Identifying Grain Quality for Maximum Economic Returns

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Abstract

Accurate and precise measurements of grain quality are required throughout the wheat production and marketing chain to insure that quality standards are maintained. One of most important uses of quality prediction tests is in the selection of high quality cultivars in plant breeding programs. Environmental factors have a large influence on grain protein concentration (PC) and there is normally a strong negative correlation between PC and cultivar grain yield potential. Because of this relationship and the large influence that flour PC has on other grain quality prediction tests, it is important that we avoid the trap of selecting and growing only cultivars with low grain yield potential in the name of maintaining grain quality standards. In the present study, spring and winter wheat cultivars representing a wide range of grain quality types and PC were grown in dryland and irrigated nitrogen fertilizer trials in western Canada to assess the effectiveness of accepted grain quality selection methods. PC was shown to have a large influence on all grain quality prediction tests considered. A nonlinear relationship between PC and Farinograph strength measurements was of special note. These studies demonstrated that, because environment has a large and variable influence on PC, it is important that cultivar selection procedures include grain quality comparisons that are made over a wide range of PC. This allows for a more accurate assessment of cultivar genetic potential and, when combined with the ability to segregate on the basis of grain PC at the time of producer delivery, provides the opportunity for much greater flexibility in cultivar release programs and improved quality control in grain handling systems.

Introduction

Wheat is the dominant grain of world commerce. It is easily transported and stored and it is used to produce a large variety of foods that include many kinds and types of breads, cakes, noodles, crackers, breakfast foods, biscuits, cookies, and confectionery items. Wheat quality is important in the marketplace, but the maintenance of high quality standards requires a continuing investment of costly resources and it is important to ensure that our prediction tests and standards reflect end-use quality that demands premiums and allows flexibility in the marketplace. Grain quality prediction tests, such as standardized LV and Farinograph measurements, are used throughout the world to predict end-use quality in breeding programs and the marketplace. However, there is considerable debate as to how these prediction tests relate to end-use quality of the many different wheat products.

Grain protein concentration (PC) is a primary quality component that influences most wheat quality measurements. Consequently, it is an important factor in the production and marketing of wheat. There is a close linear relationship between PC and loaf volume (Finney and Barmore, 1948). High water absorption, which is important to bakers because it allows them to sell more water at the same price as bread, is also highly dependent upon PC (Tipples et al., 1978). Farinograph dough development time (DDT) and stability (STAB), which are the most widely recognized measures of dough strength, are considered to be more independent of PC. DDT is a measure of dough mixing requirements while STAB is used to assess mixing tolerance. The objective of the present study was to quantify the interrelationships among these tests and to assess the effectiveness of current grain-quality selection methods as they apply to cultivar development and release in Western Canada.

Materials and Methods

The grain samples used in these studies were obtained from a total of seven fertilizer trials consisting of spring and winter wheat cultivars representing quality types and grain PC ranging from low protein soft white through Canada Prairie Spring (CPS) and hard red winter (HRW) to high protein hard red spring (HRS) grown on dryland and partial irrigation from 1992 to 1998. Cultivars were selected to represent the most highly adapted cultivars for these classes and this region. Additional data and new releases resulted in several cultivar changes over the course of this study.

Trials that included spring wheat were grown under partial irrigation at Saskatoon in 1992, 1993, 1994, 1995, and 1997 and on dryland at Saskatoon and Clair in 1997. Trials that included winter wheat were grown under partial irrigation at Saskatoon in 1993, 1994, 1995, 1997, and 1998, and on dryland at Clair in 1997. The cultivars AC Reed, Katepwa, and AC Taber were included in all spring wheat trials. BW90 and Roblin completed the spring wheat entries starting in 1992. Glenlea replaced BW90 in 1995 and AC Barrie was substituted for Roblin in 1997. CDC Ptarmigan, CDC Kestrel, S86-101, Norstar, and Winalta were included in all winter wheat trials up to 1996 and in the Clair dryland trial in 1997. The winter wheat cultivars CDC Kestrel, CDC Clair, and CDC Osprey were grown in trials under partial irrigation at Saskatoon 1997. The 1998 winter wheat cultivars were Norstar, Winalta, CDC Harrier, CDC Osprey, and CDC Clair.

