

# Prediction of Test Weight from a Small Volume Specific Gravity Measurement

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## ABSTRACT

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The specific gravity ( $\text{cm}^3/\text{g}$ ) of small (20 and 40 g) samples of soft wheats from three states were rapidly measured and compared with bulk density ( $\text{g}/\text{cm}^3$ ) measurements (microtest weights). Specific gravities were correlated with test weights for both cleaned and uncleaned samples. The relationship between specific gravity and test weight was linear unless

the samples were severely shriveled. Operator effect was not statistically significant. Simple linear regression analysis produced equations that predicted with high  $R^2$  value microtest weights from specific gravity measurements. Both 20 and 40 g sample sizes were satisfactory. However, 40 g samples produced better statistical relationships.

Test weight determination of wheat is an estimate of wheat bulk density ( $\text{g}/\text{cm}^3$ ). Test weight is most useful to indicate the relative condition of the wheat kernels. Many types of weathering damage can occur to the kernels before harvest. Kernels that are shriveled or immature have reduced test weight. Rain-induced field sprouting will reduce test weight. Cycles of wetting and drying also reduce test weight. Generally, sound, mature, fully filled out kernels that have not received wet-dry cycles from rain or dew will have the highest possible bulk density. Millers prefer such wheats.

Routine test weight bulk density determinations are accomplished at our laboratory using a standard 1-qt kettle procedure (USDA 1953, AACC 2000) requiring  $\approx 1,000$  g of wheat and a microprocedure suitable for 100 g samples. However, many samples requiring a bulk density estimate are early generation samples that are too small (25–50 g) for conventional test weight procedures. This report describes a procedure for evaluating the specific gravity of wheat samples based on 20 and 40 g of wheat. Various wheat samples encompassed a wide range of grain conditions. Small volume specific gravities were compared to microtest weights and were used to generate a regression equation to predict microtest weight.

## MATERIALS AND METHODS

### Wheats

Ninety-one soft red winter wheats (35 produced in Wisconsin, 35 produced in Missouri, and 21 produced in Georgia) were evaluated to assess the effect of cleaning on grain quality as evaluated as microtest weight. Subsamples of each wheat were cleaned using a Carter Day grain dockage tester to remove foreign material. Each sample was then subdivided into two subsamples. Thus, each wheat had an uncleaned subsample and a cleaned subsample. Two operators then independently evaluated each subsample for small volume specific gravity.

Another 204 soft wheats were also treated using a Carter Day grain dockage tester to remove foreign material. They were combined with the 91 wheats (295 total) and were randomly divided into two subsets. One subset of 148 wheats was used for development of a linear regression equation to predict microtest weight. The other subset of 147 wheats was used for validation of the prediction equation.

Four other soft red winter wheats were each sieved to produce subfractions of mostly sound and highly shriveled kernels. The sub-

fractions were blended to produce four degrees of shriveling, ranging from visually none to visually severe, for each of the four wheats.

### Small Volume Specific Gravity Procedure

The method is the inverse of the test weight measurement, weight/volume ( $\text{g}/\text{cm}^3$ ). It is based on the volume of specified weights of grain. Wheat samples (20 and 40 g) were evaluated. The very rapid procedure is: 1. Pour appropriate weight of wheat into a glass 100- $\text{cm}^3$  graduated cylinder (approximate height: 248 mm, subdivisions: 1 mL). 2. Swirl (radius 10 cm) cylinder on countertop 10 times (within 4 sec) to settle and level grain. 3. Read top of grain to nearest 0.10  $\text{cm}^3$ . We do not recommend varying swirling speed or the use of mechanical swirling. Plastic cylinders worked well but tend to be more difficult to read.

### Microtest Weight Procedure

The microtest weight procedure is necessary because large sample sizes often are not available. It consists of a 100- $\text{cm}^3$  copper cylinder 50.5 mm i.d.  $\times$  50.5 mm. A funnel is positioned so that the 15-mm opening is 178 mm above the top of the cylinder. A minimum 90 g grain sample is released all at once into the cylinder. After careful stroking, the grain in the cylinder is weighed. The weight in grams is converted to microtest weight: Microtest weight ( $\text{kg}/\text{hL}$ ) =  $0.95734 \times (\text{wt. of grain}) + 0.661$ . Similar microtest weight procedures have been developed by Aamondt and Torrie (1934), Ghaderi et al (1971), Harris and Sibbitt (1942), and Swanson (1942).

### Statistical Analysis

Data were analyzed for analysis of variance, linear least squares regression, simple correlation, and coefficient of variation. After preliminary data evaluation for linear fit, simple linear regression equations were produced to predict microtest weight from the volume of grain at both 20 and 40 g weights. A validation subset was used to corroborate the equations based on adjusted  $R^2$  values and analysis of mean residuals.

