a low of 13.8 percent in 1992, 1994, and 1995. Variability of average protein levels between shipments for No. 1 HRS has ranged from a standard deviation of .05 percent in 1995 to a high of .39 percent protein in 1989. Variability of average protein levels between shipments for United States HRS No. 2 or better was higher than for United States HRS No. 1 for 6 of the 12 years examined. This higher variability between shipments could be influenced to some extent by the higher number of shipments being exported as No. 2 OB than as No. 1 (Over 90 percent of U.S. export shipments of HRS were shipped as No. 2 OB for most years from 1986 to 1994 (Dahl and Wilson, 1996)).

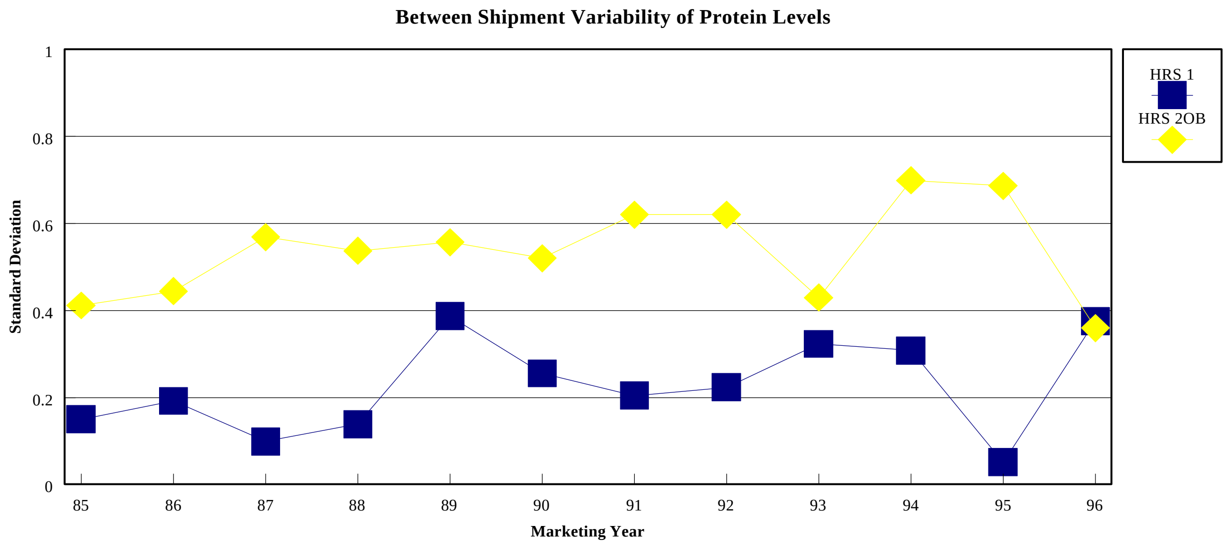
Within-shipment observations for protein variability were not available except as high and low levels of sublot samples. Comparison of the within-shipment variability measured by the range of protein observations within shipments indicates a decline in the range of variability, especially for exports of U.S. No. 1 HRS. The average range of protein samples declined from .83 percent protein in 1985 to .33 percent in 1994. Within-shipment variability for U.S. No. 2 OB HRS also suggests a general trend toward declining variability within shipments. In most years after 1989, the within-shipment range for No. 2 OB is within .10 percent protein of that for the within-shipment range for No.1 HRS. This suggests that within-shipment variability between shipments of No. 1 and No. 2 OB should not be significantly different.

Table 28. Average Protein Level, Between-shipment Variability, and Within-shipment Range of Protein Levels for U.S. HRS Exports, by Grade, 1985-1996.

Marketing Year	Average Protein Level		Between Shipment Variability of Average Protein			Within Shipment Range of Protein Levels*	
	HRS-1	HRS-2OB	HRS-1	HRS-2OB		HRS-1	HRS-2OB
	--Percent Protein--		--Std. Dev. --			--Percent Protein--	
1985	14.6	14.4	0.15	0.41		0.83	0.51
1986	14.5	14.1	0.19	0.44		0.58	0.42
1987	14.5	14.0	0.10	0.57	**	0.58	0.51
1988	14.6	14.3	0.14	0.54	**	0.51	0.50
1989	15.1	14.8	0.39	0.56		0.44	0.56
1990	14.7	14.6	0.26	0.52		0.47	0.48
1991	14.6	14.3	0.20	0.62	**	0.55	0.52
1992	14.4	13.8	0.22	0.62	**	0.54	0.50
1993	14.0	13.9	0.32	0.43		0.42	0.43
1994	14.1	13.8	0.31	0.70	**	0.33	0.42
1995	14.0	13.8	0.05	0.69	**	0.52	0.50
1996	14.3	14.0	0.38	0.36		0.38	0.36

* Range represents the highest protein level for sublots - low protein level for sublots within a shipment.
** Statistically different p>= .05.





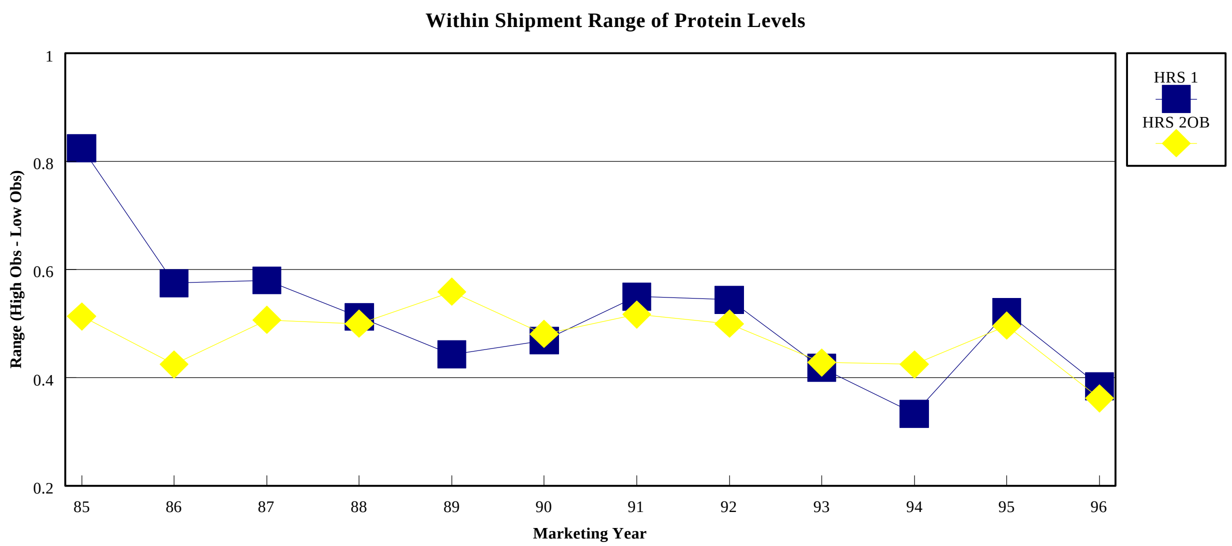


Figure 1. Average Protein Levels, Between-shipment Variability of Protein, and Within-shipment Range of Protein Levels, U.S. HRS Exports, by Grade, Marketing Years 1985/86 to 1996/97.

Dockage

Dockage in exports of U.S. HRS was reported for average, minimum, and maximum values for export shipments. Average dockage levels and within-shipment ranges were generally higher in most years for HRS No. 2 OB than for HRS No. 1. Average dockage levels by marketing year suggest a general decline in dockage levels for HRS 1 from high levels in 1987 (0.91 percent) to lower dockage levels in 1996 (0.44 percent) (Table 29, Figure 2). Similarly, the range in variation among sublots within-shipments for HRS No.1 appears to decline from a high of 0.51 percent in 1987 to a low of 0.19 percent in 1996. However, trends for levels or within-shipment ranges for HRS No. 2 OB are less apparent.

Variability between shipments for dockage ranged from standard deviations of 0.11 percent to 0.33 percent for HRS No. 1 and 0.12 percent to 0.41 percent for HRS No. 2 OB. Standard deviations of No. 2 OB were lower than for No.1 for 8 of the 12 years (1985-1996). This suggests that although dockage levels and within-shipment dockage ranges for No. 1 HRS were generally lower than for No. 2 OB, variability in average levels between shipments of No. 1 was higher than for No. 2 OB in more years.

Table 29. Average Dockage Level, Between-shipment Variability, and Within-shipment Range of Dockage Levels for U.S. HRS Exports, by Grade, 1985-1996.

Marketing Year	Average Dockage Level		Between Shipment Variability of Average Dockage			Within Shipment Range of Dockage Levels*	
	HRS-1	HRS-2OB	HRS-1	HRS-2OB		HRS-1	HRS-2OB
	--Percent Dockage--		--Std. Dev. --			--Percent Dockage--	
1985	0.54	0.55	0.32	0.41		0.30	0.20
1986	0.80	0.98	0.31	0.28		0.39	0.38
1987	0.91	0.87	0.23	0.22		0.51	0.43
1988	0.72	0.82	0.11	0.18		0.42	0.33
1989	0.63	0.71	0.19	0.16		0.25	0.31
1990	0.64	0.70	0.13	0.12		0.25	0.31
1991	0.73	0.84	0.18	0.24		0.34	0.39
1992	0.70	0.79	0.18	0.16		0.30	0.38
1993	0.62	0.82	0.33	0.17	**	0.25	0.38
1994	0.65	0.75	0.15	0.16		0.26	0.34
1995	0.56	0.76	0.24	0.16		0.23	0.36
1996	0.44	0.70	0.26	0.18		0.19	0.30

* Range represents the highest dockage level for sublots - low dockage level for sublots within a shipment.