All trials were direct-seeded into standing stubble from a previous crop (no-till) with a small plot hoe-press drill. Each plot was 5.5 m long and 1.2 m wide. Optimum seeding dates were achieved in all trials and phosphate fertilizer was applied with the seed at recommended rates. Nitrogen fertilizer was added as early spring broadcast ammonium nitrate (34-0-0) at 0, 40, 80, 120, 160 and 240 kg N/ha. Other elements were not considered limiting. Experimental design was a 4-replicate split-plot with N fertilizer rates as the main plots and cultivars as the sub-plots.
Grain from the four replicates of each cultivar from each N treatment was bulked in the 1992 to 1996 trials for quality evaluation. Grain from replicates 1 and 2 and 3 and 4 was bulked to provide two replicates of each cultivar for each N treatment in the 1997 and 1998 trials. Grain samples were milled using a Buhler laboratory mill. Flour protein concentrations (13.5 % w/w m.b.) were determined using Leco N analyses. Bread was baked using the Optimized Straight Dough Process (AACC Method 10-10B). Flour water absorption (FAB), dough development time (DDT) and stability time (STAB) values were determined according to AACC standard methods (1995) using a Farinograph equipped with a 10-g bowl.

Analyses of variance were conducted to determine the level of significance of differences due to trials, N response, and cultivar and the interactions among the main effects. Regression analyses were used to plot curves that best described the shape and behavior of the grain quality - flour PC responses. Linear equations were employed to describe loaf volume (LV) and Farinograph water absorption (FAB) relationships with flour PC. The sigmoidal four-parameter Gompertz equation was used to describe the DDT and STAB relationships with flour PC. Linear and nonlinear regression procedures outlined by SigmaPlot (SPSS Inc., Chicago, IL, USA) were used to provide least squares estimates of the regression coefficients in these equations.

Results and Discussion

The genotypes included in these trials provided a wide range of grain yield and wheat quality potential. The fields in which these trials were grown also had low levels of residual soil N that, when combined with conditions for growth that were average to excellent, produced large crop responses to fertilizer N. These large differences were reflected in the results of the analyses of variance, which indicated that differences due to trial, rate of N fertilizer application, and cultivars were significant (P<0.05) for all the quality parameters considered.

