

Fast, portable, or precise? Choosing the right grain protein estimation tool

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Fast, Portable, or Precise? Choosing the Right Grain Protein Estimation Tool



Which method should you use to measure wheat grain protein content? The answer may depend on what questions you are trying to answer and how much accuracy you are willing to trade for speed and convenience. This article compares the bias and

variability of benchtop, on-combine, and handheld near-infrared (NIR) analyzers with those of a laboratory reference method and discusses where

[each technology fits in research and crop management.](#)

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Grain protein has long been one of the most valuable measurements collected in wheat production and research. It influences market class, milling and baking quality, nitrogen management decisions, and ultimately farm profitability (Zörb et al., 2018). For researchers and agronomists, protein concentration also serves as an important indicator of crop nitrogen status, environmental stress, and treatment response (Wan et al., 2022). Therefore, accurate and reliable measurement of grain protein is critical for result accuracy, improving reproducibility, and making informed management decisions.

Only a decade ago, most researchers relied almost exclusively on laboratory chemistry or benchtop near-infrared (NIR) instruments to measure grain protein. Today, portable handheld analyzers can estimate grain protein in seconds, and on-combine sensors can generate grain protein maps of entire fields during harvest. These technologies promise faster data collection, lower labor requirements, and entirely new opportunities for precision agriculture. The question is no longer whether we can measure grain protein quickly but rather how much accuracy we are willing to trade for speed and convenience. This question motivated [our recent study](#) published in *Food Analytical Methods*

, where we independently compared four commonly used approaches to grain protein measurement. Rather than asking which technology is "best," we asked a more practical question: when should each technology be used?

Why protein measurement matters

Grain protein concentration affects nearly every sector of the wheat industry. Growers monitor grain protein because it influences market premiums (Bekkerman, 2021). Millers depend on consistent protein for flour quality (Sharma et al., 2020). Plant breeders use grain protein content as an important selection trait. Agronomists evaluate grain protein responses to nitrogen management, drought stress, fungicides, crop rotation, and numerous other management practices.

Because so many decisions depend on protein measurements, confidence in protein estimates matters.

Ways to measure grain protein

Our study compared four different approaches for measuring grain protein.

Standard laboratory (Dumas combustion): The laboratory-based Dumas combustion method remains the reference standard for protein determination. In this method, nitrogen (N) concentration is measured directly, and protein content is



The laboratory-based Dumas combustion method remains the reference standard for protein determination. Photo courtesy of Velp Scientific.

calculated from N concentration. Its strengths are obvious: excellent precision and broad acceptance throughout research and industry. However, the process is slow, relatively expensive, and requires laboratory expertise for sample analysis or outsourcing to a specialized laboratory.



FOSS Infratec has become the workhorse grain protein analyzer for many breeding programs, grain laboratories, and university research stations. Photo courtesy of S Leitenberger - stock.adobe.com.

FOSS Infratec Benchtop NIR: FOSS Infratec has become the workhorse grain protein analyzer for many breeding programs, grain laboratories, and university research stations. Grain samples are poured into the sample hopper of instrument, and protein content is estimated in seconds using calibrated NIR spectroscopy. It provides high-throughput measurements while maintaining a robust analytical performance, making it a benchmark for modern grain analysis

technologies.

H3 GrainGage On-Combine NIR: Perhaps the most exciting recent innovation is the on-combine grain protein analyzer. This technology offers grain protein measurement during harvest as grain moves through the combine, such that grain samples need not be collected for subsequent analysis. For researchers harvesting thousands of small plots, this can dramatically reduce labor requirements. For growers, similar technologies enable protein mapping across entire fields, creating opportunities for variable-rate nitrogen management and segregation of grain by quality.

GrainSense Handheld Analyzer: This latest category of grain protein analyzer is distinguished by its ease of use and simple operation. These portable devices fit in one hand and can provide rapid estimates in almost any setting. They are inexpensive compared to laboratory instruments and require minimal training, making them an attractive option for crop consultants, extension personnel, producers, and seed companies.



The HarvestMaster H3 GrainGage On-Combine NIR. Photo courtesy of HarvestMaster. It measures grain protein during harvest as grain moves through the combine, such that grain samples need not be collected for subsequent analysis.