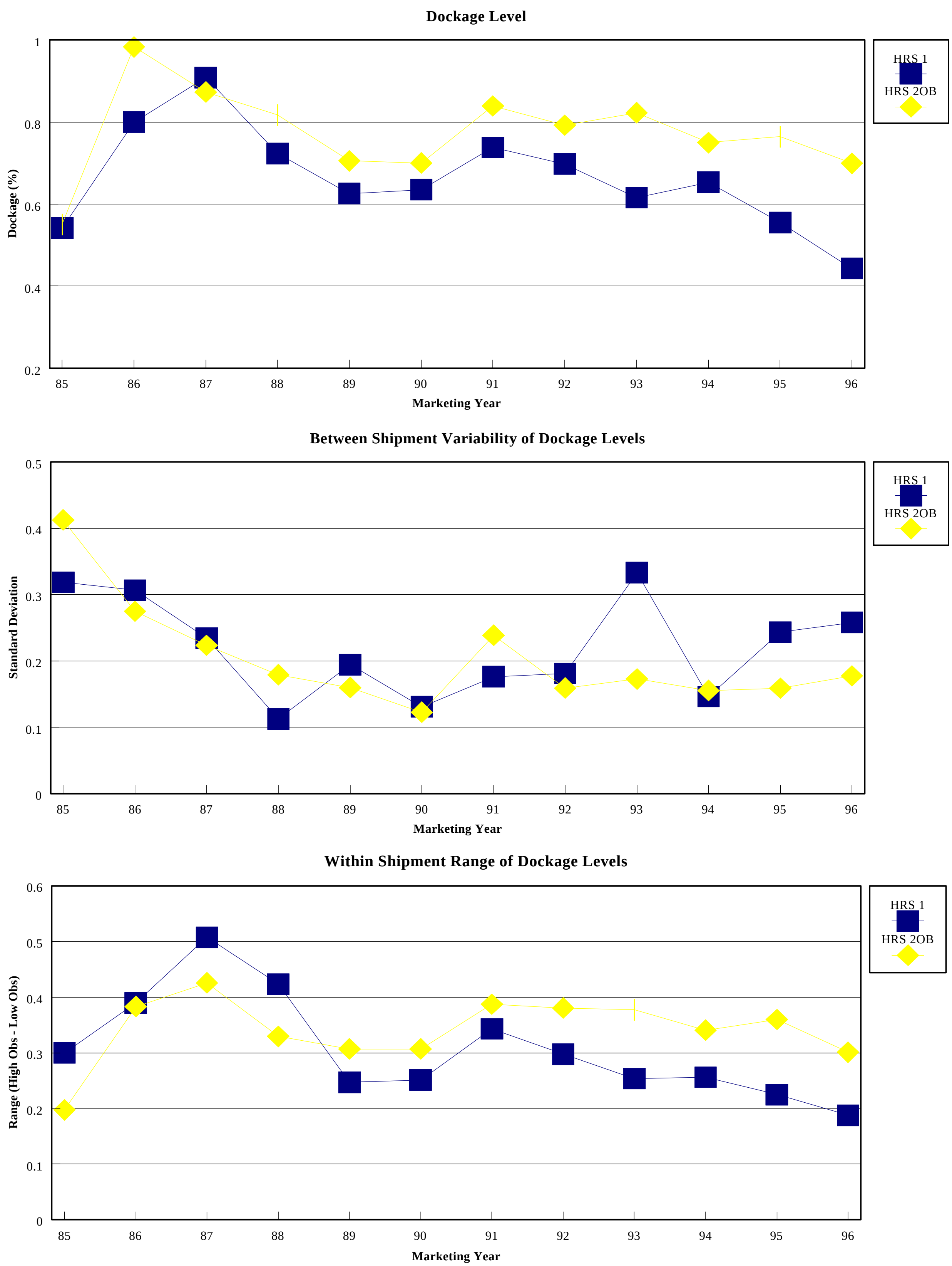


Figure 2. Average Dockage Levels, Between-shipment Variability of Dockage and Within-shipment Range of Dockage Levels, U.S. HRS Exports, by Grade, Marketing Years 1985/86 to 1996/97.

Other Grade/Non-grade Factors

Other grade and non-grade factors are measured for U.S. export shipments. Only average levels were available by shipment. This only allows for comparison of between-shipment variability across years and grades. Factors compared included test weights, percent vitreous kernels, total damaged kernels, shrunken and broken kernels, and total defects.

Average levels of test weights were higher for exports of No. 1 HRS than for No. 2 OB HRS from 1985/86 to 1996/97 (Figure 3). Meanwhile, between-shipment variability was generally higher for HRS No. 2 OB than for HRS No. 1 in most years (Figure 4). In 1994/95 and 1995/96, between-shipment variability of test weights for exports of No. 1 was higher than for exports of No. 2 OB HRS.

Similarly, average levels of vitreous kernels were higher for exports of No. 1 HRS than for No. 2 OB in most years (Figure 5). Only in the past marketing year (1996/97) were average levels of vitreous kernels lower in exports of No. 1 than in exports of No. 2 OB. Variability of vitreous kernels levels between-shipments generally had average standard deviations between 20 to 40 percent for both grades (Figure 6). However, from 1986 to 1988, HRS No. 1 had very high average levels of vitreous kernels, and standard deviations for between-shipment variability were less than 5 percent.

Average levels of total damaged kernels for export shipments of HRS No. 1 have been lower than for exports of No 2 OB from 1985 to 1996/97 (Figure 7). Variability of total damaged kernels between-shipments has also been lower for exports of No. 1 than for exports of No. 2 OB HRS over this period (Figure 8). Since total damaged kernels is a grade determining factor, it is not surprising that higher grades have lower levels and lower variability than the lower grades.

Comparison of average levels and between-shipment variability of shrunken and broken kernels across marketing years reveals a more mixed result. While average levels of shrunken and broken kernels are lower in most marketing years for HRS No. 1 than HRS No. 2 OB, variability between-shipments for No. 1 has been higher than for No. 2 OB since 1992/93 (Figures 9-10).

Finally, average levels of total defects were higher for exports of No 2 OB HRS than for No. 1 from 1986/87 to 1996/97 (Figure 11). Variability of total defects between-shipments has been lower for No. 1 HRS except for 1995/96 and 1996/97 when between-shipment variability was lower for exports of No. 2 OB (Figure 12). In addition, while average levels of total defects have generally trended higher for exports of No. 2 OB from 1985/86 to 1996/97, between-shipment variability for No. 2 OB has generally declined over the same period.

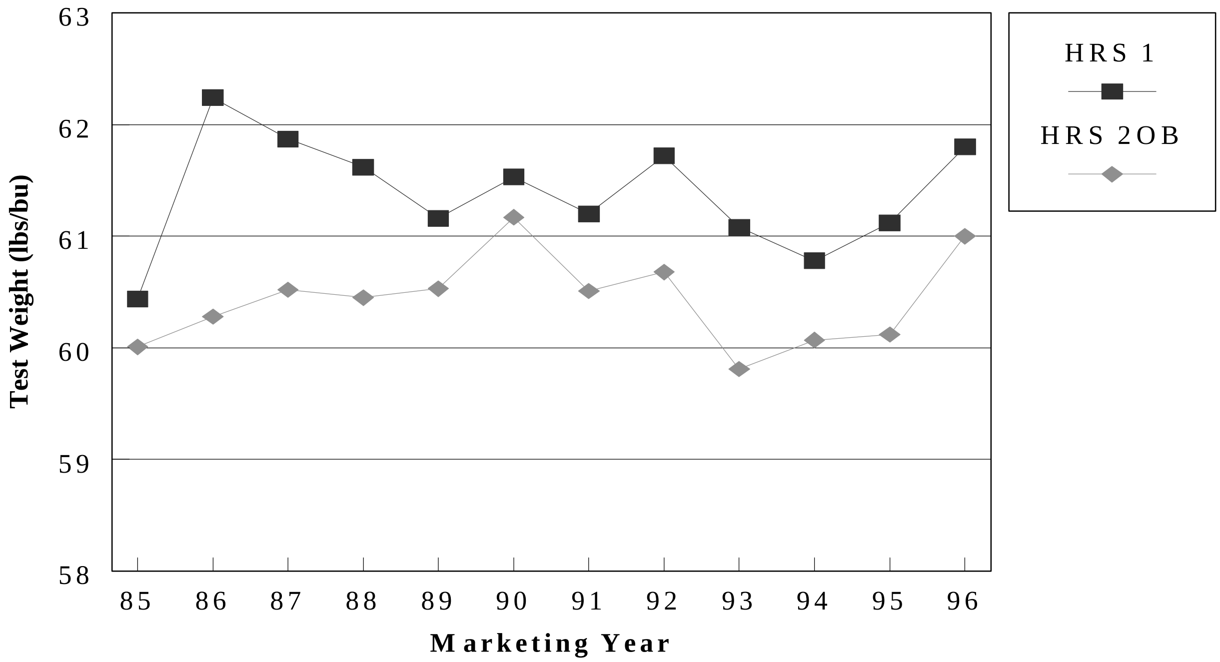


Figure 3. Average Test Weight Levels for U.S. HRS Exports, by Grade and Marketing Year, 1985/86 to 1996/97.

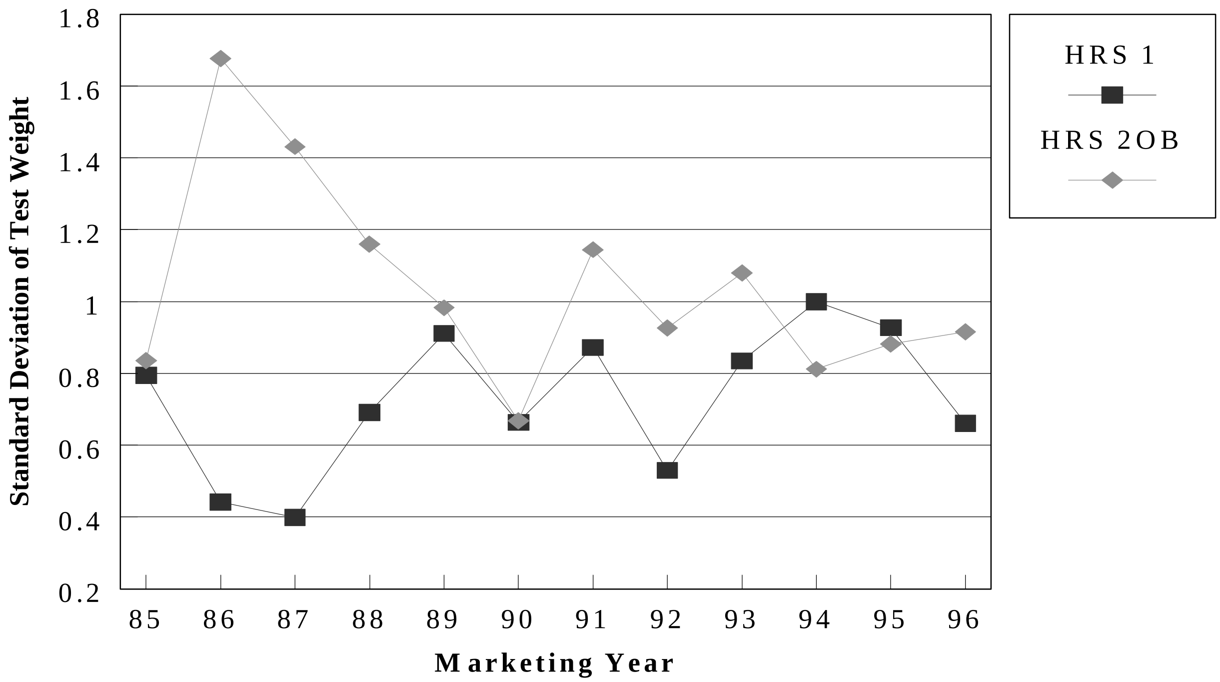


Figure 4. Standard Deviation of Average Test Weight Levels Between Shipments for U.S. HRS Exports, by Grade and Marketing Year, 1985/86 to 1996/97.