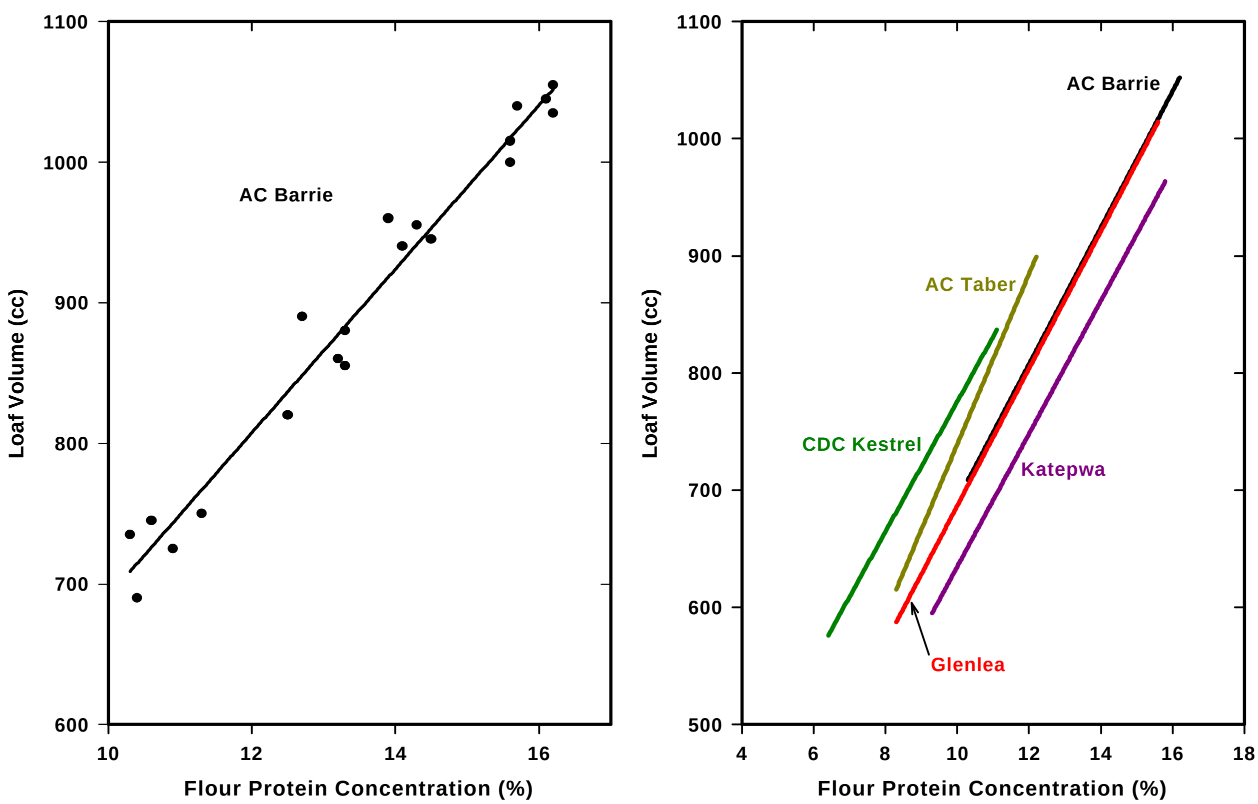

Figure 1. The relationship between protein concentration and loaf volume for spring and winter wheat cultivars grown on partial irrigation at Saskatoon and dryland at Clair in 1997.

The large differences in plant available soil N, cultivar genetic potential and trial environmental conditions produced a wide range in PC (Fowler 2002) allowing us to conduct a detailed investigation of the influence that flour PC has on other grain quality prediction tests and end products. The spring and winter wheat cultivars were grown in the same trials under partial irrigation at Saskatoon and on dryland at Clair in 1997 thereby providing us with the opportunity to make direct comparisons among cultivars representing all the common wheat quality classes grown in western Canada. As expected, loaf volume (LV) was highly dependent on flour PC and an average reduction of 85.5 % in sums of squares due to model indicated that linear equations provided excellent descriptions of this relationship for the cultivars considered (Fig. 1). Genotypic differences were evident, but were almost completely masked unless corrections were made for the large influence that weather factors (primarily water) and soil available N had on PC. Interestingly, representatives of the hard red winter (HRW) and Canadian Prairie Spring (CPS) classes had higher LV than cultivars from the premium hard red spring (HRS) wheat class when adjustments for PC were made (Table 1). The fact that the HRW cultivar CDC Kestrel, which is considered to be an extremely "weak" quality type, produced the highest LV when these adjustments were made certainly begs further explanation. There are a large number of baking methods and formulations used to determine LV, which may explain this apparent discrepancy. However, this explanation suggest that LV is highly procedure dependent and has limited use as a prediction test even though it is the only direct measure of baking product end-use considered in most laboratories.

