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CONSISTENCY OF QUALITY CHARACTERISTICS IN HARD RED SPRING WHEATS*

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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 and export markets. Other 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 impact the quality of wheats produced. Changes are also occurring in the way wheat is purchased. The grades and classes of wheat imported are changing and 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 which are correlated with end-use quality parameters, but are subject to some uncertainty. This study is a summary of a larger report that examines the variability of wheat at different points in the wheat marketing chain (variety, farm production, and

export levels). Comparisons are made with Canada.

BACKGROUND

What is Quality Consistency?

There are three important aspects of quality variability or consistency. The first is variability in quality due to sampling and grading errors. Errors in measurement can occur throughout the marketing system and impact variability in quality. This increases risks to both buyers and sellers that the product will not meet specifications and valuation when delivered.

The second is the variability in the level of grain characteristics. These are reflected in interregional and inter-temporal 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) and the ability to serve customers with heterogeneous 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.

*This is a summary of a comprehensive report by the same title which is available from the authors and at <http://agecon.lib.umn.edu/ndsu.html>.

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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. It is important that due to technological reasons, wheat buyers normally specify easily measurable characteristics (e.g., protein, test weight, etc.) which are correlated with desirable end-use characteristics (wet gluten, loaf volume, mix tolerance, etc.) that are not easily measurable. A poor correlation between wheat 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 which implies a greater correlation between wheat and end-use characteristics.

DATA SOURCES AND SCOPE OF ANALYSIS

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 for the Western Provinces for grade and protein segregations. 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.

RESULTS

VARIETAL CONSISTENCY: EXPERIMENT STATION DATA

Data on quality for varieties are evaluated annually through crop varietal trials at state experiment stations. Quality characteristics of 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. These varieties have been 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 and standard deviations were estimated for selected wheat, dough, and baking characteristics for 1989-1995. 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 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.

The effects of location, variety, and year on variability of quality characteristics were examined. Results indicate that many of the quality characteristics are affected most by year to year variations (Table 1). For example, the variability in the level of wheat protein can be explained most by the effect of year to year variations likely reflecting climatic conditions. The effect of year on wheat protein has about twice the impact of location and about 4 times the impact of variety (F-statistic for year is twice the size of F-statistic for location and 4 times the size of F-statistic for variety). This relationship where year to year variations impacted levels of quality characteristics most, followed by the effects of location and variety held for many of the wheat quality characteristics and some of the flour and end-use characteristics.

For flour and baking quality characteristics, the importance of the effects of 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 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 is most important.

FARM PRODUCTION QUALITY

Wheat quality 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 for western Canada, and estimates for other grain and end-use characteristics are derived from these composite samples. In this section, the variability of quality parameters from annual crop production surveys were compared.

Protein Variability

Observations on protein are measured for both the Canadian and United States in their respective production quality surveys. In 1996 and 1997, Canada released distributions of protein observations. In prior years, only mean values by province were released. These distributions are compared to distributions for protein in the northern regions of the United States.

Average levels of protein in Canada for all grades in 1996 declined from Alberta to Manitoba, and as protein levels declined, standard deviations increased (Table 2).

Table 1. 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

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. 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.

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 (Table 3). 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.

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 were 14.4 percent for the northern United States region from 1987 to

Table 2. Distribution of Protein in CWRS Wheat, 1996 and 1997.*

Location	CWRS 1		CWRS 2		CWRS 3		All Grades	
	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
1996								
Manitoba	14.1	1.0	14.5	1.0	13.9	1.2	14.4	1.0
Saskatchewan	13.1	1.3	13.1	1.4	12.2	1.4	12.9	1.4
Alberta	13.0	1.5	12.3	1.7	12.1	1.4	12.5	1.5
Canada	13.3	1.4	13.5	1.5	12.3	1.4	13.1	1.5
1997								
Manitoba	15.0	1.2	15.3	1.1	15.0	1.5	15.2	1.1
Saskatchewan	13.5	1.6	13.8	1.7	13.3	1.9	13.5	1.6
Alberta	13.2	1.6	12.9	1.5	12.2	1.5	12.9	1.6
Canada	13.6	1.6	14.0	1.8	12.9	1.9	13.7	1.7

* Values converted from 13.5% Moisture Basis to 12% Moisture Basis.

Source: Williams, 1997a, 1997b.

Table 3. Northern Regional HRS Protein Distribution, 1996 and 1997.