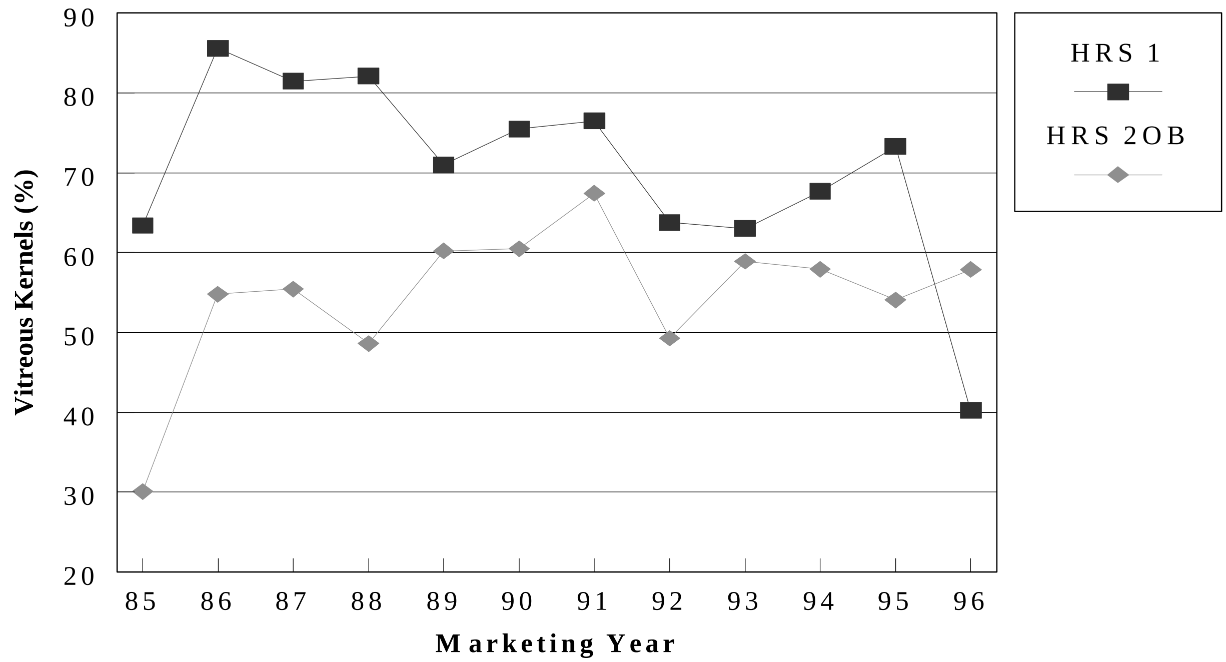


Figure 5. Average Percent Vitreous Kernels for U.S. HRS Export Shipments, by Grade, Marketing Years 1985/86 to 1996/97.

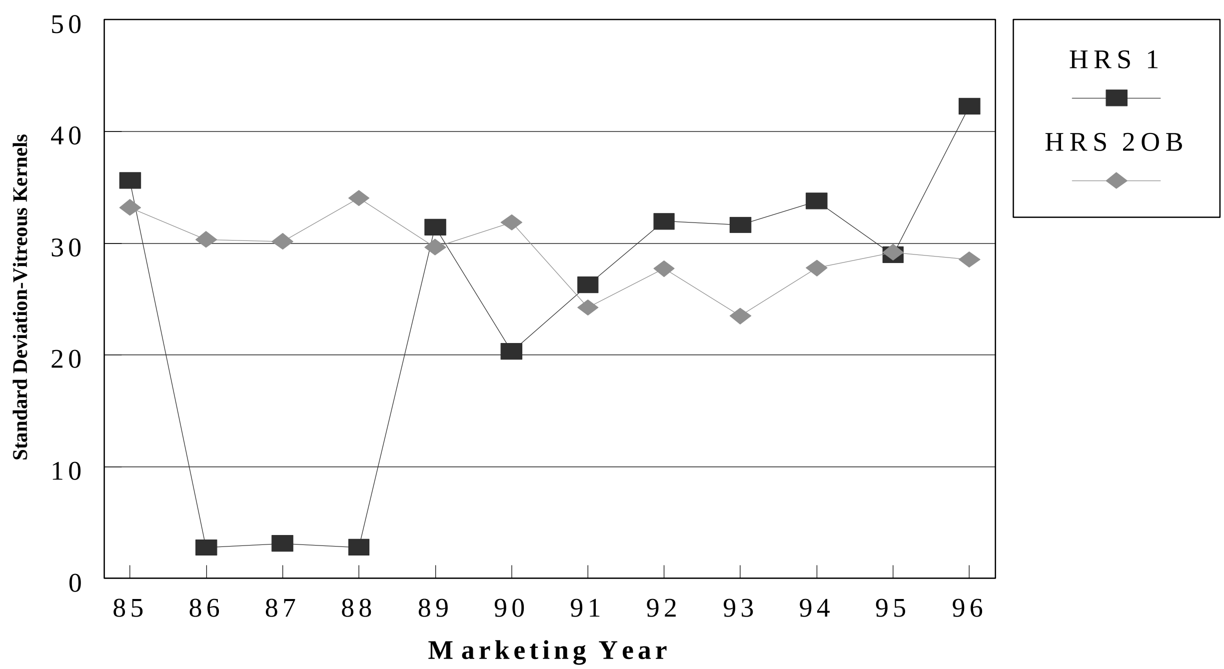


Figure 6. Standard Deviation of Average Vitreous Kernel Levels for U.S. HRS Export Shipments, by Grade, Marketing Years 1985/86 to 1996/97.

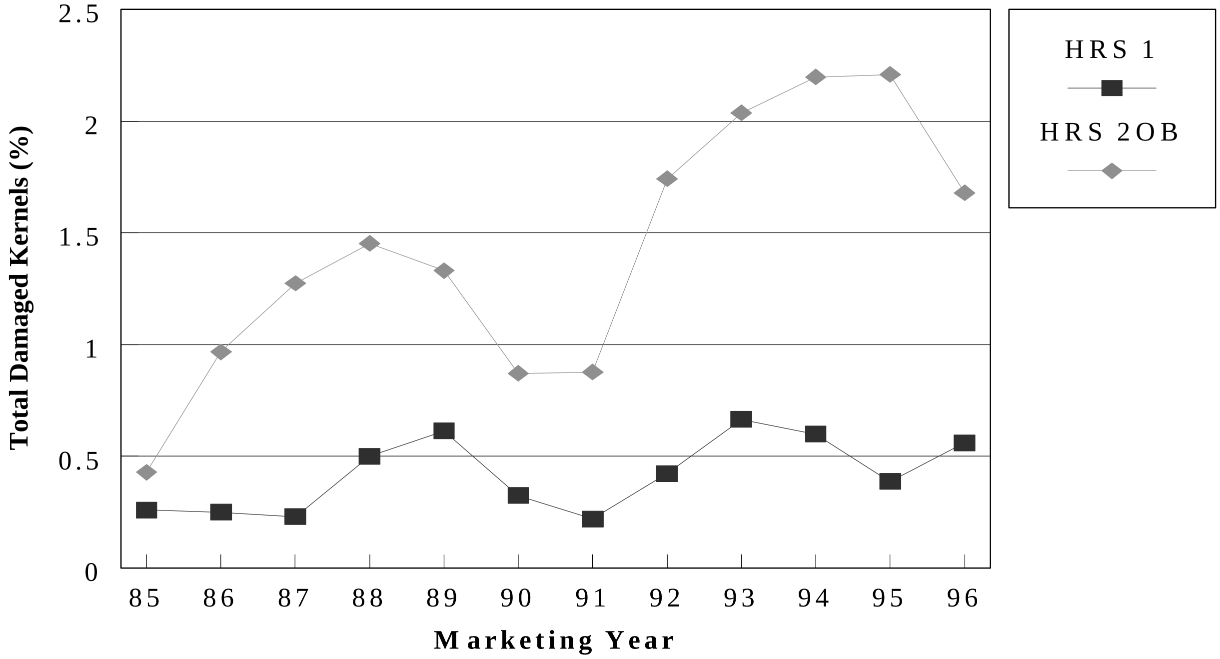


Figure 7. Average Total Damaged Kernel Levels for U.S. HRS Export Shipments, by Grade, Marketing Years 1985/86 to 1996/97.

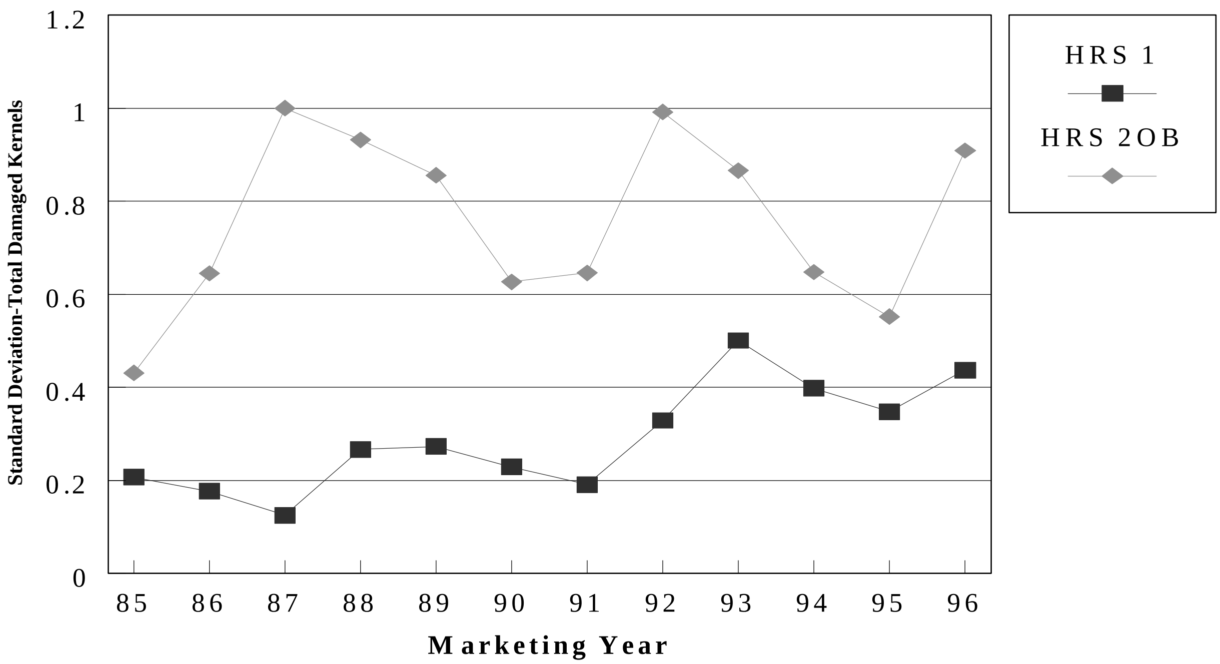


Figure 8. Standard Deviation of Total Damaged Kernels for U.S. HRS Exports, by Grade, Marketing Years 1985/86 to 1996/97.

