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Report to the Chairman, Subcommittee on Agricultural Research and General Legislation, Committee on Agriculture, Nutrition, and Forestry, U.S. Senate

November 1987

GRAIN INSPECTION

Evaluation of USDA Study on Wheat Protein Measurement

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Resources, Community, and
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The Honorable Kent Conrad
Chairman, Subcommittee on Agricultural
Research and General Legislation
Committee on Agriculture, Nutrition,
and Forestry
United States Senate

Dear Mr. Chairman:

In your letter of July 2, 1987, you asked us to analyze a change that the U.S. Department of Agriculture's (USDA) Federal Grain Inspection Service (FGIS) made in April 1987 in wheat protein measurement. In particular, you asked that we examine (1) the statistical techniques FGIS used in performing the study on which the change was based and (2) the sampling methods FGIS used in its study. Your letter expressed concern that this change, which lowered the measured protein content of Hard Red Spring wheat, had a significant negative impact on wheat producers nationwide.

On September 17, 1987, we briefed your staff on our findings. In summary, we concluded that the statistical techniques and sampling methods FGIS used in its study were appropriate. The statistical techniques are commonly used in many disciplines and are prominently featured in general statistical methods texts. The sampling methods yielded samples appropriate for determining the changes to be made in measuring wheat protein. As requested, this report summarizes the briefing and provides information on (1) the FGIS study, (2) recent changes in FGIS' quality control program to improve the accuracy of its wheat protein measurements, and (3) responsibility for ensuring that wheat protein is accurately measured by country elevators and grain merchandisers.

Protein Content Is an Important Quality Factor in Wheat

Protein content is an important determinant of how wheat will be used. For example, Hard Red Spring wheat, the wheat class highest in protein, is used to make quality yeast breads and hard rolls. Higher protein wheat generally brings a higher price, or premium, in the market. According to an FGIS official, the premium on high protein wheat is generally based on each fifth of a percent of measured protein content. In recent years, premiums have been particularly high. In early May 1987, for example, the premium for Hard Red Spring wheat with a protein

content of 15 percent was about $1.60 per bushel. The base price for Hard Red Spring wheat at that time was about $2.90 per bushel.

FGIS' Study to Determine Cause of Alleged Wheat Protein Shortages

For some time prior to the April 1987 change in wheat protein measurement, FGIS had been receiving persistent complaints from a number of U.S. export customers, particularly in Asia, that the Hard Red Spring wheat they were receiving contained less protein than what they had contracted for and less than what FGIS had certificated.[1]

In response to the complaints, FGIS selected about 600 wheat samples from various sources and analyzed the samples' protein content using two protein measurement methods—one called the Kjeldahl and the other the Near-Infrared Reflectance (NIR). The Kjeldahl, a chemical process, involves bulkier equipment, takes longer to complete, and requires a higher degree of technical expertise than the NIR. The NIR instrument, in which near-infrared light is reflected off ground grain, provides a protein reading within seconds and, in the United States, is more commonly used than the Kjeldahl. The NIR readings are based on a calibration equation that is entered into the instrument's computer memory. The equation correlates NIR readings with those provided by the Kjeldahl process, which FGIS uses as its baseline. The equation can become outdated over time as new varieties of wheat are introduced and as other factors affecting protein content, such as fertilizers and growing conditions, change.

On the basis of its analysis of the approximately 600 samples, FGIS concluded that its NIR instruments had become biased in the direction of overstating the protein content of Hard Red Spring wheat. To correct the bias, on April 15, 1987, FGIS adjusted its NIRs so that they would measure the protein content of Hard Red Spring wheat at 0.2 percentage point less than before the adjustment.[2] In addition, FGIS initiated a study to recalibrate its NIRs (i.e., update information used in the calibration equation). This recalibration was completed in September 1987.

FGIS' downward adjustment of the NIR means that the protein content of Hard Red Spring wheat will be measured more accurately but that it will

[1]FGIS issues an official certificate after it completes its inspection of grain. FGIS administers a nationwide system for officially inspecting and weighing grain. While this inspection does not routinely include a protein measurement, FGIS provides such a measurement upon request and payment of a fee.

[2]These procedures became effective on May 1, 1987.

measure 0.2 percentage point less than before the adjustment. For example, the protein content of Hard Red Spring wheat measured by the NIR at 14.8 percent before the adjustment, would measure 14.6 percent after the adjustment.

Other Issues Relevant to Your Concerns

We also discussed with FGIS officials other issues that are relevant to your concerns. The first involves changes that FGIS recently made to its quality control program to improve the accuracy of wheat protein measurements. According to FGIS officials, these changes include (1) standardizing grain coarseness by retrofitting grinders so that wheat samples will be fed into the grinder at a fixed rate before being placed in the NIR and (2) standardizing the time elapsed between grinding the wheat sample and placing it in the NIR. Both of these factors can affect protein readings. In addition, FGIS officials told us that FGIS plans to recalibrate its NIRs on an annual basis. Prior to the recent recalibration, FGIS last recalibrated its NIRs in 1982.