	1996		1997	
Location	Mean	Std. Dev.	Mean	Std. Dev.
Minnesota	13.5	1.1	14.3	0.8
Montana	14.2	1.7	14.0	1.7
North Dakota	14.0	1.0	14.7	1.0
South Dakota	13.4	1.0	14.3	1.0
Region	13.9	1.2	14.4	1.1

Table 4. 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			

1996 and ranged from a low of 13.7 percent to a high of 16.1 percent (Table 4). 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.

Test Weight

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. 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).

Vitreous Kernels

Average levels for vitreous kernels were highest in Montana (87 percent for 1987-1996) and lowest in Minnesota (67 percent from 1987 to 1996). Variability of vitreous kernels 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.

Falling Numbers

Average annual levels for falling numbers from 1987 to 1996 were lowest in Minnesota (373) and highest in South Dakota (395). 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.

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. 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. 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. 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. Meanwhile, Montana had the lowest average levels (1.4 percent) and the lowest variability (1.1 percent).

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 5). 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 where 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 all four states had varied 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). However, absorption varied most

Table 5. Selected Average Annual Flour, Dough and Baking Characteristics, by State, 1980-1996.

	Mean					Standard Deviation				
	MN	MT	ND	SD	Reg	MN	MT	ND	SD	Reg
Flour Protein	12.7	13.2	13.4	13.3	13.2	0.73	0.85	0.62	0.9	0.6
Flour Extraction	69.2	68.4	68.9	67.9	68.8	1.1	1	0.6	1	0.6
Ash	0.46	0.43	0.45	0.46	0.45	0.03	0.04	0.03	0.04	0.03
Wet Gluten	34.3	36.1	36.5	35.9	35.7	3	2.5	1.9	2.7	2.1
Absorption	62.8	66	65.3	64.8	64.7	1.8	2.5	1.5	2.1	1.6
Peak Time	7.9	13.7	10.3	12.5	10.5	2.3	4.5	3.6	6.5	3.3
Mix Tolerance	12.2	17.7	14.7	17	14.9	4.4	4.3	4.3	6.4	4.1
Classification	5.2	6.9	6.1	6.4	6	1	0.8	0.9	1.3	0.8
Loaf Volume	863	870	906	871	883	68	68	50	55	52

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 were highest for North Dakota (906 cc) while Minnesota had the lowest (853 cc). 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).

Canadian Production Quality

Farm level wheat quality by grade and protein segregation are reported 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 the entire 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 6). 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 are greater 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.

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, shrunk 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 for wheat exports. Average protein levels for United States exports of No.1 HRS within marketing years have varied from a

Table 6. 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
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

high of 15.1 percent in 1989 to a low of 14.0 percent in 1993 and 1995 (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 or as No. 1 (90 percent to >10 percent for most years).

Within-shipment observations for protein variability were not available except as high and low levels of subplot samples. Comparison of the range of protein observations within shipments indicate 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.

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) (Figure 1). 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.