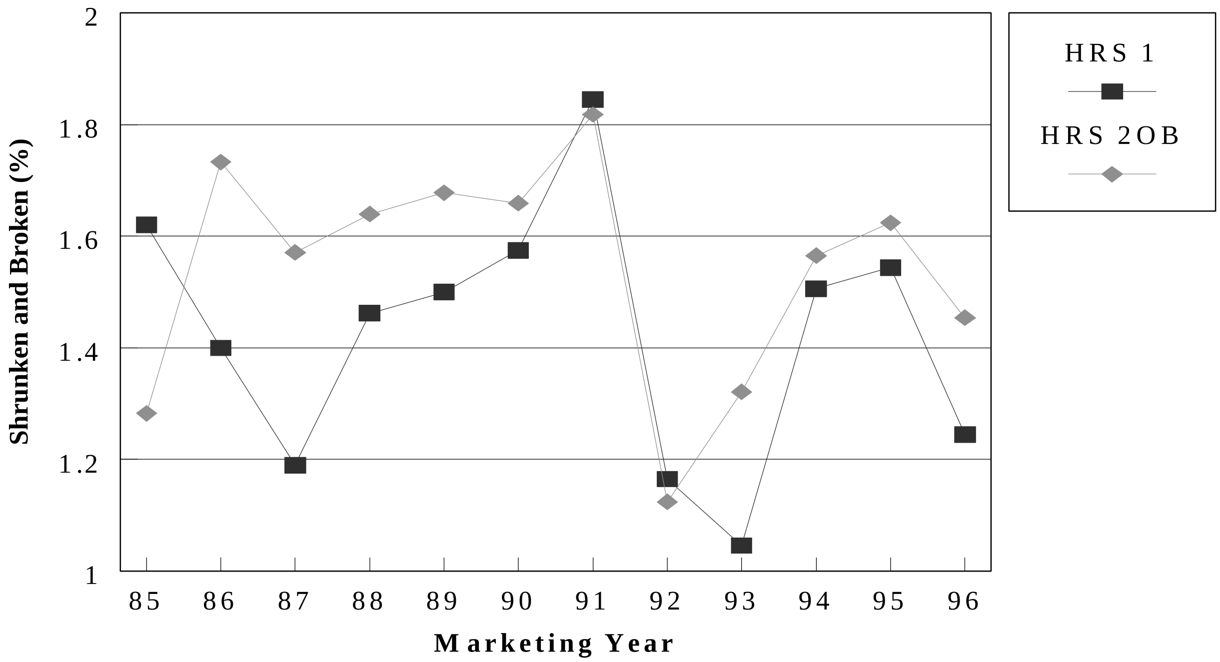


Figure 9. Average Shrunken and Broken Levels for U.S. HRS Export Shipments, by Grade, Marketing Years 1985/86 to 1996/97.

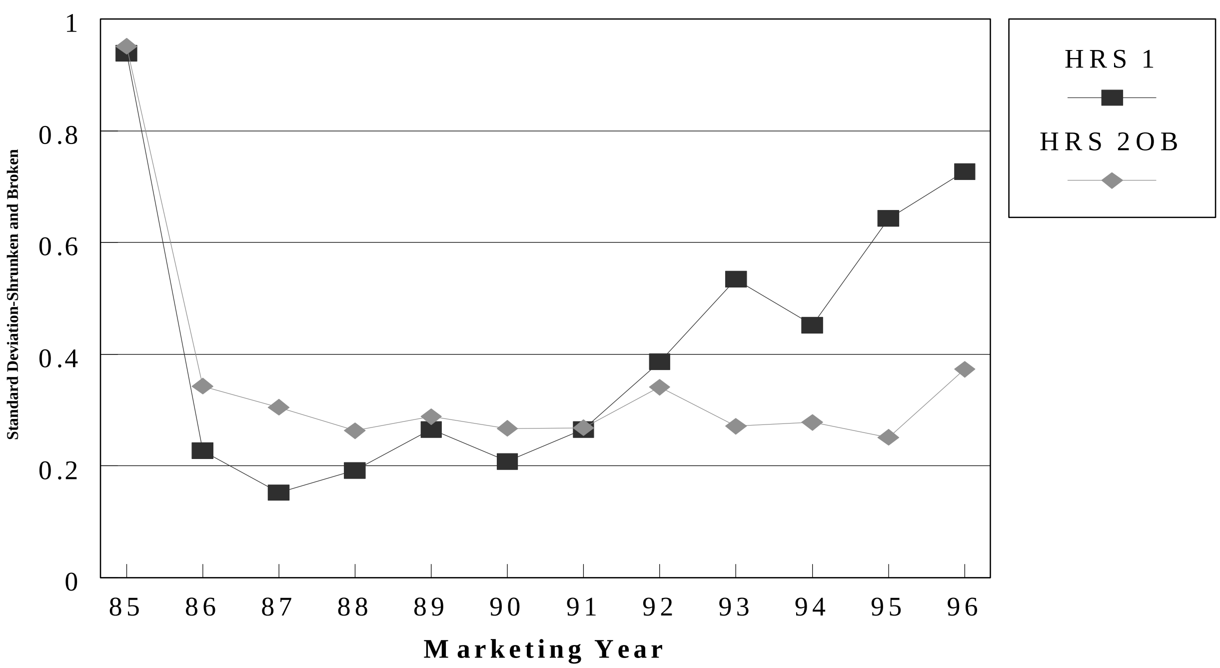


Figure 10. Standard Deviation of Shrunken and Broken Levels for U.S. HRS Export Shipments, by Grade, Marketing Years 1985/86 to 1996/97.

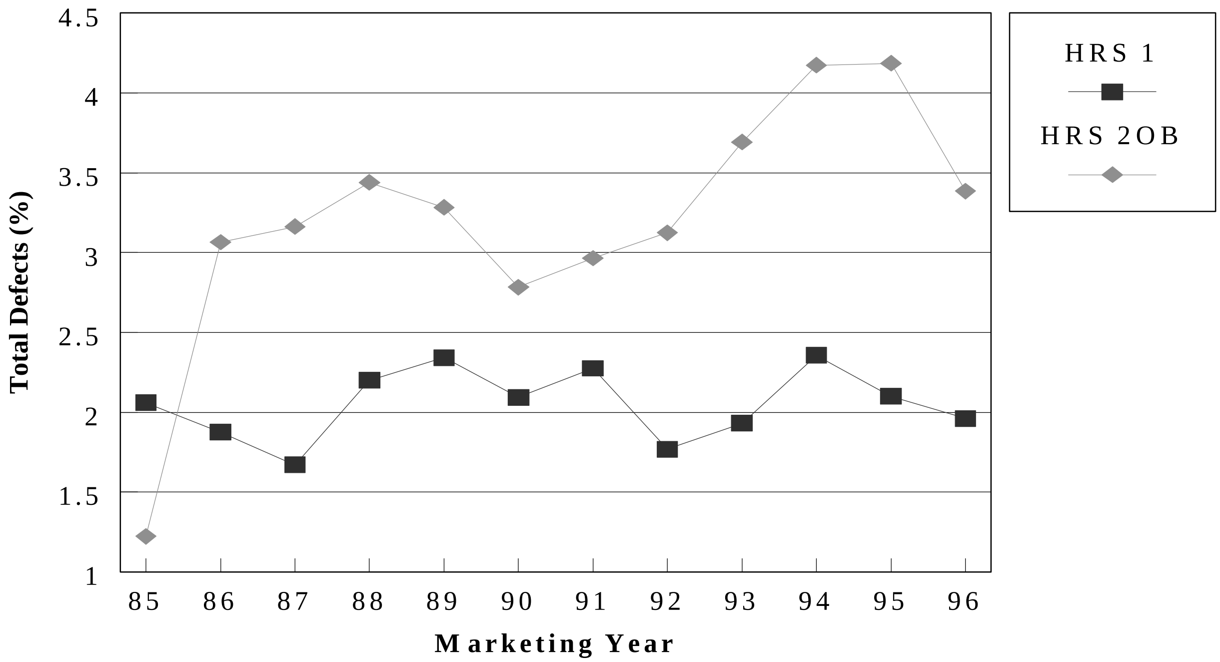


Figure 11. Average Total Defects for U.S. HRS Export Shipments, by Grade, Marketing Years 1985/86 to 1996/97.

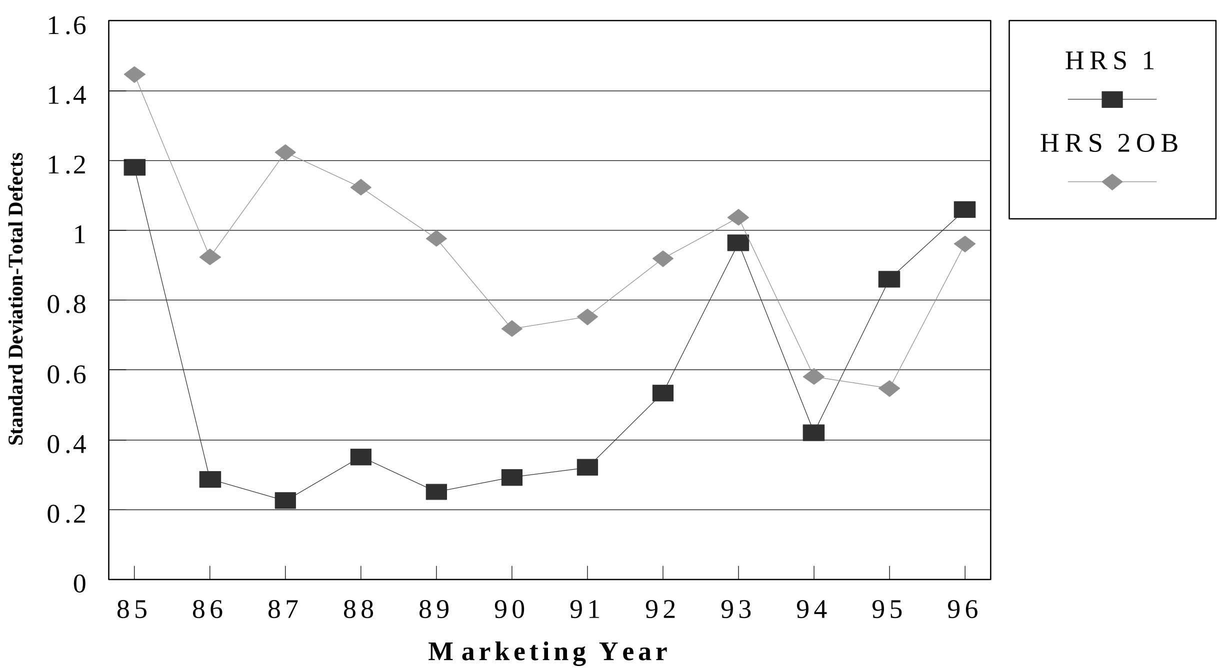


Figure 12. Standard Deviation of Total Defects for U.S. HRS Export Shipments, by Grade, Marketing Years 1985/86 to 1996/97.

Canada Export Quality Data

Data for CWRS exports were collected from 1991/92 to 1996/97 marketing years. These data are published on a semi-annual basis and have observations by grade/protein segregation for Atlantic and Pacific shipments for each half of the marketing year. Before 1991, observations were reported quarterly.

Average coefficients of variation within protein segregations for a number of wheat, flour, and baking characteristics were similar to those in the production surveys and to that by Preston et al., 1988 (Tables 30-31). However, average coefficients of variation for kernel weights for CWRS1 were 3.01 percent compared to 6.55 percent for the production quality. In addition, average coefficients of variation for loaf volumes were dramatically higher for exports from 1991/92-1996/97 than from those estimated by Preston et al. (1988) for both CWRS1 and CWRS2. Coefficients of variation for exports of CWRS1 were 11.34 percent and for CWRS2 were 11.9 percent compared to the 2.9 percent and 3.2 percent estimated by Preston et al. (1988) for CWRS1 and CWRS2, respectively.

Comparisons of coefficients of variation across grades (CWRS1 and CWRS2) indicate that variability for the two grades is similar. For some characteristics, CWRS1 had higher coefficients of variation, while for others, CWRS2 had higher CVs. However, differences between the two grades were generally not substantial, except for ash which was over 3 times higher for exports of CWRS 2 (12.52 percent) than for CWRS 1 (3.66 percent).

Table 30. Comparison of Canadian Export Quality of CWRS1, Protein Segregation, and Port Location, 1991-1996.

