NOTE

Regression Equation for Predicting Absorption for 2-g Direct Drive Mixograph[1]

J. L. HAZELTON,[2,3] O. K. CHUNG,[4] J. J. EASTMAN,[5] C. E. LANG,[6] P. J. McCLUSKEY,[2] R. A. MILLER,[2] M. A. SHIPMAN,[7] and C. E. WALKER[2]

Cereal Chem. 74(4):400–402

Although the mixograph has been used extensively for years, it is still limited by the present subjective determination of proper mixograph absorption. Under uniform conditions in any one laboratory, a usable level of replication can be obtained, but the variability is high in interlaboratory collaborative work (Kunerth and D'Appolonia 1985). Historically, mixograph users have taken different approaches to predicting mixograph absorption. Some have used a fixed absorption, whereas others used an absorption based on flour moisture and protein (Finney 1945). Yet another method requires the user to adjust absorption based on a trial curve. For this method, the need to make multiple runs is common. Mixogram data have been assessed by both manual and computerized methods, but evaluating mixograph absorption is very subjective and has been described as a "touchy-feely" process that requires much practice. This only increases the difficulty experienced by new operators.

Selecting the proper absorption when using the 2-g direct drive mixograph is even more difficult because of the rather wide curve resulting from the electronic sampling sensitivity and the dampening effect from the motor and power supply (Rath et al 1990). Although electronic analysis is less subjective and tedious when compared to manually interpreting the strip chart mixograms, the underlying basis for analysis is still the same, and determining the "proper" mixograph absorption is still very subjective. The operator takes into account the sway-back characteristic of the ascending curve, the overall "wildness", the height of the mixogram on the scale, and the band width at various points along the curve. For instance, a dough mixed with insufficient absorption produces a mixogram that has shorter mix time, increased peak height and band width, and a "wild" appearance caused by wide lever arm swings (Swanson and Johnson 1943, Finney and Shogren 1972). The opposite effects occur when excessive water is added. Also, the overall curve height, both at the peak and at the tail, are determined by absorption as well as by protein and variety (Finney 1945, Finney and Shogren 1972).

Hence, it seemed reasonable that some combination of several factors could yield a regression equation to indicate whether or not the initial or trial absorption was correct and, if not, to predict how it could be corrected. Therefore, the objective of this research was to develop a prediction equation for determining proper mixograph absorption based on chemical analysis (moisture and protein) and results from a single 2-gram mixograph trial.

[1]Published as contribution no. 97-103-J, Kansas Agricultural Experiment Station.
[2]Dept. Grain Science and Industry, Kansas State University, Manhattan, KS 66506.
[3]Corresponding author. E-mail: JLH@wheat.ksu.edu Phone: 913/532-6161. Fax: 913/532-7010.
[4]USDA-ARS Grain Marketing & Production Research Center, Manhattan, KS 66502.
[5]American Institute of Baking, Manhattan, KS 66502
[6]Dept. Plant, Soil, and Environment Sci., Montana State Univ., Bozeman, MT 59717.
[7]Dept. Agronomy, University of Nebraska, Lincoln, NE 68583.

Publication no. C-1997-0612-02R.
© 1997 by the American Association of Cereal Chemists, Inc.

MATERIALS AND METHODS

This was a cooperative study in which 156 flour samples with various mixing characteristics were collected from six sources throughout the United States, with protein contents ranging from 8.75 to 15.86%. Either 10-g or 35-g moving bowl mixograms were run, and absorptions were determined by the individual providing the samples. Some were digitized, and some were recorded by the conventional strip chart and read manually.

Two 2-g direct drive mixographs (National Mfg. Div. of TMCO, Lincoln, NE) then were used by the same operator to test all 156 flours. The fixed bowl, 2-g machine derives its mixing curve from the current draw required to maintain a constant mixing speed. Flour-water mixograms were run at 25 ± 1°C following the standard mixograph method 54-40A, modified only to accommodate the computerized format (AACC 1995). Mixograms were run for 10 min, with a mixing head speed of 88 rpm. An absorption series was run for each flour using the contributor's determined "proper" absorption as the starting point, and absorption was adjusted to ±3% for a total of 468 mixograms. All analyses, weights, and calculations were on a 14% moisture basis.