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. Meanwhile,

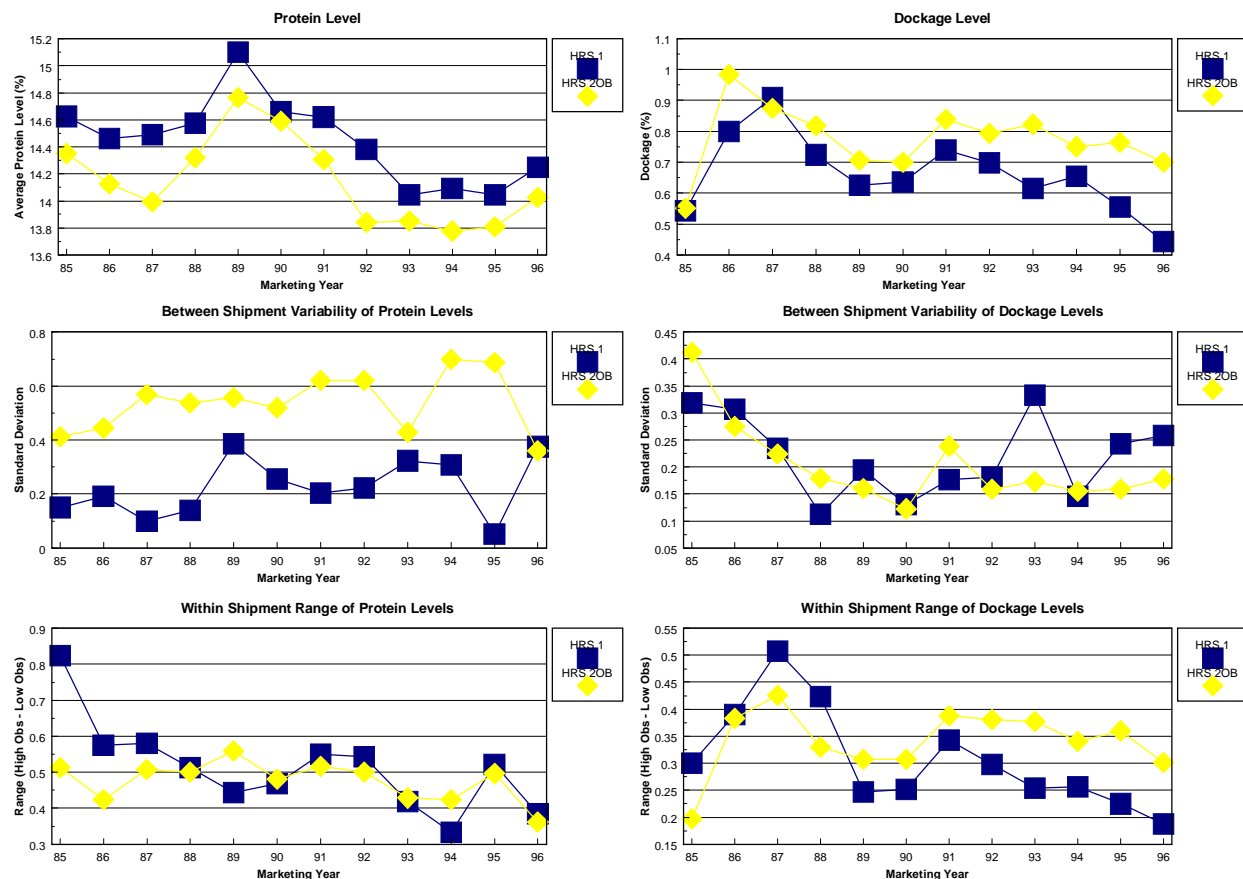


Figure 1. Average Levels, Between Shipment Variability and Within-Shipment Range of Protein and Dockage for U.S. HRS Exports, by Grade, Marketing Years 1985/86 to 1996/97.

between-shipment variability was generally higher for HRS No. 2 OB than for HRS No. 1 in most years. 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. Only in the past marketing year (1996/97) were average levels of vitreous kernels lower in exports of No. 1 than of No. 2 OB. Variability of vitreous kernels levels between-shipments generally had average standard deviations between 20 to 40 percent for both grades. 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. 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. 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.

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. 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. 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.

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 (Table 6). 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 11.3 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 where the coefficient of variation was over 3 times higher for exports of CWRs 2 (12.52 percent) than for CWRs 1 (3.66 percent).

Comparison of Quality Consistency by Importer

Variability of U.S. HRS exports was examined by grade and importer to evaluate consistency of shipments. 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.

Variability of protein for individual importers measured both between shipments and within shipments was lower for individual importers than for total exports of HRS. Specific importers had lower variability in exports than did others. For example, Korea, Taiwan, Japan, and Hong Kong had lower

Table 6. Comparison of Canadian Export Quality of CWRS1, Protein Segregation, and Port Location, 1991-1996

	12.50		13.50		14.50		
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

variability on most wheat characteristics than did other importers. This was primarily evident for damaged kernels in exports of No. 2 OB HRS. 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). 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 than for other importers.

Variability of total defects also reflected this trend. 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.

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 exports as having less consistent quality than either Australian and Canadian wheat imports.

Quality variability 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 the variety, farm production, and export levels. Comparisons were made with Canada where similar data were available.

Variability for selected quality characteristics was similar across varieties in North Dakota. However, the effects of location, variety, and year had different impacts on the variability of quality characteristics. Variability in wet gluten and MTI were affected most by location and variety, whereas, that for loaf volumes were most affected by interyear variability. Many wheat characteristics were impacted 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 weights, total defects, 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 the dockage, test weights, total defects, shrunken and broken kernels, and total defects.

The range of within-shipment variability of U.S. exports (high subplot - low subplot) 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 variability of protein for exports of HRS No. 1.

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 annual average levels and within-year variability of protein at the farm level were 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 lower 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 elicited 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.

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