	12.5		**13.5**		**14.5**		
CWRS1	**Atlantic**	**Pacific**	**Atlantic**	**Pacific**	**Atlantic**	**Pacific**	**Avg CV**
Wheat Protein	12.9	12.85	13.9	13.88	15.03	14.93	0.88
Test Weight	62.33	62.56	62.13	61.28	61.57	62.08	1.41
WOC	0.31	0.18	0.3	0.2	0.26	0.16	27.66
CGOTW	0.16	0.16	0.17	0.17	0.14	0.15	14.79
Kernel Weight	31.07	32.15	30.6	31.83	29.88	29.93	3.01
Falling Number	401	395	413	394	413	411	3.86
Flour Yield	75.74	76.05	75.55	75.95	75.73	75.1	0.78
Flour Protein	12.19	12.12	13.11	13.1	14.18	14.05	1.65
Wet Gluten	34.84	34.57	37.8	38.25	40.92	41.23	3.81
Ash	0.5	0.5	0.51	0.49	0.51	0.48	3.66
Absorption	64.12	64.87	64.48	65.39	64.92	65.53	1.02
Development Time	4.53	4.55	5.16	5.25	5.67	5.81	6.83
MTI	28.33	27.27	25.63	24.38	23.33	20	17.96
Stability	9.39	9.09	10.69	10.69	11.42	13.88	13.01
Loaf Volume	851	851	956	958	1050	1006	11.34

Table 31. Comparison of Canadian Export Quality for CWRS2, Protein Segregation, and Port Location, 1991-1996.

	12.5		13		13.5		
CWRS2	**Atlantic**	**Pacific**	**Atlantic**	**Pacific**	**Atlantic**	**Pacific**	**Avg CV**
Wheat Protein	13.07	12.88	13.48	13.36	14.00	13.90	0.98
Test Weight	60.84	61.71	60.75	61.61	60.62	61.18	1.23
WOC	0.46	0.27	0.42	0.26	0.51	0.26	32.78
CGOTW	0.29	0.29	0.27	0.24	0.31	0.3	31.91
Kernel Weight	30.81	32.03	30.6	32.29	30.08	31.61	3.01
Falling Number	368.00	375.00	358.00	382.00	356.00	370.00	7.49
Flour Yield	75.59	75.77	75.77	75.83	75.24	75.60	0.78
Flour Protein	12.28	12.10	12.68	12.60	13.26	13.09	1.08
Wet Gluten	35.37	34.34	35.82	36.20	37.99	38.24	3.73
Ash	0.52	0.60	0.52	0.50	0.52	0.50	12.52
Absorption	63.59	64.56	63.93	65.33	64.08	64.85	1.05
Development Time	4.53	4.57	4.92	5.08	5.25	5.34	7.37
MTI	29.44	28.64	30	28.33	29.44	25.91	11.09
Stability	9.11	9.05	8.75	9.53	9.89	10.68	12.10
Loaf Volume	868	857	960	914	950	935	11.9

Comparison of Quality Consistency by Importer

Variability of U.S. HRS exports were examined by grade and importer to evaluate consistency of shipments for importers. Only variability for larger importers was contrasted. Exports of US HRS were examined for two grades, U.S. No. 1 and U.S. No. 2 OB, for selected importers over the marketing years 1986 to 1996. Average quality characteristics for protein, dockage, test weight, vitreous kernels, foreign material, damaged kernels, shrunken and broken, and total defects were measured for each of the grades for importing countries that imported significant numbers of shipments over this period.

Korea, Belgium, and Taiwan imported significant numbers of shipments of HRS No. 1 from 1986 to 1996. Average protein levels for shipments for these countries ranged from a low of 14.2 percent for Korea to a high of 14.6 percent for Belgium (Table 32). Variability of average protein levels between-shipments was lowest in Korea (Standard deviation=0.3 percent) and highest in Belgium (Standard deviation=0.51 percent). The range of average protein levels for shipments ranged from 13.5 percent to 15.5 percent for these three countries. The average variation of the range of within-shipment protein observations (high protein - low protein) was lowest for Belgium (0.2 percent) and highest for Taiwan (0.61 percent). The range of within-shipment variations was widest in Taiwan (0.0 percent to 1.8 percent).

Table 32. Variability of Protein Levels and Range of Within-shipment Protein Observations for No. 1 HRS Shipments, by Country, 1986-1996.

Country	Mean	Std	Min	Max	CV
Average Protein Level					
Belgium	14.6	0.51	14.0	15.2	3.49
Taiwan	14.4	0.33	13.6	15.5	2.29
Korea	14.2	0.30	13.5	15.0	2.11
Range of Protein Observations					
Belgium	0.2	0.09	0.1	0.3	
Taiwan	0.61	0.28	0.0	1.8	
Korea	0.44	0.26	0.0	1.4	

A number of countries imported significant shipments of HRS No. 2 OB. Observations are reported for 11 of these importing countries. Bangladesh had the lowest average protein level across HRS No. 2 OB shipments (12.2 percent) (Table 33). The remainder of the countries had average protein levels across shipments of 13.9 to 14.8 percent protein. Variability of average protein levels between-shipments was least variable for El Salvador (Standard deviation=0.2 percent) and most variable for Bangladesh (Standard deviation=0.65 percent). Average within-shipment variability measured at (high - low) of protein observations for sublots were lowest for Belgium (0.3 percent) and highest for Bangladesh (0.83 percent). For the two countries that imported both U.S. No. 1 and No. 2 OB in significant numbers of shipments (Belgium and Korea), variability of protein both within and across shipments for this period was similar across grades.

Table 33. Variability of Protein Levels and Range of Within-shipment Protein Observations for No. 2 OB HRS Shipments, by Country, 1986-1996.

Country	Mean	Std	Min	Max	CV
Average Protein Level					
Bangladesh	12.2	0.65	11.1	14.0	5.33
Belgium	14.6	0.55	14.0	15.6	3.77
Dom. Rep.	14.2	0.51	13.4	15.5	3.59
El Salvador	14.2	0.20	14.0	14.6	1.41
Honduras	14.2	0.32	13.6	15.0	2.25
Hong Kong	14.8	0.42	13.3	15.4	2.84
Italy	14.6	0.57	13.6	16.1	3.90
Japan	14.2	0.37	13.9	16.1	2.61
Korea	14.6	0.26	14.0	15.5	1.78
Philippines	13.9	0.44	10.0	14.9	3.17
Venezuela	14.2	0.42	13.2	15.5	2.96
Range of Within-shipment Protein Observations					
Bangladesh	0.83	0.39	0.2	1.6	
Belgium	0.30	0.17	0.0	0.6	
Dom. Rep.	0.49	0.26	0.1	1.2	
El Salvador	0.44	0.21	0.1	1.0	
Honduras	0.38	0.22	0.0	0.9	
Hong Kong	0.42	0.22	0.1	1.0	
Italy	0.31	0.22	0.0	1.2	
Japan	0.53	0.22	0.0	1.2	
Korea	0.37	0.24	0.0	1.2	
Philippines	0.52	0.21	0.0	1.1	
Venezuela	0.46	0.31	0.0	1.8	

Dockage levels were compared for importing counties by grade (No.1 HRS or No. 2 OB HRS). Average levels of dockage for shipments of No. 1 HRS were lowest for Belgium (0.51 percent) and highest for Taiwan and Korea (0.69 percent) (Table 34). All three importing countries had similar variation in average dockage levels across shipments for HRS No. 1 (Standard deviation=0.18-0.19 percent). Average within-shipment consistency ranged from a low of 0.21 percent and 0.24 percent in Korea and Belgium, respectively, to a high of 0.4 percent for Taiwan.

Average dockage levels for HRS No. 2 OB ranged from a low of 0.53 percent for Hong Kong to a high of .85 percent for Honduras (Table 35). Variability of average dockage levels across shipments ranged from a low (Standard deviation=.1 percent) in Bangladesh to a high (Standard deviation=.45 percent) in Belgium. Within-shipment variability measured at from high to low sublot observations ranged from a low of .18 percent in Korea to a high of .42 percent in both Bangladesh and the Philippines. Unlike protein, average dockage levels were higher for Belgium imports of No. 2 OB than for No. 1 (0.51 percent vs. 0.74 percent). In addition, the variation of average dockage levels was higher for exports of HRS No. 2 OB to both Belgium and Korea (HRS No. 1 - standard deviation=0.19 percent and 0.18 percent versus HRS No. 2 OB - standard deviation=0.45 percent and 0.35 percent, respectively).

Table 34. Variability of Dockage Levels and Range of Within-shipment Dockage Observations for No. 1 HRS Shipments, by Country, 1986-1996.

Country	Mean	Std	Min	Max	CV
Average Dockage Level					
Belgium	0.51	0.19	0.28	0.86	37.25
Taiwan	0.69	0.19	0.00	1.38	27.54
Korea	0.69	0.18	0.00	1.24	26.09
Range of Dockage Observations					
Belgium	0.21	0.11	0.10	0.40	
Taiwan	0.40	0.20	0.10	1.02	
Korea	0.24	0.14	0.00	0.70	

Table 35. Variability of Dockage Levels and Range of Within-shipment Dockage Observations for No. 2 OB HRS Shipments, by Country, 1986-1996.

Country	Mean	Std	Min	Max	CV
Average Dockage Level					
Bangladesh	0.79	0.10	0.56	0.92	12.66
Belgium	0.74	0.45	0.00	1.81	60.81
Dom. Rep.	0.74	0.33	0.00	1.20	44.59
El Salvador	0.69	0.33	0.00	1.08	47.83
Honduras	0.85	0.26	0.00	1.40	30.59
Hong Kong	0.53	0.41	0.00	1.27	77.36
Italy	0.68	0.39	0.00	1.85	57.35
Japan	0.61	0.30	0.00	1.35	49.18
Korea	0.57	0.35	0.00	1.21	61.40
Philippines	0.74	0.24	0.00	1.37	32.43
Venezuela	0.69	0.34	0.00	1.38	49.28
Range of Within-shipment Dockage Observations					
Bangladesh	0.42	0.11	0.23	0.60	
Belgium	0.22	0.17	0.00	1.61	
Dom. Rep.	0.28	0.21	0.00	0.91	
El Salvador	0.32	0.26	0.00	0.96	
Honduras	0.31	0.21	0.00	0.95	
Hong Kong	0.20	0.21	0.00	0.80	
Italy	0.25	0.21	0.00	1.17	
Japan	0.30	0.21	0.00	0.95	
Korea	0.18	0.20	0.00	1.42	
Philippines	0.42	0.25	0.00	1.80	
Venezuela	0.31	0.23	0.00	1.20	

Average levels of test weight No. 1 HRS from 1986 to 1996 for the three importing countries ranged from 61.3 to 61.6 lbs/bu (Table 36). Test weights for imports of No. 1 to Belgium varied most with tests weights for shipments ranging from 59.6 to 62.5 lbs/bu (Standard deviation=1.11 lbs/bu). Average levels for test weight for countries importing No. 2 OB ranged from a low of 59.8 lbs/bu for Belgium, the Dominican Republic, and Italy to a high of 61.6 lbs/bu for Bangladesh (Table 37). Variability of levels of test weights between-shipments for importing countries were similar across grades. Standard deviations for test weights ranged from .74 to 1.11 lbs/bu for No. 1 and .76 to 1.2 lbs/bu for No. 2 OB.

Table 36. Variability of Test Weight and Vitreous Kernel Levels for No. 1 HRS Shipments, by Country, 1986-1996.