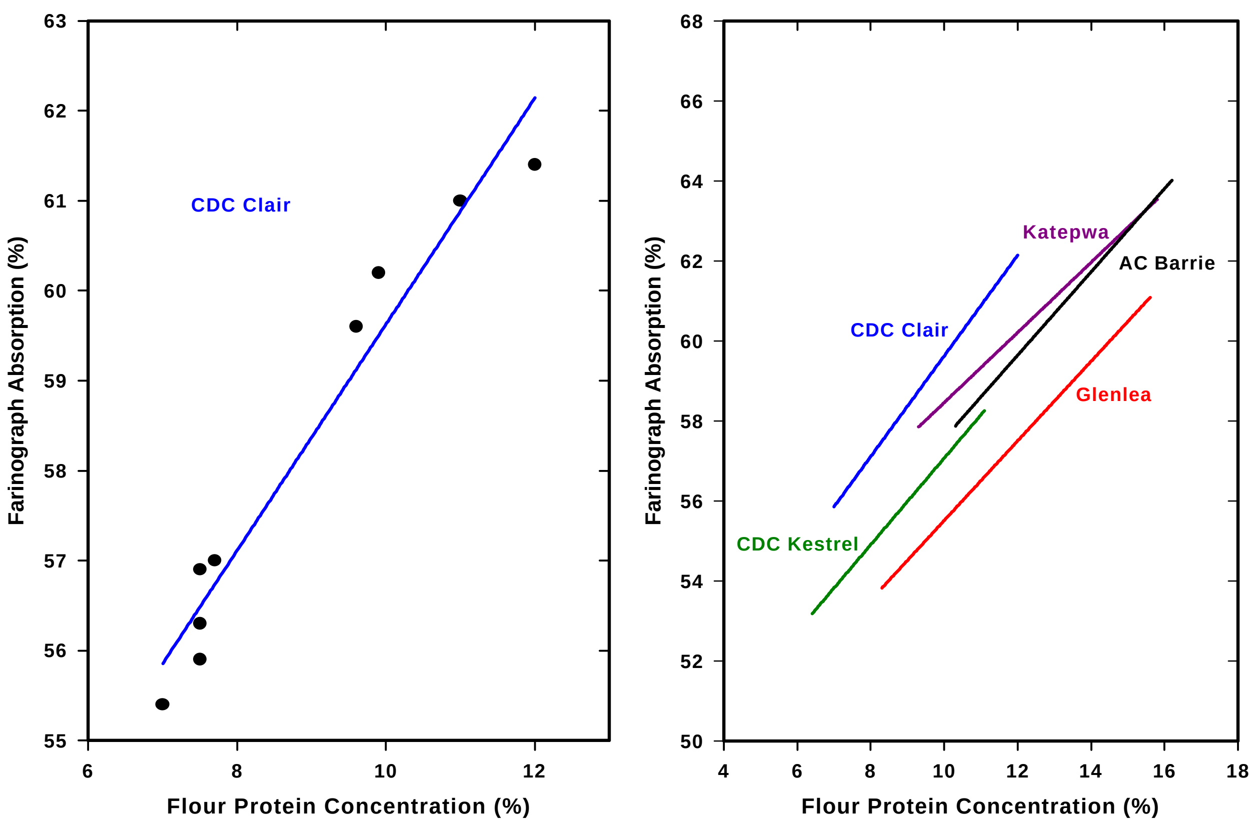

Figure 2. The relationship between protein concentration and flour water absorption for spring and winter wheat cultivars grown on partial irrigation at Saskatoon and dryland at Clair in 1997.

As with LV, an average reduction of 65.2 % in sums of squares due to model indicated that linear equations provided good descriptions of water absorption and PC relationships (Fig. 1).

When adjusted for PC, CDC Clair and Glenlea bracketed the water absorption range for the hard wheat cultivars considered in this study (Table 1). These observations indicate that PC is a primary factor determining water absorption and that, when adjustments are made for differences in PC, high water absorption is not restricted to culivars from the premium quality HRS class.

Table 1. The influence of protein concentration on loaf volume and flour water absorption of five spring and seven winter wheat cultivars grown on partial irrigation at Saskatoon and dryland at Clair in 1997. Loaf volume (see Fig. 1) and flour water absorption (see Fig. 2) at each protein concentration was estimated using linear equations.