A second issue concerns whether FGIS has authority to ensure that wheat protein is accurately measured by other entities, such as country elevators and grain merchandisers. Although FGIS is authorized to officially test wheat for protein content under the United States Grain Standards Act, as amended (which it does only upon request and payment of a fee), no federal agency is responsible for routinely assuring that wheat protein measurements by unofficial entities are accurate.

Our analysis of the FGIS study included a review of the methods FGIS used to analyze the results of protein determinations, the appropriateness of the wheat sample sources, and the data generated by the study. We also discussed the study with FGIS officials, including the official responsible for designing and executing the study and for interpreting its results.

In addition, we obtained through discussions with FGIS officials information on (1) recent changes in FGIS' quality control program and (2) whether FGIS or any other federal agency has authority to ensure the accuracy of wheat protein measurements by other entities, such as country elevators and grain merchandisers. We did our work at USDA headquarters in Washington, D.C., during August and September 1987.

Appendix I provides information on FGIS' protein measurement study, including how protein is measured, the events leading up to the study,

and how the study was conducted. Appendix II lists the main contributors to this report. FGIS officials reviewed a draft of the report and their suggestions have been included where appropriate.

As arranged with your office, unless you publicly disclose its contents earlier, we plan no further distribution of this report until 5 days from the date of this letter. At that time, we will send copies to the Secretary of Agriculture; the Administrator, FGIS; and other interested parties.

Sincerely yours,

Brian P. Crowley
Senior Associate Director

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Abbreviations

FGIS	Federal Grain Inspection Service
GAO	General Accounting Office
NIR	Near-Infrared Reflectance
USDA	U.S. Department of Agriculture

Information on the FGIS Protein Measurement Study

How Wheat Protein Is Measured

Wheat protein may be measured by using the Kjeldahl method or the Near-Infrared Reflectance (NIR) instrument. The Kjeldahl method involves a somewhat elaborate chemical process which measures the amount of nitrogen in a substance. This amount, expressed as a percentage, is then multiplied by a factor of 5.7 to determine the percentage of protein in a sample of wheat. At a minimum, the process takes over 2 hours to produce a measurement. In addition, the equipment involved is bulky, and considerable technical expertise is necessary to perform the test.

The NIR, on the other hand, uses a process whereby a sample of wheat is ground and placed in the instrument, which directs near-infrared light at the sample. The amount of light reflected from the grain provides an indication of protein content. The response of the reflected light on photocells is fed into the NIR's computer, which provides a protein reading within seconds, using a previously entered calibration equation.

Calibration equations are a complex set of mathematical equations that are programmed into the NIR instrument. These equations take into account such factors as moisture levels and classes of wheat. The Federal Grain Inspection Service (FGIS) developed a new calibration equation for Hard Red Spring wheat in September 1987. Before then, it relied on a calibration equation it had developed in 1982.

According to an FGIS official, protein measurement is an inexact science. The NIR is a sensitive instrument affected by temperature, moisture, and other environmental factors. Even when the instrument is properly used and calibrated, an NIR protein measurement for the same wheat sample may vary up to plus or minus 0.2 percentage point.

Because NIRs are faster, easier to use, and less costly, they have largely replaced the Kjeldahl method in the United States as a means of measuring wheat protein. The NIR instrument is FGIS' only approved method for official protein determinations of export wheat. However, the Kjeldahl method remains the basic reference standard used in the United States. FGIS' Quality Control Branch uses the Kjeldahl method to monitor the accuracy of NIR measurements.

FGIS maintains NIRs in most of its 28 field offices. In addition, it maintains a master NIR and a master Kjeldahl in its Quality Control Branch in Kansas City, Missouri.

Why FGIS Made Its Protein Measurement Study

Starting in mid-1986, FGIS began receiving an unusually high number of complaints from U.S. grain customers, particularly in Asia, regarding protein shortages in U.S. wheat. According to FGIS officials, FGIS had received such complaints before, but these recent complaints were noteworthy because they were persistent, were more frequent, and alleged much larger protein discrepancies.

In addition, the Japanese Food Agency indicated that it was experiencing problems with protein shortages in U.S. wheat. FGIS has been involved in a joint wheat protein measurement project with the Japanese agency since 1982. Twice a year, FGIS exchanges samples of wheat with the Japanese. Protein measurements are obtained on Kjeldahl units at FGIS' Quality Control Branch laboratory and at the Japanese Food Agency laboratory. Results are then tabulated and differences compared. The results of the two Kjeldahl units have been generally uniform.