Country	Mean	Std	Min	Max	CV
Test Weight					
Belgium	61.5	1.11	59.6	62.5	1.80
Taiwan	61.6	0.74	59.4	63.2	1.20
Korea	61.3	0.87	59.3	62.7	1.42
Vitreous Kernels					
Belgium	-NA-	-NA-	-NA-	-NA-	-NA-
Taiwan	81.6	3.73	75	90	4.57
Korea	81.8	5.14	65	91	6.28

Levels of Vitreous Kernels were not available for all shipments for specific countries.

Table 37. Variability of Test Weight and Vitreous Kernel Levels for No. 2 OB HRS Shipments, by Country, 1986-1996.

Country	Mean	Std	Min	Max	CV
Test Weight					
Bangladesh	61.6	0.76	60.3	62.7	1.23
Belgium	59.8	0.93	57.5	61.8	1.56
Dom. Rep.	59.8	0.93	58.1	62.2	1.56
El Salvador	60.2	1.04	58.7	62.3	1.73
Honduras	60.0	1.20	57.1	62.4	2.00
Hong Kong	61.1	0.86	59.2	61.3	1.41
Italy	59.8	1.00	57.7	62.6	1.67
Japan	61.2	0.96	58.8	64.0	1.57
Korea	61.5	0.86	59.1	63.5	1.40
Philippines	60.8	1.10	58.2	63.4	1.81
Venezuela	60.0	0.84	57.5	62.0	1.40
Vitreous Kernels					
Bangladesh	71.7	5.24	63	81	7.3
Belgium	-NA-	-NA-	-NA-	-NA-	-NA-
Dom. Rep.	60.3	7.76	40	80	12.9
El Salvador	66.4	9.04	52	83	13.6
Honduras	61.1	8.77	40	79	14.4
Hong Kong	83.0	3.93	73	92	4.7
Italy	-NA-	-NA-	-NA-	-NA-	-NA-
Japan	78.3	6.25	59	97	8.0
Korea	80.6	5.74	67	94	7.1
Philippines	75.4	7.09	27	90	9.4
Venezuela	64.5	8.42	48	83	13.1

Comparisons of average levels for damaged kernels by country indicated that Taiwan and Korea had levels of defects that were on average less than half those for Belgium imports of No. 1

(Table 38). Variation of damaged kernels between-shipments was similar for all three countries importing No. 1 HRS. Standard deviations for damaged kernels ranged from .29 percent for Taiwan to .38 percent for Belgium.

Table 38. Variability of Total Damaged Kernels and Foreign Material for No. 1 HRS Shipments, by Country, 1986-1996.

Country	Mean	Std	Min	Max	CV
Average Total Damaged Kernels					
Belgium	1.00	0.38	0.20	1.60	38.00
Taiwan	0.43	0.29	0.00	1.10	67.44
Korea	0.44	0.36	0.00	1.50	81.82
Average Foreign Material					
Belgium	0.21	0.09	0.10	0.40	42.86
Taiwan	0.22	0.07	0.10	0.40	31.82
Korea	0.20	0.09	0.00	0.40	45.00

Levels of damaged kernels for imports of No. 2 OB were more distributed (Table 39). Three countries, Korea, Hong Kong, and Japan, had average levels over 1986-1996 that were less than 1 percent (0.32 percent, 0.3 percent, and 0.75 percent, respectively). The other countries had average levels of damaged kernels for imports of No. 2 OB over 1.3 percent. Variation of damaged kernel levels between-shipments were also lower, especially for imports to Korea and Hong Kong. The levels for imports to Korea of No. 1, both average levels and standard deviations for damaged kernels, were similar to those for imports of No. 2 OB.

Comparisons of foreign material and shrunken and broken kernels for No. 1 and No. 2 OB suggest levels were similar between grades and across countries while variability between-shipments was similar to or higher for countries importing No. 2 OB HRS (Table 39). Levels of foreign material for imports of No. 1 ranged from .2 to .21 percent and ranged from .18 to .33 percent for No. 2 OB. Variation across shipments for foreign material ranged from .1 to .17 percent for No. 2 OB to 0.07 to 0.09 percent for No. 1. Average levels of shrunken and broken kernels for importing countries ranged 1.12 to 1.58 percent for No. 1 HRS and 1.11 to 1.54 percent for No. 2 OB (Tables 40-41). Standard deviations for shrunken and broken kernels between-shipments ranged from .24 to .4 percent for No. 1 and .34 to .83 percent for importing countries importing No. 2 OB.

Variability of total defects mirrored many of the other characteristics. Korea and Taiwan had lower standard deviations for variability between-shipments for No. 1 than did importers for No. 2 OB. However, while variability may have been higher for one or more characteristics, Korea, Japan, Hong Kong, and Taiwan tended to have lower variability and levels, indicating higher quality than did many of the other importers for the majority of the characteristics examined.

Table 39. Variability of Damaged Kernels and Foreign Material Levels for No. 2 OB HRS Shipments, by Country, 1986-1996.

Country	Mean	Std	Min	Max	CV
Average Damaged Kernels					
Bangladesh	1.74	0.89	0.20	3.20	51.15
Belgium	1.24	0.91	0.00	3.00	73.39
Dom. Rep.	1.70	0.98	0.00	3.40	57.65
El Salvador	1.54	1.02	0.00	3.10	66.23
Honduras	1.84	0.82	0.00	3.00	44.57
Hong Kong	0.30	0.37	0.00	1.70	123.33
Italy	1.30	0.86	0.00	3.10	66.15
Japan	0.75	0.78	0.00	2.80	104.00
Korea	0.32	0.41	0.00	2.90	128.13
Philippines	1.27	0.92	0.00	3.20	72.44
Venezuela	1.62	0.96	0.00	3.30	59.26
Average Foreign Material					
Bangladesh	0.29	0.10	0.10	0.50	34.48
Belgium	0.29	0.17	0.00	0.60	58.62
Dom. Rep.	0.29	0.15	0.00	0.60	51.72
El Salvador	0.24	0.13	0.00	0.40	54.17
Honduras	0.33	0.13	0.00	0.50	39.39
Hong Kong	0.18	0.16	0.00	0.60	88.89
Italy	0.27	0.17	0.00	0.60	62.96
Japan	0.25	0.16	0.00	0.70	64.00
Korea	0.20	0.16	0.00	0.80	80.00
Philippines	0.30	0.13	0.00	0.80	43.33
Venezuela	0.30	0.17	0.00	0.80	56.67

Table 40. Variability of Shrunken and Broken Kernels and Total Defects for No. 1 HRS Shipments, by Country, 1986-1996.

Country	Mean	Std	Min	Max	CV
Average Shrunken and Broken Kernels					
Belgium	1.12	0.24	0.80	1.50	21.43
Taiwan	1.44	0.38	0.20	2.20	26.39
Korea	1.58	0.40	0.00	2.40	25.32
Average Total Defects					
Belgium	2.28	0.32	1.70	2.70	14.04
Taiwan	2.10	0.44	1.30	2.90	20.95
Korea	2.23	0.48	0.00	3.00	21.52

Table 41. Variability of Shrunken and Broken Kernels and Total Defects for No. 2 OB HRS Shipments, by Country, 1986-1996.

Country	Mean	Std	Min	Max	CV
Average Shrunken and Broken					
Bangladesh	1.53	0.34	0.90	2.00	22.22
Belgium	1.54	0.72	0.00	2.50	46.75
Dom. Rep.	1.40	0.64	0.00	2.20	45.71
El Salvador	1.33	0.70	0.00	2.50	52.63
Honduras	1.50	0.47	0.00	2.20	31.33
Hong Kong	1.11	0.83	0.00	2.40	74.77
Italy	1.41	0.71	0.00	2.40	50.35
Japan	1.31	0.64	0.00	2.40	48.86
Korea	1.20	0.73	0.00	2.70	60.83
Philippines	1.49	0.45	0.00	2.60	30.20
Venezuela	1.33	0.65	0.00	2.20	48.87
Average Total Defects					
Bangladesh	3.56	0.94	1.50	4.80	26.40
Belgium	3.07	1.51	0.00	4.80	49.19
Dom. Rep.	3.38	1.52	0.00	5.00	44.97
El Salvador	3.11	1.66	0.00	4.90	53.38
Honduras	3.67	1.11	0.00	5.00	30.25
Hong Kong	1.59	1.20	0.00	3.80	75.47
Italy	2.97	1.49	0.00	5.00	50.17
Japan	2.32	1.30	0.00	4.80	56.03
Korea	1.72	1.06	0.00	4.40	61.63
Philippines	3.07	1.14	0.00	4.80	37.13
Venezuela	3.25	1.51	0.00	5.00	46.46

COMPARISONS ACROSS GRADES AND LEVELS

A number of comparisons can be made among exporters at different stages in the marketing system, across grades, etc. For example, variability of protein levels in Canada and the United States at the farm production level were measured as variation in mean protein levels from year-to-year and within-year variability. Estimated variabilities for both measures were similar in both countries. This indicates that for protein, variability is similar at the production level in both countries.

It is notable that where data were available by grade, generally higher grades exhibited lower variability for many quality characteristics. This pattern was observed in both the Canadian and U.S. marketing systems. For example, the variability of within-year protein for Canadian production was generally lower for No. 1 CWRS than for No. 2 and No. 3 CWRS. Similarly, the variability of protein levels between-shipments for export of HRS No.1 was significantly lower than for exports of No. 2 OB in a number of years.

Comparisons of variability at the farm production and export levels indicated that, especially in the United States, variability was lower at the export level than at the farm production level for protein, dockage, test weights, total damaged kernels, shrunken and broken kernels, and total defects. Average within-year variability of protein at the production level had standard deviations of 1.0 to 1.7 percent in the northern production regions while exports of No. 1 and No. 2 OB HRS had average standard deviations of .15 percent to .39 percent and .41 percent to .70 percent, respectively. Similar results were found for dockage where production had average standard deviations of 1.28 to 2.32 percent and exports of No. 1 and No. 2 OB HRS had standard deviations for dockage that ranged from .11 to .33 percent and .12 to .41 percent, respectively. Variability of test weights at the farm level had standard deviations of 1.7 to 2.3 lbs/bu while standard deviations between-shipments for both No. 1 and No. 2 OB HRS were less than 1.2 lbs/bu for all but No. 2 OB in the marketing years 1986/87 and 1987/88. Similarly, standard deviations for farm level total damaged kernels, while averaging .2 percent for Montana, were 1.3 to 2.1 percent in the other northern tier states. Meanwhile, variability for total damaged kernels for exports of No 1. and No. 2 OB HRS were less than .5 percent and 1 percent, respectively, from 1985/86 to 1996/97. Similar results were present for shrunken and broken kernels and total defects. Average levels of variability at the farm level ranged from .7 to 1.1 percent for shrunken and broken and 1.1 to 2.6 percent for total damaged kernels. This compared to average levels of variabilility between-shipments for shrunken and broken of less than .7 percent for the marketing years 1986/87 to 1996/97 for No. 1 HRS and less than .4 percent for No. 2 OB HRS. Average standard deviations for total defects ranged from .2 to 1.2 percent for exports of No. 1 HRS to .55 to 1.45 percent for HRS No. 2 OB.