		Loaf Volume (cc)						Flour Water Absorption (%)					
	Market	Flour Protein Concentration (%)						Flour Protein Concentration (%)					
Cultivar	**Class**	**10**	**11**	**12**	**13**	**14**	**15**	**10**	**11**	**12**	**13**	**14**	**15**
Spring Wheat													
Katepwa	HRS[z]	635	692	748	805	862	918	58.5	59.3	60.2	61.1	62.0	62.8
AC Barrie	HRS	691	749	808	866	924	982	57.6	58.6	59.6	60.7	61.7	62.8
Glenlea	ESS	687	746	804	862	921	979	55.5	56.5	57.5	58.5	59.5	60.5
AC Taber	CPSR	739	812	885				57.0	57.4	57.8			
AC Reed	SWS	639	690					54.3	55.1				
Winter Wheat													
Winalta	HRW	745	800	855				57.4	58.1	58.9			
Norstar	HRW	762	827					56.3	57.2				
CDC Osprey	HRW	774	829	884				56.8	57.9	59.0			
CDC Kestrel	HRW	776	832					57.1	58.2				
CDC Clair	HRW	762	828	894				59.6	60.9	62.1			
S86-101	HRW	756	814					56.1	57.0				
CDC Ptarmigan	SWW	681						52.0					

[z] **HRS -** Hard Red Spring, **ESS -** Extra Strong Spring, **CPSR -** Canadian Prairie Spring red, **SWS -** Soft White Spring, **HRW -** Hard Red Winter, **SWW -** Soft White Winter.

Data for seven spring and eight winter wheat cultivars grown in seven fertilizer trials on dryland and partial irrigation from 1992 to 1998 were available for the evaluation of the effect of PC on DDT and STAB. There was a nonlinear relationship between flour PC and both DDT and STAB that was best described by the sigmoidal four-parameter Gompertz equation. Average reductions in sums of squares due to model was 69.2 % for DDT and 68.4 % for STAB indicating that these equations provided good descriptions of the relationships between PC and these two measures of dough strength. There was a distinct transition region in both the DDT (Fig. 3) and STAB (Fig.4) curves that occurred between approximately 9 and 12 % PC. DDT and STAB both hovered in the 2-minute region when flour PC was below 8 %. This was followed by a rapid climb that appeared to plateau above 12 % PC. Variability around the cultivar response curves also increased for both DDT and STAB at PC greater than 12 %.

There are procedural differences that influence measures of mixing strength and it is important to establish that the relationships with PC observed in this study were not artifacts associated with the 10-g Farinograph mixing bowl. As an example of the importance of changes in methodology, the Prairie Recommending Committee for Grain (PRRCG) Quality Evaluation sub-committee routinely uses data from higher rpm evaluations to allow for greater expression of the stronger dough characteristics of cultivars in the extra strong wheat class. The PRRCG also uses a 50-g mixing bowl in the final evaluation of cultivars being considered for registration. However, while the protein range within trials is much narrower in the PRRCG data, similar trends can be seen indicating that the PC response patterns reported in this study are not unique to the 10-g bowl methodology. The trends in the PRRCG data are especially evident for the HRW quality class where the average flour PC was 11.6 % over the last 10 years. As expected, the influence of PC on these strength measurements was much less evident in the PRRCG data for HRS, where the average flour PC was 13.4 % over the same period.