Data sources and methods

A set of 100 wheat grain samples from the Oregon State University Cereal Extension Program were used for grain protein analysis. The grain protein content ranged from 7.16 to 17.24%, and moisture content ranged from 8.28 to 10.39% in the wheat grain samples. Grain samples were analyzed for protein content by laboratory-based Dumas combustion and three NIR-based methods: on-combine H3 GrainGage by Harvest Master (Logan, UT), benchtop grain protein analyzer FOSS Infratech NIR (FOSS Analytics, Hillerød, Denmark), and handheld grain protein analyzer GrainSense NIR (GrainSense Ltd, Oulu, Finland). The laboratory-based grain protein analysis was conducted by the certified commercial laboratory A&L Great Lakes Laboratories, Fort Wayne, IN.



The GrainSense Handheld Analyzer is portable, easy to use, and inexpensive compared with lab instruments.

Bland–Altman analysis was used to test the agreement in grain protein measurements by different methods (Altman & Bland, 1983).

The laboratory-based Dumas combustion was used as a reference method. The mean bias (d) and limits of agreement (LOA) were determined by comparing two methods at a time.

Mean bias = mean difference in grain protein

measurement between two methods

$$\text{LOA} = \text{mean bias} \pm 1.96 \times \text{SD}_d$$

where SD_d indicates the standard deviation of differences between two methods.

Additionally, simple linear regression and Pearson correlation were also applied to understand the general relationships between the methods.

Comparison with reference method

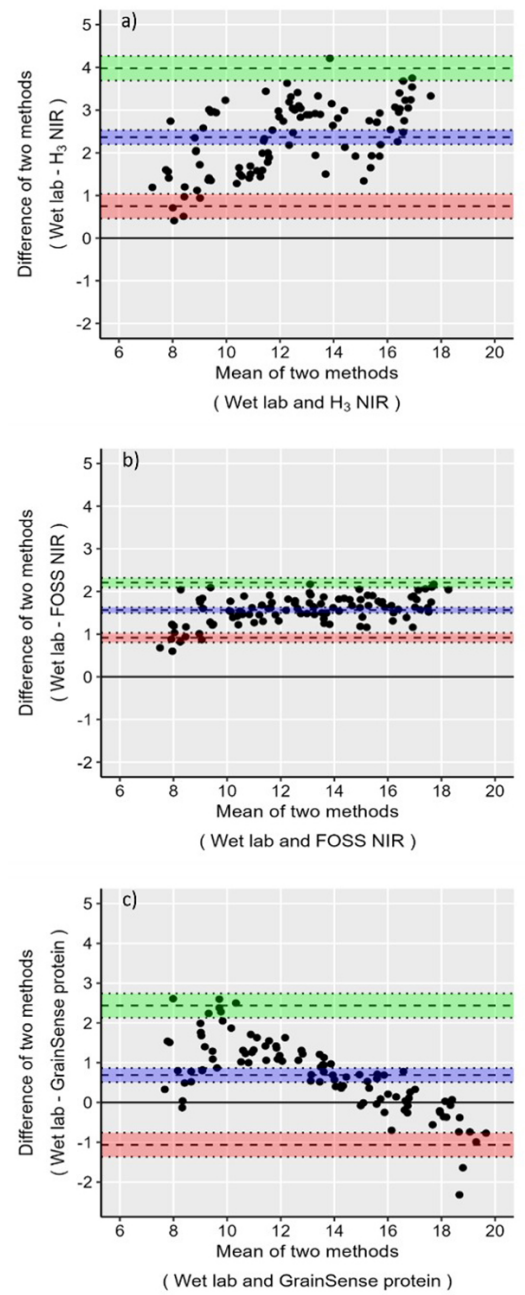


Figure 1. Bland-Altman plot originally derived from Mahato et al. (2026), showing mean bias and limits of agreement (LOA) between methods. Mean bias, upper, and lower LOA are represented by purple, green, and red shaded areas, respectively. The shaded

All NIR based estimates showed a measurable bias in grain protein when compared with the reference method (Table 1). The overall mean bias was positive in all

NIR systems, indicating the NIR-based

methods underestimated grain protein compared with the reference method. Among three NIR systems evaluated, the FOSS Infratec demonstrated the most consistent performance. It had the lowest prediction error and the lowest variability in bias across the range of protein concentrations evaluated. The H3 GrainGage also correlated strongly with standard laboratory values but exhibited greater systematic bias, particularly for samples with higher protein contents (Figure 1). The GrainSense handheld analyzer behaved differently; it demonstrated greater variability and bias at the lower end of the protein range (Figure 1). While overall mean bias appeared relatively small for the GrainSense handheld analyzer, the bias varied substantially depending on protein concentration.

area represents confidence interval limits for mean bias and LOA. The black solid line aligning with zero represents no bias between two methods.