Approximately 40 different mixing parameters were derived electronically from each curve and were considered in developing the model (Mixsmart software authored by AEW Consulting, distributed by National Mfg. Div. of TMCO, Lincoln, NE) (Fig. 1). Parameters such as mid-line peak time and height, ascending and descending slopes (left- and right-of-peak), band width at several locations on the curve, and the area under the curve (integral, representing work input) were evaluated. The 55% of peak-time parameters (height, slope, and band width) were assessed also as typical proper absorption indicators. The envelope-area (the area swept by the curve between the upper and lower envelope lines from peak to peak +2 min); 8-min location; and tail heights, widths, and integrals also were evaluated. Time was expressed in minutes; height and width were expressed as percent of full-scale torque values; slope was expressed as the change in percent value divided by time; and the work function was expressed as an integral of percent torque multiplied by time. In an attempt to define the "sway" of the ascending portion of the mixogram, another parameter, called sway factor, was calculated. The sway factor (sf) value was assessed at the 55% of peak-time location (sf = height at 55% of peak-time – 0.55[peak height]).

To reduce the initial number of parameters, stepwise multiple regression was conducted to select those that contributed the most to the absorption effect (SAS ver. 6.11, SAS Institute Inc., NC). Interaction terms for each parameter also were tested (RSMplus, AEW Consulting, Lincoln, NE). Then, using those terms that most consistently occurred with the larger coefficients, an equation was developed for predicting the absorption adjustment by a multiple regression approach (Excel ver. 7.0, Microsoft, Redmond, WA, and SigmaStat ver. 2.0, Jandel Scientific, San Rafael, CA).