## RESULTS AND DISCUSSION

### Regression Prediction

The effect of cleaning on the relationship between grain volume at 20 and 40 g and microtest weight was to reduce the range in both (Fig. 1). However, the slopes of both relationships were not statistically different (0.82 [not cleaned] vs. 0.85 [cleaned] for the 20 g volumes and 0.88 [not cleaned] vs. 0.87 [cleaned] for the 40 g volumes). Thus, data from both uncleaned and cleaned wheat were combined and used together to increase the robustness of the prediction equations. One-half of the data from the 295 wheat set was randomly chosen as the regression sample subset to produce regression equations to predict microtest weight from the volume of grain at both 20 and 40 g weights. Regression equations were:

$$20 \text{ g grain weight, MTW} = 150.5 - 2.76 (V_{20}) \text{ (adjusted } R^2 = 0.82)$$

$$40 \text{ g grain weight, MTW} = 157.0 - 1.54(V_{40}) \text{ (adjusted } R^2 = 0.90)$$

<sup>1</sup> U.S. Department of Agriculture, Agricultural Research Service, Soft Wheat Quality Laboratory, Ohio Agricultural Research and Development Center, Ohio State University, Wooster, OH 44691. Names are necessary to report factually on available data; however, the USDA neither guarantees nor warrants the standard of the product, and the use of the name by the USDA implies no approval of the product to the exclusion of others that may also be suitable.

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TABLE I  
Prediction and Validation Sets' Residual Error, Adjusted  $R^2$ , and Predicted Values<sup>a</sup>

Source	Mean Residual Error	Adjusted $R^2$	Predicted Microtest Wt 78.6	Predicted Microtest Wt 70.0	Predicted Microtest Wt 82.0
Prediction equation set					
20 g	0.00	0.82	78.62 ± 0.10	71.11 ± 0.35	81.23 ± 0.15
40 g	0.00	0.90	78.42 ± 0.07	70.89 ± 0.26	81.40 ± 0.11
Validation set					
20 g	0.11	0.82	78.26 ± 0.10	71.26 ± 0.31	79.40 ± 0.10
40 g	0.06	0.90	78.37 ± 0.08	70.80 ± 0.24	81.36 ± 0.11

<sup>a</sup> Predicted values ±95% confidence interval.

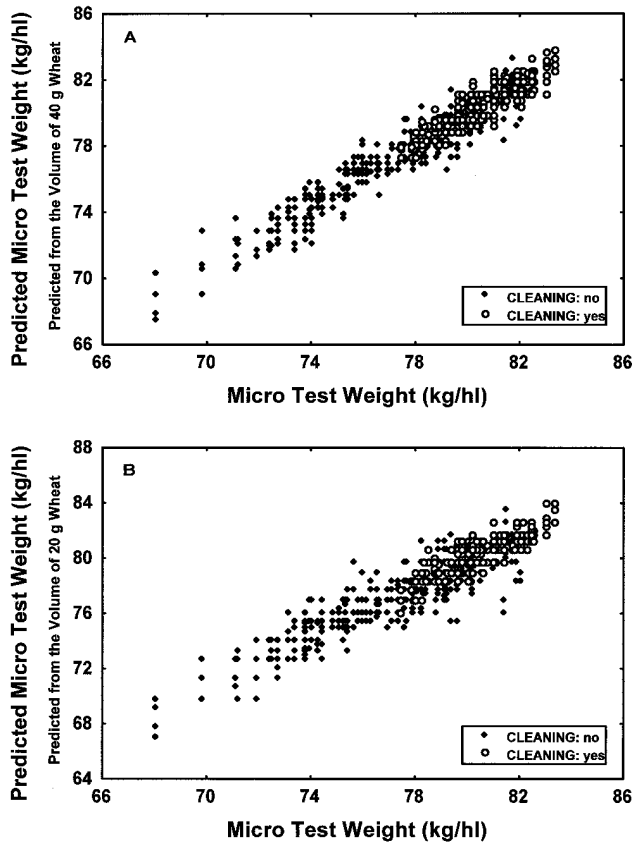


Fig. 1. Relationship between grain volume at 20 and 40 g and microtest weight.

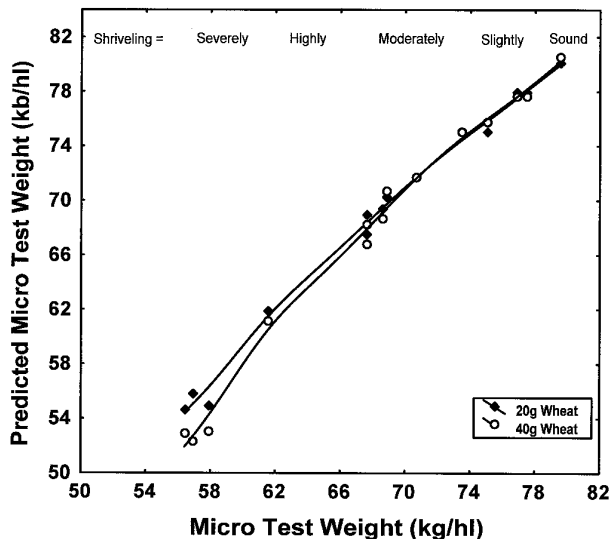


Fig. 2. Relationship between microtest weight and test weight predicted from 20 and 40 g volumes of shriveled wheat.

where MTW is microtest weight,  $V_{20}$  is the volume of 20 g of wheat, and  $V_{40}$  is the volume of 40 g of wheat. Both equations were similar, however the larger (40 g) measured volumes produced better  $R^2$  values. (To convert equations to lb/bu, multiply the slopes and intercepts by 0.7767.)

