A More Meaningful Way to Think About Protein – "Grain Protein Deviation" (updated May 2019)

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Introduction

Since 2014, relatively high winter wheat grain yields have been achieved in Colorado with grain protein content often lower than desired, or at least lower than the market place is willing to accept without price discounts. Why has this happened? The following are a few possible reasons:

- Higher than average precipitation. As an example, the overall yield average of the CSU dryland variety trials for the period 2014-2018 was 64.9 bu/a, about 19 bu/a higher than the average over 2010-2013 ("*Multiple Location Trial Data*" at http://ramwheatdb.com).
- Higher grain yield of newer varieties – and especially higher grain yield potential at higher moisture levels. As an example using CSU dryland variety trial data the average grain yield difference of Prairie Red vs Hatcher is 4.6 bu/a (9.9%), Hatcher vs Byrd is 4.2 bu/a (7.4%), and Prairie Red vs Byrd is 9.9 bu/a (15.3%) ("*Head-to-Head Comparisons*" at http://ramwheatdb.com, then click "*View Grain Yield Regression Plot*").
- Later season precipitation, after the time when many wheat producers have completed top-dressing with nitrogen fertilizers, resulting in nitrogen deficiency during the critical grain filling period.
- A lack of historical price premiums for higher grain protein, and current low market prices and economic returns for wheat production, causing a reduction of inputs including nitrogen fertilizer.
- Larger acreages managed by individual operations, resulting in fewer fields and fewer acres being soil tested to enable optimum fertility management (see http://bit.ly/2rkECJZ and https://bit.ly/2Iw3c1m).

Protein and Bread Baking Quality

To illustrate the effect of grain protein on bread baking quality, we evaluated a small set of samples from the Julesburg trial location – where the grain protein contents were very low – along with the complete set of samples from the Burlington, Akron, and Orchard trial locations (reported elsewhere in this book). Samples were evaluated for grain protein content, water absorption, and loaf volume. These characteristics are vitally important to the milling and baking industry with respect to their influence on economically producing a loaf of baked bread. Data from these evaluations are shown below in Table 1, in order of average grain protein content by field location.

Table 1. Grain protein, water absorption, and loaf volume of hard red and hard white winter (W) wheat varieties evaluated at four locations in the 2017 CSU Dryland Variety Trial.

	Grain Protein (%)				Water Absorption (%)				Loaf Volume (cubic centimeters)			
Entry	Burlington	Akron	Orchard	Julesburg	Burlington	Akron	Orchard	Julesburg	Burlington	Akron	Orchard	Julesburg
Antero (W)	12.5	11.2	9.7	8.8	62.2	59.2	58.2	56.2	815	715	655	605
Denali	12.5	10.9	10.3	9.6	62.3	58.2	59.1	56.9	705	710	705	625
Avery	12.6	9.8	9.7	8.5	63.1	58.2	57.1	56.0	850	810	725	675
Byrd	12.6	10.2	9.4	8.7	65.0	58.3	57.1	55.1	870	805	740	615
Hatcher	12.8	10.5	10.2	9.3	62.9	59.3	58.2	57.2	985	720	695	625
Langin	12.9	10.6	9.0	8.1	63.0	59.3	54.1	53.9	945	845	690	610
Breck (W)	13.2	12.6	9.7	9.2	65.1	62.2	59.2	57.1	900	850	805	650
Snowmass (W)	13.1	11.2	9.9	8.6	65.0	62.3	60.0	56.0	1020	915	865	720
Sunshine (W)	13.0	12.2	10.1	8.8	65.9	63.4	59.2	57.2	945	865	765	665
Average	12.8	11.0	9.8	8.8	63.8	60.0	58.0	56.2	893	804	738	643
Flour Protein Average	11.9	9.8	9.2	8.0	--	--	--	--	--	--	--	--

* note – data highlighted in gray represent values that meet the minimum Recommended Quality Targets for Hard Winter Wheat established by the Hard Winter Wheat Quality Targets Committee in 2006 (see http://bit.ly/2E2ZHjP).

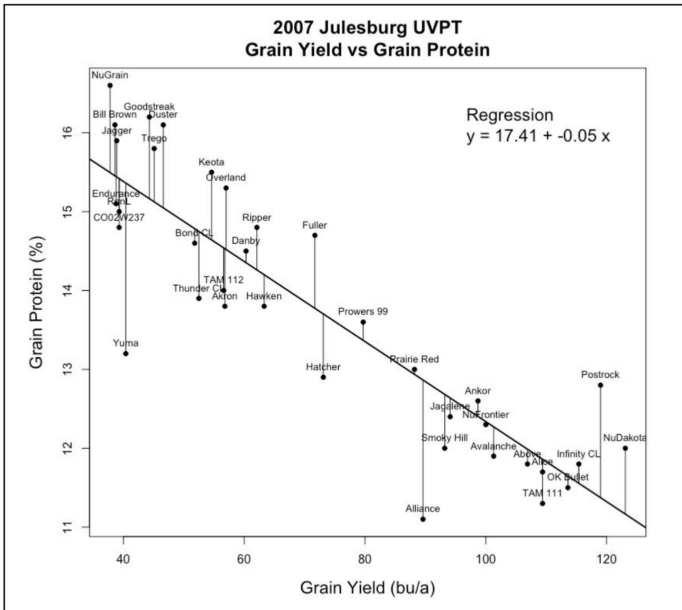
Stark differences among varieties and trial locations were apparent, and the following conclusions can be made:

- A strong trend was observed among varieties and trial locations with lower protein content leading to lower water absorption and lower loaf volume. This leads to added costs in the industry through the need to "blend up" with higher protein flour or add vital wheat gluten to make a suitable dough.
- At Burlington, which had an average of 12.8% grain protein, all of the varieties met the water absorption target (62% minimum) and most of the varieties met the loaf volume target (850 cc), with the exception of Antero and Denali. Most varieties can make a decent loaf of bread at higher protein content.
- At Akron, which had the next lowest average of 11.0% grain protein, only the three hard white varieties (Breck, Snowmass, Sunshine) met either the water absorption or loaf volume target. This is likely a primary reason why these varieties are currently commanding a grower premium.
- At Orchard, which had the next lowest average of 9.8% grain protein, none of the varieties met the water absorption target and only Snowmass met the loaf volume target, in spite of its grain protein being below the target. This is likely one part of the reason why Snowmass currently commands a greater grower premium than either Sunshine or Breck.
- At Julesburg, which had the lowest average of 8.8% grain protein, none of the varieties met either the water absorption or loaf volume targets. This is why very low protein wheat has very little value in the market.

<u>Grain Yield and Grain Protein Relationships</u>

In order to optimize economic returns, the producer would like to pick varieties that maximize both grain yield and grain protein at the same time. For the breeder, this implies that we ought to try to breed for varieties that have both high grain yield <u>and</u> high protein content. This is seldom if ever done because a) grain protein is not a very highly heritable trait (i.e., environmental effects such as management and weather far outweigh genetic effects) and b) the common inverse relationship between yield and protein among entries (i.e., varieties with high yield show lower protein, and vice versa). This is referred to as the "*dilution effect*" as higher yielding varieties produce more kernels and thus each kernel then contains proportionately less protein.

A very attractive method to sidestep this negative yield vs protein relationship is what's known as "*grain protein deviation*", as depicted in **Figure 1** below. These data come from the 2007 CSU dryland variety trial at the Julesburg trial location.



How to Calculate Grain Protein Deviation

- Plot-level yield and protein data from a single location are plotted on a scatterplot with yield on the horizontal axis and protein on the vertical axis.
- The best fit through these data points is determined via a statistical method called *linear regression*.
- The vertical distance between the best fit line and the observed value is the grain protein deviation for that variety at that location.
- Varieties above this line at this location show a greater tendency toward higher protein for their yield level, or positive grain protein deviation.
- Varieties below this line show a greater tendency toward lower protein for their yield level, or negative grain protein deviation.

Calculation of Grain Protein Deviation

The graph shown in Figure 1 indicates how grain protein deviation may be calculated for a given trial at a given location. In this graph, we can see that Hatcher and Fuller had similar yield (about 72 bu/a) but differed by about 1.8% protein with Fuller about 0.9% above the straight line and Hatcher about 0.9% below the straight line. In this case, Fuller is showing a higher grain protein deviation value than Hatcher.

As with any trait we measure in breeding there may be confounding effects due to spatial variability in the field, errors in estimation, human errors in the conduct of the experiments, and all sorts of other factors that collectively hinder our ability to rely on values from a single trial location. Because of this, we assembled a very large dataset across years, locations, and trials to derive a more robust estimate of grain protein deviation for individual varieties. These data included 3,876 total datapoints, across 15 years (2003-2017), and across the CSU Elite Trial and the CSU dryland and irrigated variety trials. Overall, the dataset comprised 280 different varieties and exprerimental lines and 91 total year-location-trial combinations. Well-known and widely-accepted statistical techniques were employed to enable analysis of such a large and imbalanced data set. The method is extremely appealing as it allows for rapid estimation of grain protein deviation as new data are collected in the context of the breeding and variety testing programs.

Overall, the individual and combined trial analyses showed the following:

- Of the 91 individual year-location-trial combinations, a statistically significant ($P<0.05$) negative relationship between yield and protein was observed for 53 combinations. If the statistical probability level used by the CSU Crop Testing program was used ($P<0.30$), 72 out of 91 combinations showed a statistically significant negative relationship.
- The average correlation between yield and protein in the 53 trials used for the combined varietal analysis was -0.52, with a range of -0.25 to -0.88 (for the Julesburg 2007 UVPT example shown in Figure 1). As expected, there was no correlation between grain yield and the derived grain protein deviation value.
- Trials that did not show a significant negative relationship were often trials that had been affected by a secondary factor, such as a severe stripe rust infection or weather event.
- Values for varieties included in the analyses were derived and then converted to a 1-9 scale for reporting. These values are in the Variety Characteristics Table in this report and will be updated each year on the Colorado Wheat Variety Database ("*Wheat Variety Information*" at http://ramwheatdb.com).

Table 2. Grain protein deviation (GPD) scores (1=good to 9=poor scale) of entries in the 2018 and 2019 CSU dryland and irrigated variety trials.

High Postive GPD (1-3)				Medium GPD (4-6)				High Negative GPD (7-9)	
Brawl CL Plus	1	SY Rugged	2	AM Eastwood	4	Whistler	5	Hatcher	7
Breck	1	SY Wolf	2	Canvas	4	Winterhawk	5	Thunder CL	7
CO13D0787	1	WB4458	2	LCS Mint	4	Avery	6	Snowmass	7
LCS Chrome	1	SY Sunrise	3	Snowmass 2.0	4	Byrd	6	Incline AX	7
Oakley CL	1	Underwood	3	SY Legend CL2	4	Byrd CL Plus	6	CO15SFD107	7
WB4721	1	WB4303	3	SY Monument	4	Denali	6	Monarch	8
NHH144913-3	2	WB4462	3	WB4418	4	Langin	6	Crescent AX	8
Sunshine	2			Antero	5	Long Branch	6	CO15SFD092	8
				WB-Grainfield	5	Spur	6		

Acknowledgements

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