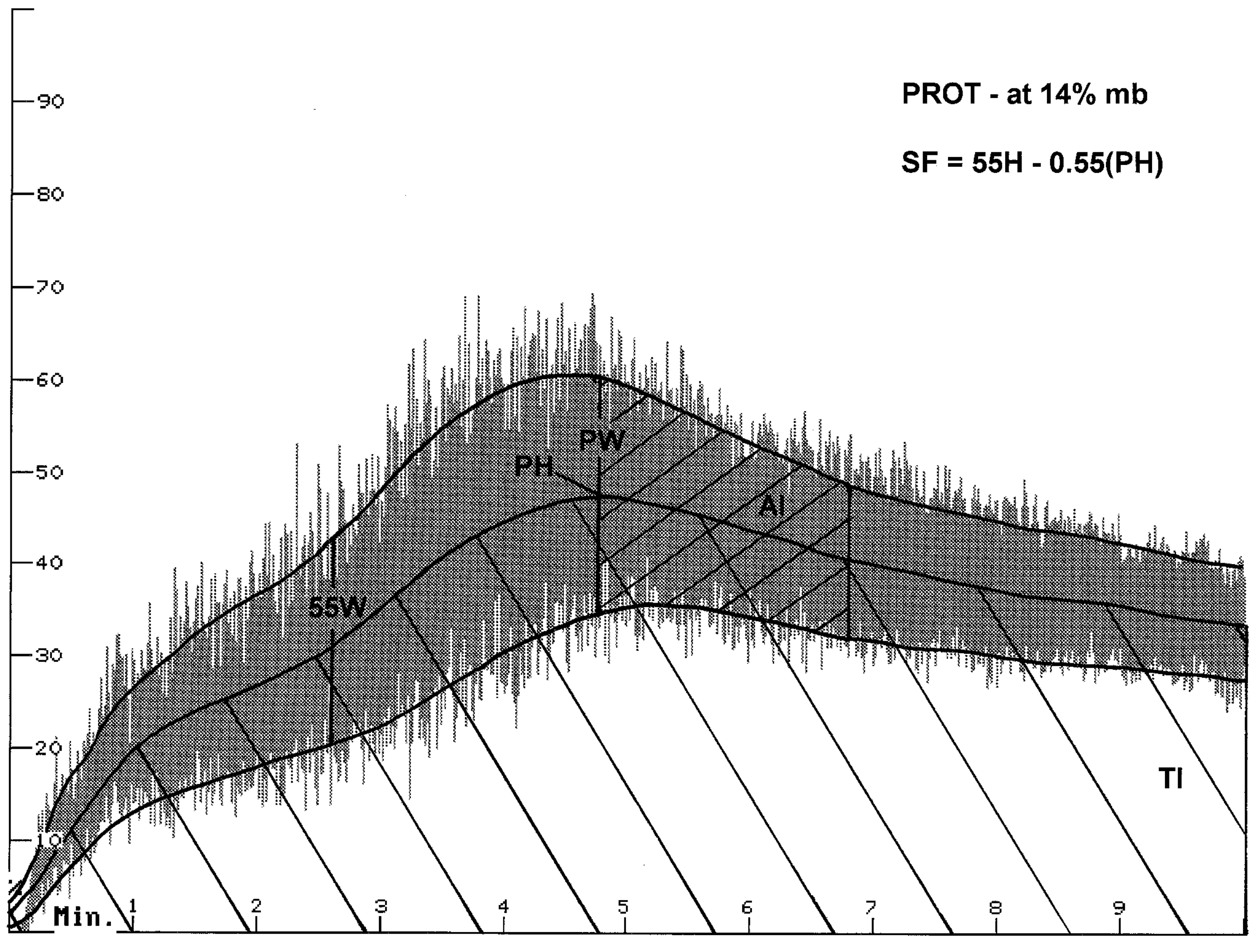

Fig. 1. Typical mixogram identifying the curve locations from which the data are collected.

To test the resulting regression equation, an additional 35 flours were selected that ranged from 58 to 67.5% in mixograph absorption. Again, these flours were run initially using a 10-g moving-bowl mixograph, and absorption was determined by the individual providing the sample. For the 2-g machine, flour moisture and protein were used to calculate a starting absorption, and samples were run by one operator (Finney 1945, AACC 1995). After mixograph analysis, the mixing data were entered into the equation through a spreadsheet, and the absorption adjustment was determined. The corrected absorptions were then compared to the operator's determined absorption, and the resulting before and after curves were compared.

RESULTS

Preliminary results were promising when each contributor's data were evaluated individually, but low predictability resulted when all the data sets were grouped. The original mixograms and derived data from the contributors and the 2-g mixograms were compared. This showed that some operators tended to consistently run either drier or wetter mixograms as compared with other operators. Therefore, we reevaluated the proper absorption from our 2-g curves for all the samples, adjusted the "too much" or "too little" percent absorption values to a common point, and reanalyzed the data statistically.

An equation was developed that related absorption to peak height (ph), width at 55% of peak-time (55w), tail integral (ti), protein (prot), sway factor (sf), peak width (pw), envelope area integral (ai), and a combination of some of the interactions and second-order terms (Fig. 1). When the independent variables are entered, the equation will predict a percent absorption adjustment (%Abs Adj) necessary to correct the starting absorption and provide the recommended mixograph absorption:

$$\begin{aligned}\text{\% Abs Adj} = {} & -1.601 - 1.417\,(\text{ph}) + 1.527\,(\text{55w}) + 0.083\,(\text{ti}) \\ & + 0.050\,(\text{prot})(\text{sf}) + 0.047\,(\text{prot})(\text{ph}) - 0.134\,(\text{prot})(\text{55w}) \\ & + 0.112\,(\text{ph})(\text{pw}) + 0.065\,(\text{ph})(\text{55w}) - 0.0093\,(\text{ph})(\text{ti}) \\ & - 0.096\,(\text{pw})(\text{55w}) + 0.00041\,(\text{ti})(\text{ai}) \\ & - 0.026\,(\text{sf}^2) - 0.059\,(\text{pw}^2) + 0.00042\,(\text{ti}^2)\end{aligned}$$

The regression equation accounts for ≈60% of the deviation ($r^2 = 0.595$) between the operator's determined absorption and the starting absorption predicted by Finney's Rule, where %Abs = 1.5 × %protein + 43.6 (Finney 1945 and AACC 1995). The equation was developed with flours ranging from 8.75 to 15.86% protein, with a coefficient of multiple correlation (r) of 0.77 and a standard error of 1.79%. Analysis of variance for the multiple regression equation yielded an F value of 47.57.

In testing the equation, simple linear regression showed a good correlation between the equation-adjusted absorption and the operator-determined absorption ($r = 0.82$) (Fig. 2). A smaller difference occurred between the equation-adjusted absorption and the starting absorption ($r = 0.87$). Differences between the starting and adjusted absorptions were apparent in that the amount of sway in the ascending arm of the mixograms was reduced, and the peak heights and band widths increased when flours were run at lower absorptions. Although the starting absorption is a good estimator of the proper mixograph absorption, it is based on protein quantity