Both Canadian production and export grade and protein segregations have variability that is similar for many of the quality characteristics. Variability for loaf volumes was higher for export than for production segregations, and variability of kernel weights was lower for export than for production segregations. However, comparisons between these two levels are complicated by differences in the number of years contained in each data series.

One potential explanation for the perceived lower quality variability in Canada versus the United States is that Canada exports a higher percentage of CWRS as No. 1 than the United States in the 1980s and 1990s. During this period, Canada has routinely exported over

40 percent of CWRS exports as No. 1 while the United States has exported less than 15 percent as No. 1 HRS (Dahl and Wilson, 1996). Since higher grades for both countries have generally exhibited lower variability, it is expected that there should be less consistency problems in Canada.

Comparisons between the United States and Canada are limited by the differences in aggregation and data availability between countries. Specifically, comparisons of farm production were limited except for protein due to differences in aggregation. The United States collects data on individual samples and calculates means for defined areas. However, in Canada, a composite sample is created for grade and protein segregations for each crop year.

SUMMARY AND CONCLUSIONS

Greater sophistication of buyers in the wheat market has increased demands for higher quality wheats. Increased demands have in turn focused attention on the consistency of the quality of wheat purchased. Several studies have indicated that many importers perceive United States wheat to be of less consistent quality than either Australian or Canadian wheat imports. Variability of quality can be affected by many factors (environment, marketing systems, grading systems, etc) and can be measured in a number of different ways (within-shipment, between-shipments, across years, etc.). In this study, the variability of wheat quality characteristics was examined at different stages of the marketing chain. Variability was measured by variety, and at farm production and export levels. Comparisons were made with Canada where similar data were available. Different measures of variability were utilized.

Examination of variability at the variety level in North Dakota indicated that the variability of selected quality characteristics was similar across varieties. However, the effects of location, variety, and year had different impacts on the variability of quality characteristics. Variability in wet gluten and MTI was most affected by location and variety, whereas, variability in loaf volumes was most affected by factors that vary between crop years (ie, climate, etc). Most wheat characteristics were affected most by year to year variability followed by location and finally variety.

Variability in the quality of U.S. spring wheats was reduced as it moved from the farm level production to U.S. export level. This was evident for protein, dockage, test weight, shrunken and broken kernels, and total defects. Average within-year variability of protein at the production level had standard deviations of 1.0 to 1.7 percent in the northern production regions while exports of No. 1 and No. 2 OB HRS had average standard deviations of .15 percent to .39 percent and .41 percent to .70 percent, respectively. For dockage, production levels had average standard deviations of 1.28 percent to 2.32 percent, and exports of No. 1 and No. 2 OB HRS had standard deviations for dockage that ranged from .11 percent to .33 percent and .12 percent to .41 percent, respectively. Similar results were found for test weights, shrunken and broken kernels, and total defects.

Variability of protein and dockage levels for selected countries importing U.S. No. 1 and No. 2 HRS was similar, suggesting that specifications for these parameters by the importing countries were similar for both grades.

The range of within-shipment variability of U.S. exports (high sublot - low sublot) was lower than the variation indicated between export shipments (represented by standard deviations) for both protein and dockage for individual importing countries. This result was not as prevalent for total exports of HRS when segmented by marketing year and grade, especially when comparing the within-shipment and between-shipment variability of protein for exports of No. 1 HRS.

In Canada, the between-year variability of average protein levels for protein segregations was similar at both the production and export levels. However, there were differences by grade where No. 1 CWRS was less variable than No. 2 and No. 3 CWRS.

Comparisons between the United States and Canada indicated that protein levels were highest in Manitoba and North Dakota and lowest in Saskatchewan and Alberta. Variability of protein at the production level measured as the between-year variability of annual average levels and the within-year variability of protein was similar between the United States and Canada.

There were significant differences in the variability of selected quality parameters in both the U.S. and Canada where higher grades exhibited lesser variability than did lower grades. This effect was especially evident at the export level for the United States This effect was also present in Canada where No. 1 CWRS varied less than No. 2 and No. 3 CWRS.

A couple of implications can be drawn from these results. First, since variability for many quality characteristics was less for higher grades than for lower grades and Canada exports a higher proportion of CWRS as No. 1 than the United States exports of No. 1 HRS, it is expected that consistency should be less of a problem in Canadian wheat exports. Further, an effective way for importers to reduce variability is to either specify No. 1 versus No. 2OB, and/or limits on specific quality factors. Second, since both between-year variation in average protein levels and within-year variation of protein levels were similar in Canada and the United States at the farm production level, differences in consistency of protein quantities may be more related to differences in marketing systems between the two countries and protein levels. Third, an increased emphasis on variety and location could aid in controlling quality variability in some end-use characteristics.

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APPENDIX

Factors Affecting Quality Variability

Quality variability (consistency) is introduced/impacted by a number of factors, some that are controllable, while others are less so. These factors can have significant influences on consistency and vary by country, marketing system, production area, variety release and development procedures, etc. However, environment plays a large part in determining quality, such quality variability. Effects of environment and their influence on quality consistency are reviewed.

General Climatic Effects on Variability

Climate impacts the yield and quality of wheat produced. Much of the effects of climate on yields are known, and mechanistic descriptions exist (e.g., crop growth models such as Godwin et al.). In addition, climate has been known to impact end-use quality for some time. Studies have been conducted to examine trends in yields and protein while controlling for environment effects. Further, the effects of climate on end-use quality variability have been examined extensively in Australia and New Zealand.

One of the earlier studies examining the effect of the environment on wheat end-use quality was Waldron et al. (1942). They examined the effects of temperature and rainfall on protein and quality for hard red spring wheats. They indicated that the general perception at that time was that moist climates resulted in flour with lower protein that may be lower in baking strength than for wheats grown in regions of less rainfall with relatively high temperatures during certain periods of plant growth. They found protein varied more between years than between locations within a year. Therefore, they concluded that weather, rather than soils, was the larger factor affecting wheat protein levels. Waldron et al. (1942) also examined the effect of day and night temperatures on wheat quality measured as loaf volumes. They found that high day temperatures from 10 days before heading up to 2 weeks before harvest were conducive to higher protein levels in wheat. They also indicated that higher day and night temperatures during this same period were correlated to higher loaf volumes with high nighttime temperatures having the larger impact. However, they indicated that high day and night temperatures after the middle of July (last two weeks before harvest) worked against high loaf volumes.

Harris et al. (1947) also examined the effects of season, location, and variety. They also found location and season had significant impacts on wheat quality characteristics. Loaf volumes for 1945 were significantly higher than for the other years. However, unlike Sandstedt and Fortmann, Harris et al. did not find a significant relationship between protein content and protein quality among the varieties tested. Mixing properties also varied substantially across locations and seasons. They found lower dough strengths in selected years and indicated this may be due to variations in certain properties of wheat gluten. They found different aspects of mixograms were affected differently by location, yearly, and varietal variations. Annual changes in weather were found to be the most important factor impacting most mixogram properties. However, dough stability was most influenced by varietal differences.

Similar studies have also examined the effect of environment on hard red winter wheats. Sandstedt and Fortmann (1944) examined hard red winter wheat varieties across locations in

Nebraska and found significant variability in end-use quality characteristics (loaf volumes, mixing times) not explained by differences in protein content. They indicate that wheat varieties grown at the same locations had loaf volumes and mixing times that were similar and that larger variability resulted among locations for individual varieties. Responses to environments varied by variety with varieties with lower average levels generally responding less to changes in environment that those with higher average levels.

More recently, Salinger, Jamieson, and Johnstone (1995) examined the effects of rainfall and temperature on baking quality of bread wheat in New Zealand. They examined the relationship between average monthly temperatures and rainfall with a measure of baking quality (Mechanical Dough Development) from 1974-1991. They found strong positive influences of temperature and negative influences of rainfall on baking quality for most spring planted varieties. Most varieties were highly influenced by January temperatures and December-January rainfall. One variety (Rongotea) was most affected by November-December average temperatures and December rainfall. These results tended to bolster earlier thought that hot dry environments foster higher wheat quality while lower temperature wet seasons foster lower quality wheat production.

Effects of Heat Stress

High temperatures have long been known to impact yields and protein content of wheat. Similarly, the effects of temperatures on wheat quality have long been known.

One of the earliest studies examining the effects of temperatures at different stages of plant growth examined HRS wheat varieties in North Dakota (Waldron, Harris, Stoa, and Sibbitt). Waldron et al. (1942) examined the effects of temperatures on wheat protein and loaf volumes for three stages of plant growth (ten days preheading, first half postheading, and second half postheading. They found protein levels were correlated to higher temperatures in the preheading and first half of postheading. Higher temperatures in the second half of postheading tended to reduce loaf volumes.

Another of the earlier studies examining the effects of high temperatures on wheat quality was done by Finney and Fryer. They examined the effects of high temperatures on wheat quality for hard red spring and hard red winter wheats grown under a wide range of climates in the United States They examined correlations of loaf volumes with accumulated temperatures above 90 degrees Fahrenheit for three periods during fruiting (first two weeks, last 15 days, and entire fruiting period). They found loaf volumes were correlated with cumulative temperatures over 90 F during the last 15 days and over the entire period with the strongest correlations for the last 15 days of fruiting. Mixing times also decreased with increasing accumulated degrees F above 90 during the last 15 days of fruiting. They further indicated that the effects of temperatures varied by variety. Varieties with longer mixing times were more tolerant to high temperatures than varieties with shorter mixing times.

Several more recent studies have examined the effects of heat stress on wheat quality. Most of these studies have been conducted in Australia and New Zealand for hard white wheat. Randall and Moss (1990) examined the effects of temperature throughout grain filling on dough strength. They found that dough strength increased as temperatures increased up to 30 degrees C. If temperatures exceeded 30 degrees C for even short periods, dough strengths declined.

Therefore, they argued for what they term a threshold heat level, above which wheat quality is affected. They also indicated that kernel weights are impacted by higher temperatures, but effects do not appear to be related to changes in dough strength. They found that effects on quality (dough strength) were larger in the later portions of grain filling (80 percent or more of final kernel weight), while effects on kernel weight were largest in the early portions of grain filling (60 percent of final kernel weight).

Blumenthal et al. (1991) found similar results in their examination of the effects of cumulative heat stress on wheat quality in Australia. They indicate that dough strength of wheat is impacted by high levels of heat (cumulative time over 35 degrees C). High heat was found to be correlated with lower dough strength, lower loaf volume, lower yields, and higher protein.

Stone and Nicolas (1995) examined the effects of heat stress at 10 and 30 days after anthesis on 75 varieties. They found that high heat stress lowered dough strengths for most varieties and impacted the composition of proteins. Effects of high temperatures varied by variety with some varieties more heat tolerant than others. Effects on dough strengths were larger for high temperatures occurring in the later stage of growth.

Stone and Nicolas (1996) also examined the effects of timing of short heat stresses on wheat quality; and Stone, Gras, and Nicolas (1997) examined the effects of recovery temperatures on short-term heat stress. Both of these studies indicated that short periods of high temperatures reduced dough strengths of bread wheats. Stone and Nicolas indicated that the timing of heat stress and total impact on quality varied by variety.

The effect of heat stress has been attributed to continued synthesis of gliadin proteins at a greater rate than glutenin synthesis during heat stresses. This higher gliadin production results in lower dough strengths (Blumenthal, Barlow, and Wrigley, 1993; and Stone and Nicolas, 1995).