### Regression Validation

The regression validation data subset was also used to predict microtest weight from the volume of 20 and 40 g of wheat. Mean residual errors for predicted microtest weights, adjusted  $R^2$  values, and predicted values are shown in Table I. The mean microtest weight (78.6 kg/hL) and a high and a low microtest weight were also predicted. Mean predicted values from the validation set were not statistically different ( $P = 0.000$ ) from the actual microtest weight values.

### Combined Sets Analyses and Effects of Cleaning

The prediction and validation sets were combined and the full set was analyzed. Adjusted  $R^2$  values for prediction test weights and microtest weights were 0.82 and 0.90 for 20 and 40 g volume measurements, respectively. Regression slopes for the relationship between microtest weight and predicted test weight were 0.82 and 0.88 for 20 and 40 g volume measurements of uncleaned wheat, respectively. Regression slopes for the relationship between microtest weight and predicted test weight were 0.85 and 0.87 for 20 and 40 g volume measurements of cleaned wheat, respectively. There was a large difference among the degree of cleaning of those samples, however, that degree of cleaning will not materially influence the prediction of microtest weight from specific gravity measurements. Regression equations generated from the full combined set were:

$$20 \text{ g grain weight, MTW} = 152.3 - 2.83(V_{20}) \text{ (adjusted } R^2 = 0.82)$$

$$40 \text{ g grain weight, MTW} = 157.0 - 1.54(V_{40}) \text{ (adjusted } R^2 = 0.90)$$

where MTW is microtest weight,  $V_{20}$  is the volume of 20 g of wheat, and  $V_{40}$  is the volume of 40 g of wheat. Coefficients of variation were very low, and the larger (40 g) measured volumes produced lower values for coefficient of variation, 0.6 vs. 0.4% for 20 and 40 g, respectively. (To convert equations to lb/bu, multiply the slopes and intercepts by 0.7767.)

### Operator and Sample Size Effects

Two operators independently evaluated 91 uncleaned and cleaned samples. The mean values for predicted microtest weight were 78.4 kg/hL and 78.8 kg/hL for each operator for the 20 g grain volume measurements (not statistically different  $P > 0.05$ ), and 78.6 kg/hL for both operators for the 40 g grain volume measurements, not statistically different.

Across all the samples, the coefficient of variation for microtest weight was 0.5%. The coefficients of variation for 20 and 40 g grain volume were 0.8 and 0.6%, respectively. The coefficients of variation for 20 and 40 g predicted microtest weights were 0.6 and 0.5%, respectively. The two grain weights utilized were analyzed for their ability to distinguish among the 91 wheat set. Both volumes produced highly significant differences ( $P < 0.0000$ ) among wheat means. The 20 g measurement could distinguish 28 least significant

difference ( $LSD_{0.05}$ ) divisions, whereas the 40 g measurement could distinguish 31  $LSD_{0.05}$  divisions. Duncan's multiple range test ( $P = 0.05$ ) produced 19 and 23 divisions for the 20 and 40 g grain weight evaluations, respectively.

### Shriveling Range

Wheat that is not properly, fully filled out during grain fill will have a shriveled appearance. Four wheats were sieved to produce subsamples of wheat with sound and severely shriveled grain and were then blended to produce levels of shriveling from sound, unshriveled kernels to severely shriveled kernels. The relationship between microtest weight and test weight predicted from the volumes of 20 and 40 g of those variously shriveled wheat volumes is shown in Fig. 2. The degree of shriveling directly reduced wheat test weight. The relationship between actual and predicted values was mostly linear until the samples were severely shriveled. Practically, commercial wheat does not often exceed moderately shriveled.

### CONCLUSIONS

In contrast to larger volume standardized test weight measurements, the specific gravity of soft wheat can be determined equally as quickly by easily measuring the volume of small (20 and 40 g) samples of wheat. Specific gravity of soft wheats are well correlated with standard test weights for both cleaned and uncleaned wheat samples, as shown with sample sets from three states. Severe kernel shriveling will degrade that linear correlation. As in this study, and presumably in other laboratories, the specific gravity measurement should not have a statistically significant operator effect. Simple linear regression analysis can produce equations to predict standard test

weights (density) from specific gravity measurements of wheat. Both 20 and 40 g sample sizes are satisfactory for specific gravity, however 40 g samples produced better statistical relationships in this study. Where sample sizes are too small for reliable bulk density measurements, this method allows the prediction of bulk density (test weight) values from specific gravity observations. That will be very useful for the wheat breeder or quality evaluator who often does not have sample sizes large enough for direct test weight evaluation.

### ACKNOWLEDGMENTS

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