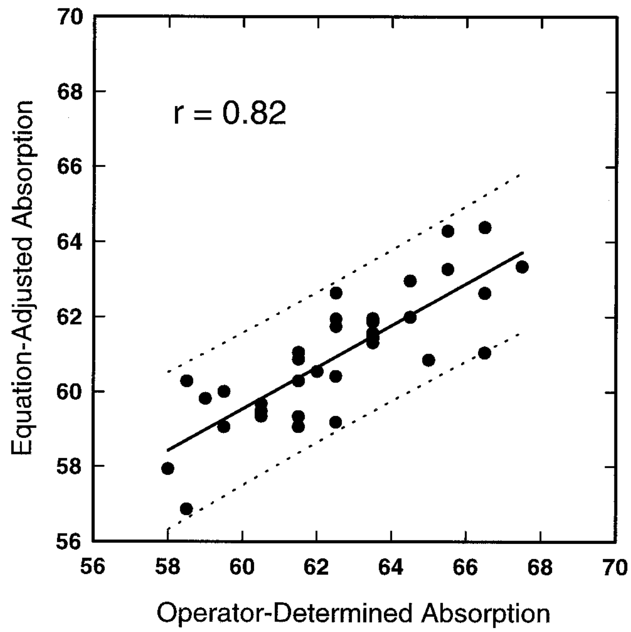

Fig. 2. Comparisons of equation-adjusted absorption to operator-determined absorption. The dotted lines represent the 95% confidence interval for the regression. Results for 35 flours were used as a verification set.

and may not take into account other flour characteristics, such as protein quality, the degree of starch damage, or fiber content, which also affect absorption.

DISCUSSION

To use the equation for the 2-g machine, first run a mixogram with a trial absorption based on protein content, where %Abs = 1.5 × %protein + 43.6 with all calculations and weights based on 14% moisture (Finney 1945, AACC 1995). Then, using the equation given above, calculate the recommended absorption adjustment. As long as the adjusted absorption is within ±3.5% of the actual absorption that was run, note the correction and proceed. If the recommended adjustment exceeds 3.5%, make the adjustment and repeat the test with the new starting point. Do not expect to get a zero recommended adjustment. Repeated iterations are pointless. It should be noted that few operators can consistently manually determine changes of <2% in absorption because those changes are smaller than the random variations between replicate mixograms.

CONCLUSIONS

This is an objective method that places less reliance on experienced operators and could allow for comparisons among laboratories, operators, and machine configurations (moving- and fixed-bowl, and direct drive). The equation could be useful for routine mixograph analysis, especially by plant breeders running large numbers of samples with the 2-g machine. An adjustment for dry or wet preferences requires only an adjustment to the equation's first-term constant.

The same principle could be applied to the 10- and 35-g machines, but the equation constants and coefficients would be different because the band widths differ for the different versions (moving- and fixed-bowl, and direct drive) of the mixograph.

ACKNOWLEDGMENTS

We thank Gui Xiang Lu (Dept. Grain Science and Industry, Kansas State University, Manhattan, KS); Margo S. Caley (USDA-ARS Grain Marketing and Production Research Center, Mahattan, KS); and David Shelton (Dept. Agronomy, University of Nebraska, Lincoln, NE) for assistance in supplying some of the mixograph data. We also thank National Mfg. Div. of TMCO (Lincoln, NE) for providing the 2-g direct drive mixographs.

LITERATURE CITED

American Association of Cereal Chemists. 1995. Approved Methods of the AACC, 9th ed. Method 54-40A, approved April 1961, revised October 1988 and October 1994, final approval November 1995. The Association: St. Paul, MN.

Finney, K. F. 1945. Methods of estimating and effects of variety and protein content level on the baking quality of flour. Cereal Chem. 22:149-160.

Finney, K. F., and Shogren, M. D. 1972. A 10-gram mixograph for determining and predicting functional properties of wheat flour. Baker's Dig. 46(2):32.

Kunerth, W. H., and D'Appolonia, B. L. 1985. Use of the mixograph and farinograph in wheat quality evaluation. Pages 27-49 in: Rheology of Wheat Products. H. Faridi, ed. Am. Assoc. Cereal Chem.: St. Paul, MN.

Rath, C. R., Gras, P. W., Wrigley, C. W., and Walker, C. E. 1990. Evaluation of dough properties from two grams of flour using the mixograph principle. Cereal Foods World 35:572-574.

Swanson, C. O., and Johnson, J. A. 1943. Description of mixograms. Cereal Chem. 20:39-42.

[Received October 11, 1996. Accepted March 19, 1997.]