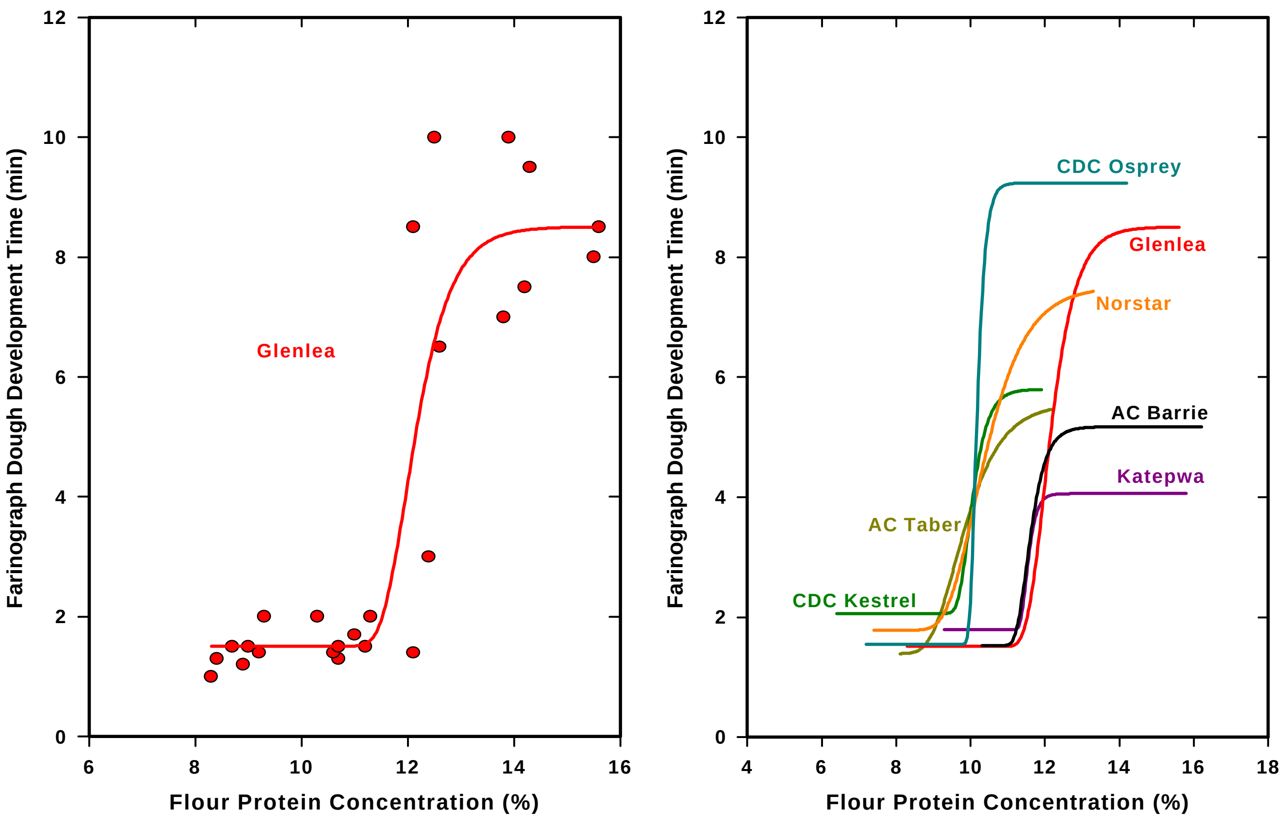

Figure 3. The relationship between protein concentration and farinograph dough development time for spring and winter wheat cultivars grown in seven fertilizer trials on dryland and partial irrigation from 1992 to 1998.

Even a casual inspection of the PC - DDT and - STAB response curves (Fig. 3 and 4) reveals the large influence that PC has on these two measures of dough strength. Nonlinear relationships further confound the expression of these characters making it nearly impossible to draw meaningful conclusions when flour PC is less than 12 % (Fig. 3 and 4). While cultivar differences become much more obvious at PC above 12 %, increased variability affects the accuracy with which comparisons can be made. Surprisingly, adjustment of DDT and STAB for differences in flour PC (Table 2) revealed that Katepwa and AC Barrie were on the weak end of the strength range even though the HRS class targets moderate mixing properties. Even the HRW cultivar CDC Kestrel, which is considered to be an extremely "weak" quality type, had higher DDT and STAB values than Katepwa and AC Barrie at 12 % flour PC. In fact, most of the cultivars in the HRW class exhibited properties at the high end of strength range.

Environmental factors have a large influence on grain PC and there is normally a strong negative correlation between PC and cultivar grain yield potential, which makes PC the quality character that is least accessible to manipulation by the plant breeder. As demonstrated in the present study, the nonlinear relationships between flour PC and both DDT and STAB further complicates grain quality selection procedures. At present, the PRRCG Quality Evaluation sub-committee decisions are made using composites from a large number of trials without any attempt to correct for differences in PC. This procedure ignores the negative relationship between grain yield and PC with the result that high grain yielding lines are nearly always discarded by the cultivar registration system currently employed western Canadian. The observations made in the present study demonstrate that alternative approaches that include grain quality comparisons made over a wide range of PC and adjustment for difference in PC should be considered.