Beginning in June 1986, however, Japan began noting differences between the protein content of U.S. Hard Red Spring wheat as measured by its Kjeldahl units and as certificated by FGIS using NIR instrument readings. The average difference went from less than 0.1 percentage point prior to June 1986, to between 0.3 and 0.6 percentage point after that time. FGIS' Quality Control Branch laboratory in Kansas City analyzed the wheat samples in question using its master Kjeldahl and NIR instruments. On the average, the master NIR's readings were found to be about 0.3 percentage point higher than those of the master Kjeldahl.

How the Study Was Conducted

FGIS initiated its study at the request of U.S. Wheat Associates, a farmer-funded organization that promotes wheat sales. The organization had received repeated complaints about protein shortages in U.S. wheat shipments arriving in Southeast Asia. The study's purpose was to determine why wheat protein measurements were 0.2 percentage point or more lower than FGIS had certificated at U.S. origin. The study, conducted by the Chief of FGIS' International Monitoring Staff, consisted of three series of samples. Samples were measured for protein content using both the Kjeldahl and NIR methods.

The first series consisted of 155 samples taken from 10 vessels containing Hard Red Spring wheat on which FGIS had received formal protein complaints. Protein measurements on these samples were performed using the master Kjeldahl and NIR at FGIS' Quality Control Branch laboratory. These measurements were then compared with the measurements

that had been previously taken at the loading elevators. A total of 465 protein determinations were made on these samples.

The second series consisted of 205 samples taken at the origin port from 4 vessels destined for 9 Southeast Asian mills. Each sample was divided into four equal parts: one to be tested in FGIS' Quality Control Branch laboratory, one for testing in an Agricultural Research Service quality control laboratory, one to be tested at the destination mill in Southeast Asia, and the final portion to be maintained by FGIS' International Monitoring staff for analysis using destination mill laboratory methods. In addition, samples from the shipments were collected at destination mills and sent back to FGIS for analysis in U.S. Department of Agriculture laboratories. In all, some 932 protein determinations were made on the second series of samples.

The third series consisted of wheat samples taken at random from 29 export vessels and 199 railcars, barges, and bins. The samples had been analyzed at FGIS' Portland field office laboratory as part of the field office's routine monitoring from December 1986 through the first week of April 1987. Protein content had been determined at the export elevators, and the field office analyzed the samples using both the NIR and Kjeldahl methods. A total of 768 protein determinations were made on these samples.

What the Study Found

On the average, the NIRs consistently gave protein results higher than the Kjeldahl results. The combined results of the three series representing 588 samples showed an average difference between origin-NIR readings and Kjeldahl readings of 0.27 percentage point. Specific results for each of the three series are as follows:

- For the first sample series, origin NIRs gave the highest average protein readings, followed by Quality Control Branch laboratory NIR readings, and lastly by Quality Control Branch laboratory Kjeldahl readings. The differences between the origin NIRs' results, i.e., the FGIS-certificated values, and the quality control laboratory Kjeldahl results averaged about 0.34 percentage point. The average difference between the Quality Control Branch laboratory NIR results and the Kjeldahl results was 0.19 percentage point.
- For the second sample series, study data showed that the average protein content for the origin NIRs (certificated value) was 0.36 percentage point higher than that for the Quality Control Branch laboratory Kjeldahl. The average protein content for the Quality Control Branch

laboratory NIR was 0.27 percentage point higher than that for the Quality Control Branch laboratory Kjeldahl. Further, Kjeldahl readings at destination of samples taken at origin and destination showed essentially the same readings, ruling out sampling as a source of differential readings.

- For the third sample series, data were analyzed separately for export and domestic samples. For the export samples, 61 percent showed NIR results that were 0.2 percentage point or more higher in protein than the Portland office's Kjeldahl results. About 50 percent of the domestic samples had NIR results that were 0.2 percentage point or more higher than the Kjeldahl results. In total, over 50 percent of the samples certified on the NIR gave protein readings averaging over 0.4 percentage point higher than the Kjeldahl results.

Action Taken as a Result of the Study

As a result of its study, in April 1987 FGIS adjusted its NIR instruments downward by 0.2 percentage point for Hard Red Spring wheat; thus, NIR protein readings now measure 0.2 percentage point less than before. According to an FGIS official, private industry (e.g., grain companies and elevators) uses the FGIS NIR calibration as the standard for their own NIRs. Thus, FGIS' action has had wide-ranging effects on producers of Hard Red Spring wheat.

In September 1987, FGIS completed a study to establish a new calibration equation for Hard Red Spring wheat. The NIRs will thus be recalibrated to reflect the 0.2-percentage point downward adjustment that has already taken place. According to FGIS officials, the NIRs will be recalibrated annually henceforth. FGIS believes such action is necessary in order for the NIRs to reflect any changes (e.g., new wheat varieties, farming practices) that might affect their accuracy.

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