Effects of Frost (Freeze Damage)

Effects of low temperatures (freeze damage) have been examined extensively for Canadian wheats. One analysis of freeze damage examined the effects of frost and immaturity on wheat quality (Preston, Kilborn, Morgan, and Babb, 1991). They found temperatures below -3 degrees C were required to bring out the effects of frost damage. Damage varied by stage of maturity and for quality characteristics. Frost damage decreased wheat protein in the early stages of maturity, but did not affect protein levels in the later stages of maturity (less than 50percent moisture in the kernel). Test weights were also decreased if frost occurred in the earliest maturity examined (1-8 days after achieving 70percent kernel moisture). Milling quality was negatively affected by frost in all but the latest stages of maturity, with the heaviest damage done at the earliest maturing stages examined. Baking quality was also impacted at the earlier maturities (above 45percent moisture) with lesser quality for loaf volumes, baking strength index, and crumb and crust characteristics. Their results were similar to a number of studies that had also examined the effects of freeze damage on wheat. Further, they indicate that differences in baking qualities may be due to differences in the composition of proteins caused by low temperatures.

Effects of Disease (Fusarium)

Effects of disease infestation on wheat quality have been examined. Focus has been on the effects of fusarium head blight (F. Graminearum). Dexter, Clear, and Preston (1996) examined the effects of fusarium head blight on quality characteristics of selected wheat varieties. They found fusarium reduced the end-use quality of hard red spring wheats however, the effects on end-use quality were cultivar specific.

Effects of Variety and Variety by Environment Interactions

Effects of variety on wheat quality have been known and evaluated largely in the context of breeding programs. Examinations of effects of variety are largely conducted over a range of environments to assess the adaptability of varieties to larger scale production before release. Many studies examining effects of variety by environment interactions have focused on assessing the degree of environment, genotype, and genotype environment variability or on determining the number of replications required to obtain sufficient results for analysis of experimental lines in breeding programs. Studies examining effects of variety by environment interactions include McGuire and McNeal for Hard Red Spring (HRS), Mariani et al. for durum, and Peterson et al. for Hard Red Winter Wheat (HRW).

McGuire and McNeal examined selected hard red spring wheat varieties to determine if evaluation of composite samples was appropriate. They concluded that quality characteristics of HRS cultivars do not respond similarly to changes in environments. Thus, they argue that significant information is lost when composite samples are created across environments.

Lukow and McVetty examined effects of cultivar, environment, and interactions on quality characteristics for spring wheat. They examined quality parameters for samples of spring wheats grown in Canada in 1986 and 1987. They found significant cultivar by environment interactions; however, the effects of cultivar were far greater than the interactions for most parameters. Larger cultivar by environment interactions were found for test weights and kernel weights, indicating multiple environment testing should be undertaken to assess new wheat lines for these parameters.

ENVIRONMENTAL EFFECTS

Climate has an important effect on quality variability. A number of studies have examined this relationship for wheats, McGuire and McNeal for spring wheat in Montana and Mariani et al. for durum. Eskridge et al. cite a number of other studies for HRS, HRW, SRW, and SWWW.

Mariani et al. examined the effects of environment, genotype, and interactions for durum in Italy from 1990-1993. They found significant environment, genotype, and genotype-environment interaction (GE) effects for protein and alveograph. However, they found the interaction GE effects were small compared to the additive effects of environment and genotype. Their study confirms results of other studies in which "for protein content, the environmental effect overcomes that of genotype and the GE interaction appears negligible; whereas for technological characteristics (alveograph), the genotype effect is predominant and the GE interaction is small (p. 196)."

Milling quality varies by variety and location. Blumenthal et al. evaluated comparisons for individual varieties. Eskridge et al. cite a number of other studies for HRS, HRW, SRW, and

SWWW that examined effects of genetics and environment. Eskridge et al. also examined a different concept, a probability-based approach to determine if varieties are within parameter limits using data from Nebraska. The focus was on flour protein, mixing time, mixing tolerance, SDS sedimentation volume, and kernel hardness. They defined acceptable quality as either within specified upper and lower limits (absolute limits on acceptability) or as acceptability as compared to a check variety (safety first or greater is better analysis). They found that either of these methods were flexible tools for identifying (selecting) varieties that performed with high probabilities within acceptable limits for multiple characteristics across environments.

Appendix Table 1. Correlations for Wheat Characteristics in U.S. Regional Farm Level Wheat Quality Surveys 1987-1996.

	Protein	Falling Number	Dockage	Test Weight	Kernel Weight	Vitreous Kernels	Shrunken and Broken	Foreign Material	Damaged Kernels	Total Defects	Contrasting Classes
Protein	1.0000	0.2231	ns	-0.2413	-0.3801	0.3862	0.1291	ns	-0.0515	ns	ns
Falling Number	0.2231	1.0000	-0.1047	0.2655	-0.0940	0.3898	0.0456	ns	-0.3610	-0.3357	ns
Dockage	ns	-0.1047	1.0000	-0.3076	-0.1419	-0.0735	0.1722	0.1803	0.2039	0.2812	ns
Test Weight	-0.2413	0.2655	-0.3076	1.0000	0.5255	0.2590	-0.2388	-0.0899	-0.5229	-0.5775	0.0529
Kernel Weight	-0.3801	-0.0940	-0.1419	0.5255	1.0000	-0.1859	-0.4338	-0.0490	-0.1215	-0.3007	ns
Vitreous Kernels	0.3862	0.3898	-0.0735	0.2590	-0.1859	1.0000	0.1249	ns	-0.3440	-0.2569	0.0328
Shrunken and Broken	0.1291	0.0456	0.1722	-0.2388	-0.4338	0.1249	1.0000	0.0313	0.0365	0.4428	ns
Foreign Material	ns	ns	0.1803	-0.0899	-0.0490	ns	0.0313	1.0000	0.0349	0.1890	0.0311
Damaged Kernels	-0.0515	-0.3610	0.2039	-0.5229	-0.1215	-0.3440	0.0365	0.0349	1.0000	0.8715	ns
Total Defects	ns	-0.3357	0.2812	-0.5775	-0.3007	-0.2569	0.4428	0.1890	0.8715	1.0000	ns
Contrasting Classes	ns	ns	ns	0.0529	ns	0.0328	ns	0.0311	ns	ns	1.0000

Appendix Table 2. Correlations for Crop Reporting District Observations for Wheat and End-use Characteristics, Regional HRS Farm Quality Surveys, 1980-1996.

	Flour Protein	Flour Extraction	Flour Ash	Wet Gluten	Absorp.	Peak Time	Mix Tolerance	MTI	FClass	Extens.	Resist.	Loaf Volume	Crumb Color	Crust Color	Symmetry
Wheat Protein	0.9734	-0.4106	0.3226	0.8339	0.5558	0.5597	0.5456	-0.4931	0.5705	0.3442	0.1765	0.3962	ns	ns	0.2511
Dockage	ns	ns	0.1127	ns	-0.1654	-0.1493	ns	0.2288	-0.1749	ns	-0.1455	0.1599	ns	ns	-0.1029
Test Weight	-0.2576	0.3608	-0.5245	ns	0.1221	ns	ns	-0.1063	ns	ns	ns	ns	0.2544	ns	ns
Kernel Weight	-0.4429	0.2940	-0.3787	-0.2706	ns	-0.2574	-0.2695	0.2677	-0.2756	-0.3058	-0.2334	-0.1953	ns	ns	-0.1378
Vitreous Kernels	0.3401	-0.1376	-0.1208	0.4791	0.2703	0.2249	0.2583	-0.2072	0.2731	0.2775	-0.1674	0.3262	ns	ns	0.1883
Falling Number	0.1502	ns	ns	ns	0.1761	0.3184	0.3111	-0.4138	0.3846	ns	0.2984	ns	ns	0.2781	0.2058
Foreign Material	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Damaged Kernels	-0.1711	-0.2316	0.1979	ns	-0.2319	-0.3123	-0.3765	0.5887	-0.5107	-0.1033	-0.4909	ns	-0.3312	ns	ns
Shrunken and Broken	0.4033	-0.3522	0.2817	0.2416	0.1202	0.2758	0.2975	-0.3011	0.3481	0.2434	0.3744	0.1804	ns	ns	0.1718
Total Defects	ns	-0.3549	0.2912	ns	-0.1536	-0.1468	-0.1950	0.3519	-0.2731	ns	-0.2336	0.1047	-0.2803	ns	ns
Contrasting Classes	ns	ns	ns	ns	ns	ns	ns	ns	ns	0.1468	ns	ns	ns	ns	ns
Flour Protein	1.0000	-0.3695	0.2923	0.8439	0.6036	0.5915	0.5679	-0.5342	0.6050	0.3460	0.2068	0.4022	ns	ns	0.2526
Flour Extraction	-0.3695	1.0000	-0.2013	-0.3852	-0.1739	-0.2103	-0.1273	ns	-0.1364	-0.1352	ns	-0.1663	ns	ns	-0.1067
Flour Ash	0.2923	-0.2013	1.0000	0.1610	0.1205	ns	ns	ns	-0.1174	0.1497	ns	ns	-0.2368	0.1752	0.1825
Wet Gluten	0.8439	-0.3852	0.1610	1.0000	0.6080	0.4178	0.4124	-0.2951	0.3744	0.2563	-0.1244	0.4880	ns	ns	0.2995
Absorption	0.6036	-0.1739	0.1205	0.6080	1.0000	0.4358	0.3743	-0.4046	0.3657	ns	ns	0.1707	0.1889	0.1823	0.3603
Peak Time	0.5915	-0.2103	ns	0.4178	0.4358	1.0000	0.8170	-0.6355	0.7937	0.1132	0.3679	ns	0.2181	ns	0.1845
Mix Tolerance	0.5679	-0.1273	ns	0.4124	0.3743	0.8170	1.0000	-0.7474	0.8222	ns	0.4068	ns	0.2535	ns	0.1287
MTI	-0.5342	ns	ns	-0.2951	-0.4046	-0.6355	-0.7474	1.0000	-0.8215	-0.1431	-0.5241	ns	-0.1934	ns	ns
FClass	0.6050	-0.1364	-0.1174	0.3744	0.3657	0.7937	0.8222	-0.8215	1.0000	0.1249	0.5540	ns	0.2730	ns	ns
Extensibility	0.3460	-0.1352	0.1497	0.2563	ns	0.1132	ns	-0.1431	0.1249	1.0000	ns	0.3278	ns	ns	0.1578
Resistance	0.2068	ns	ns	-0.1244	ns	0.3679	0.4068	-0.5241	0.5540	ns	1.0000	ns	0.1722	-0.1342	-0.1753
Loaf Volume	0.4022	-0.1663	ns	0.4880	0.1707	ns	ns	ns	ns	0.3278	ns	1.0000	ns	ns	0.3027
Crumb Color	ns	ns	-0.2368	ns	0.1889	0.2181	0.2535	-0.1934	0.2730	ns	0.1722	ns	1.0000	0.1162	0.1734
Crust Color	ns	ns	0.1752	ns	0.1823	ns	ns	ns	ns	ns	-0.1342	ns	0.1162	1.0000	0.7935
Symmetry	0.2526	-0.1067	0.1825	0.2995	0.3603	0.1845	0.1287	ns	ns	0.1578	-0.1753	0.3027	0.1734	0.7935	1.0000