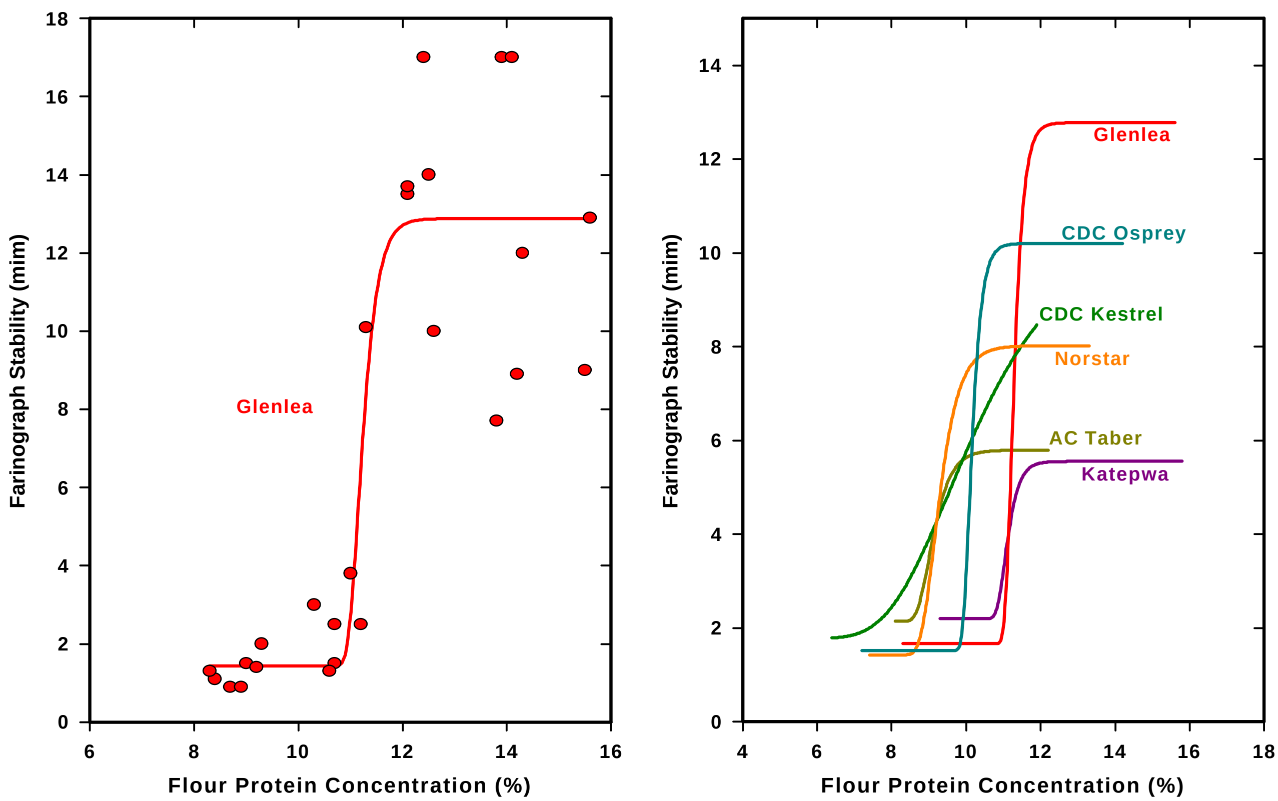

Figure 4. The relationship between protein concentration and farinograph stability for spring and winter wheat cultivars grown in seven fertilizer trials on dryland and partial irrigation from 1992 to 1998.

When PC is measured at the time of grain delivery, there is no need to attempt to control the protein level of western Canadian wheat through restricted cultivar release. Segregation of the different PC targets in separate storage bins is all that is required. This procedure would allow lower protein, higher yielding cultivars to become legitimate options for the farmer whenever their yield advantage was equal to or greater than the protein premium realized for high protein, lower yielding cultivars. This is an especially important consideration given the rapidly expanding opportunity for wheat in the domestic livestock feed market, which often pays a higher premium than the domestic milling market. As an added bonus, this option would provide farmers with an opportunity to identify cultivars and adjust N fertilizer inputs for grain quality targets that they select to maximize net returns on their farm.