These findings highlight an important point: a single average bias does not tell the whole story. Understanding the variability in bias across the range of protein concentrations is just as important as knowing how much bias exists. This result is not necessarily surprising as, unlike laboratory-based methods, NIR instruments do not directly measure grain protein. Instead, they estimate grain protein using calibration models developed from large datasets of known samples.

Looking beyond correlation

Many people use correlation coefficients to evaluate the agreement between analytical instruments or methods. Our study found strong correlations and high R^2 values among different methods. Correlation coefficients ranged from 0.97 to 0.99,

and R^2 values ranged from 0.94 to 0.99 when compared with laboratory measurements. If we stopped there, we might conclude that every instrument performs equally well. But correlation tells only part of the story.

Imagine two scales that always differ by five pounds. They will still correlate almost perfectly. Strong correlation coefficients and high R^2 values do not always indicate strong agreement between two methods. The correlation coefficient only shows the relationship between variables, while R^2 value measures the percentage of variability in the response variable explained by the independent variables. However, neither of these parameters confirm the agreement between two methods (Giavarina, 2015). Despite strong correlations and high R^2 values between two methods, the mean bias still could be high.

To evaluate the degree of agreement, we used Bland–Altman analysis, which measures systematic bias between methods. This approach allowed us to determine whether each instrument consistently overestimated or underestimated grain protein relative to the standard laboratory method. For practical decision making, this is often more informative than correlation alone.

Table 1. Comparison of NIR-based grain protein measurement methods vs. the reference method.

Method comparison	Correlation coefficient	R^2	RMSE	Mean bias
Dumas method vs H3 NIR	0.97	0.94	0.73	2.36 (2.20 to 2.53)

Dumas method vs FOSS NIR	0.99	0.99 0.29	1.56 (1.50 to 1.63)
Dumas method vs GrainSense NIR	0.98	0.97 0.53	0.69 (0.51 to 0.86)

^aRMSE, root mean square error.

The values within parenthesis indicate the 95% confidence interval of the mean bias.

Why do measurements differ among NIR instruments?

Several factors contribute to differences in grain protein measurement among NIR systems. First, every instrument relies on calibration models developed using different sample populations. Calibration quality ultimately determines accuracy as calibration models are never free from prediction errors. If calibration datasets do not adequately represent the diversity of environments, varieties, range of protein concentrations, and grain characteristics encountered in practice, the prediction accuracy suffers (Kaur et al., 2026). Secondly, these NIR systems are operated under different environmental conditions. For example, benchtop instruments analyze grain protein under controlled laboratory environments. On-combine systems operate during harvest under changing temperatures, dust, vibration, and variable grain moisture. These conditions inevitably introduce additional variability. Finally, calibration drift occurs over time. Routine recalibration remains essential regardless of instrument type.

Choosing the appropriate instrument or method based on your need

Rather than asking which instrument is "best," we suggest agronomists ask which instrument best fits the question they are trying to answer. When maximum precision matters, laboratory chemistry remains the preferred option. If research decisions,

publications, or regulatory work require the highest confidence, laboratory methods continue to provide the benchmark.

When processing a large volume of samples, the FOSS Infratec remains difficult to beat. Its combination of speed, repeatability, and relatively low bias makes it an outstanding choice for breeding programs, research stations, and grain laboratories.

When harvest efficiency and rapid data collection are priorities, the on-combine NIR system changes the workflow entirely. Instead of collecting and processing thousands of grain samples after harvest, protein data become available immediately. This advantage can dramatically reduce labor requirements while simultaneously providing protein information in real time. Researchers should simply recognize that this convenience comes with some additional systematic bias.

When mobility matters, handheld analyzers occupy a unique niche. Extension specialists, consultants, seed companies, and producers often need immediate answers in the field. For those applications, portability may outweigh the modest reduction in precision.



Four different approaches for measuring grain protein were compared (l to r): HarvestMaster H3 GrainGage On-Combine NIR, FOSS Infratec Benchtop NIR, GrainSense Handheld Analyzer, and standard laboratory (Dumas combustion).

What this means for precision agriculture

Beyond traditional research, on-combine protein analyzers offer great potential. On-combine protein analyzers can create spatial maps showing protein variation throughout individual fields. These maps can help improve nitrogen management, identify areas of differing crop performance, and potentially support variable-rate fertilizer applications in future seasons. As precision agriculture continues to evolve, grain quality maps will likely become just as valuable as yield maps. However, precision management decisions depend on confidence in the underlying measurements. Improving calibration robustness remains one of the most important challenges for manufacturers.

Where do we go from here?

The encouraging news is that every NIR technology evaluated in this study demonstrated a strong relationship to laboratory measurements. All instruments in this study provide tremendous value in certain instances. These are increasingly capable tools, and their performance will likely continue improving through expanded calibration datasets, adaptive machine-learning models, and cloud-based calibration updates. Future studies may evaluate performance across additional environments, growing seasons, market classes, and protein ranges. Larger calibration libraries representing diverse wheat production systems will certainly improve prediction accuracy.

The bottom line is that there is no universal "best" protein analyzer; each technology serves a distinct purpose. If your priority is maximum analytical precision, the laboratory-based method remains the gold standard. If you need high-throughput laboratory efficiency, the FOSS Infratec continues to set the benchmark. If your goal is real-time data for precision agriculture applications, the on-combine grain protein analyzer offers capabilities that were unimaginable only a few years ago. If you need rapid, portable field measurements, handheld analyzers provide remarkable convenience.

As agronomists, we often search for the single best tool. The best protein analyzer depends entirely on the question you're trying to answer. And as NIR technology continues to advance, the gap between fast, portable, and precise will likely continue to narrow.

Dig deeper

Mahato, G., Graebner, R. C., Hunt, M. P., Namdar, G., Plunkett, R., Wood, D., Krause, M., Singh, S., Calderon, F. J., & Hagerty, C. (2026). Comparative analysis of wheat grain protein content: wet chemistry and NIR based methods. *Food Analytical Methods*, 19(7), 208. <https://doi.org/10.1007/s12161-026-03123-7>

Disclaimer

While we presume that the laboratory-based protein values are accurate and these NIR instruments tended to underestimate actual protein values, without independent validation, we cannot rule out the possibility that the laboratory-based methods may overestimate actual protein values.

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1. Which of the following statements is true?

- a. Correlation coefficient measures the strength of relationship between two variables.
- b. Correlation coefficient can measure the systematic bias between a new method and the reference method.
- c. Correlation coefficient applied along with R^2 value can determine the systematic bias between a new method and the reference method.
- d. All are correct.

2. If the correlation coefficient is very strong, the bias between a new method and the reference method will be always low.

- a. True.
- b. False.

3. The correlation coefficient cannot determine the bias between a new method and the reference method.

- a. True.
- b. False.

4. Which factors affect wheat grain protein content?

- a. Wheat variety.
- b. Nitrogen management.
- c. Drought or soil moisture stress.
- d. All are correct.

5. **Which of the following statements is NOT true.**

- a. Grain protein is a component of grain quality.
- b. Grain protein does not affect wheat marketing; only yield matters.
- c. Grain protein influences wheat market class.
- d. Grain protein influences milling and baking quality.

6. **At what grain protein range was a greater variability in bias generally based in this article?**

- a. The variability in bias was consistent across all ranges of grain protein concentrations.
- b. The variability in bias was greater at mid-range of grain protein concentrations.
- c. The variability in bias was greater at lower or higher range of grain protein concentrations.
- d. There is no bias at all.

7. **What factors related to the calibration of NIR instruments can affect the accuracy of grain protein measurement?**

- a. Grain samples used for the calibration procedure.
- b. Accuracy of grain protein measurement by the reference method.
- c. Accuracy of the calibration model itself.
- d. All are correct.

8. **What can cause differences in grain protein measurement among the NIR based systems?**

- a. Different operating environmental conditions of the NIR systems.
- b. Different calibration models of the NIR systems.
- c. Different grain samples used for calibrating the NIR systems.
- d. All are correct.

9. Among the grain protein measurement methods described in this article, which will be the most effective for grain protein mapping of large farm fields?

- a. Benchtop grain protein analyzer.
- b. Handheld grain protein analyzer.
- c. On-combine grain protein analyzer.
- d. Standard laboratory-based methods.

10. Which of the following statements is NOT true about NIR-based systems.

- a. Calibration drift may occur in NIR-based instruments after years of use.
- b. Routine calibration is required to maintain the robustness of NIR based instruments over years of use.
- c. Grain cleanliness and presence of foreign materials may impact accuracy of grain protein readings.
- d. Grain temperature and grain moisture have no effect on grain protein measurements.

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