Table 2. The influence of protein concentration on farinograph dough development time (DDT) and stability (STAB) of seven spring and eight winter wheat cultivars grown in seven fertilizer trials on dryland and partial irrigation from 1992 to 1998. DDT (see Fig. 3) and STAB (see Fig. 4) at each protein concentration was estimated using the sigmoidal four-parameter Gompertz equation.

		Dough Development Time (min)						**Stability (min)**					
		Flour Protein Concentration (%)						**Flour Protein Concentration (%)**					
Cultivar	**Market Class**	**10**	**11**	**12**	**13**	**14**	**15**	**10**	**11**	**12**	**13**	**14**	**15**
Spring Wheat													
BW90	HRS[z]		3.34	6.90	7.30	7.33	7.33		8.84	10.04	10.05	10.05	10.05
Roblin	HRS		6.74	7.46	7.46	7.46	7.46		10.27	10.27	10.27	10.27	10.27
Katepwa	HRS	1.60	1.73	3.82	4.17	4.19	4.19	2.10	3.26	5.51	5.55	5.55	5.55
AC Barrie	HRS	1.42	1.45	4.55	5.16	5.18	5.18	1.41	4.14	5.80	5.80	5.80	5.80
Glenlea	ESS	1.47	1.48	4.36	7.74	8.41	8.51	1.44	2.62	12.70	12.88	12.88	12.88
AC Taber	CPSR	3.73	5.17	5.40				5.64	5.79	5.80			
AC Reed	SWS	1.42	1.68					1.15	1.62				
Winter Wheat													
Winalta	HRW	2.27	2.30	6.74	6.83	6.83	6.83	3.76	8.51	8.70	8.70	8.70	8.70
Norstar	HRW	3.57	6.01	7.07	7.39			7.42	7.98	8.02	8.02		
CDC Osprey	HRW	2.36	9.22	9.24	9.24	9.24		3.25	10.14	10.20	10.20	10.20	
CDC Harrier	HRW	4.09	5.65	6.41				6.38	7.75	8.43			
CDC Kestrel	HRW	3.73	5.71	5.80				5.75	7.40	8.47			
CDC Clair	HRW	4.76	7.12	8.15	8.51			9.09	9.09	9.09	9.09		
S86-101	HRW	3.61	4.48	4.92				5.88	5.94	5.96			
CDC Ptarmigan	SWW	2.27						4.07					

[z] **HRS** - Hard Red Spring, **ESS** - Extra Strong Spring, **CPSR** - Canadian Prairie Spring red, **SWS** - Soft White Spring, **HRW** - Hard Red Winter, **SWW** - Soft White Winter. Note: BW90 and S86-101 are not registered cultivars.

The Canadian Wheat Board's Special Canada Western Red Winter Wheat Market Development Contract Program that was put into place this crop year is a case in point. Only selected cultivars that have been rated by the PRRCG as having strong gluten and high water absorption potential have been declared eligible for this program. The use of pedigreed seed is an additional requirement for program eligibility. A minimum grain protein concentration of 11.5 % is required and a sliding scale for protein premiums up to 13.5 % has been suggested (note that grain PC is normally from 0.6 to 1.0 % higher than flour PC). A quick look at the results from the present study suggests that a far simpler, more practical option is available that would provide the desired product to test export markets and at the same time eliminate the need for pedigreed seed and changes in our present list of registered cultivars. This option simply requires a protein measurement at the time of producer delivery and, as in the CWB program, the segregation of all deliveries with PC higher than 11.5 % into a separate bin. The end result would be cargoes with the desired minimum grain PC, water absorption in the range of HRS wheat, and strength characteristics stronger than that of AC Barrie. All this would be achieved with lower production and marketing costs and without the need to compromise the agronomic performance and disease resistance of the winter wheat cultivar options available to farmers.

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