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THE RELATIONSHIP BETWEEN FARINOGRAPH MOBILITY AND ABSORPTION[1]

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ABSTRACT

Dough mobility bore a parabolic relationship to absorption in farinograph studies of a number of flours when tested over the dough consistency range from 200 to 950 Brabender units. The absorption equivalent to a given interval of farinograph consistency varied for different ranges of consistency and with different flours. The parabolic relationship provides a more satisfactory interpretation of dough behavior in the farinograph than the linear relationship previously reported.

In a previous paper Hlynka (3) presented certain preliminary aspects of dough mobility and absorption, and a linear relationship was reported between dough mobility, obtained as the reciprocal of maximum farinograph consistency, and the absorption, the latter calculated for the two cases of 14% moisture and dry flour basis. The linear relationship was employed in 1) establishing a method for precisely determining the equivalence between consistency and absorption, and 2) evaluating by extrapolation the amount of water in dough that is independent of mobility.

In some preliminary experiments the relation between mobility and absorption appeared to be a parabolic one. This paper reports the results of an investigation of the nature of this relationship using five flours and dough consistencies from 200 to 950 Brabender units (B.u.). A study was also made of the absorption equivalent to a given interval of farinograph consistency over different ranges of consistency for the different flours.

Materials and Methods

The flours used for the investigation were: A, a commercial unbleached flour with an ash content of 0.47%; B, a commercial un-

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bleached flour with an ash content of 0.81%; C, a commercial bleached flour with an ash content of 0.75%; D, unbleached flour from experimentally milled Manitoba No. 3 wheat with an ash content of 0.56%; and E, an arbitrary blend of unbleached experimentally milled flours with an ash content of 0.65%.

The data were obtained on a farinograph with a large mixing bowl and a 59.0 r.p.m. drive to the bowl. The scale system of the instrument was investigated and proved to be linear.

For each flour sample a series of farinograms were obtained by varying the absorption so that the maximum dough consistencies were obtained in the range 200 to 950 B.u. Consistency readings were taken at the center of the farinograph curve at the point of maximum consistency.

The experiments were conducted according to both the constant flour weight and constant dough weight procedures of the farinograph method for flour as given in *Cereal Laboratory Methods* (1). Flours A and B were carried through both procedures, while only the constant dough weight procedure was used for flours C, D, and E.

The data were calculated in terms of 1) absorption on either a 14% moisture basis or dry matter basis, as indicated; and 2) the dough mobility which was obtained as the reciprocal of the maximum consistency and expressed in reciprocal Brabender units.

The dough mobilities were plotted graphically against the absorption, the latter being regarded as the independent variable.

Results

Constant Flour Weight Procedure. In this case the results have bearing on the practical use of the farinograph, and it was deemed sufficient to calculate the absorption only on a 14% moisture basis. The resulting graphical relationships are given in Fig. 1.

From the curves it was clear that a linear relationship was inade-

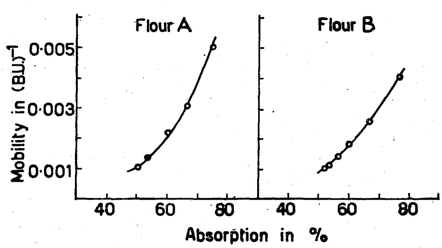

Fig. 1. Variation of dough mobility with absorption on 14% moisture basis using the constant flour weight procedure.

quate for representing the behavior of the curves. Consequently a mean square regression curve was sought to fit the data of each flour. For the relationship between dough mobility and absorption on a 14% moisture basis the following general equation was considered:

$$M = As^2 + Bs + C \tag{1}$$

where M = dough mobility measured by the reciprocal of the maximum consistency of the farinogram and expressed in reciprocal Brabender units;

s = absorption expressed as percent of flour (14.0% moisture basis);

A, B, C = constants.

Assuming that the error lies only in the values of the ordinates M_i, the method of least squares was applied to obtain the best-fitting curve (2). Evaluation of the constants A, B, and C led to the following equations:

$$M = 3.724 \times 10^{-6} s^2 - 3.105 \times 10^{-4} s + 7.340 \times 10^{-3} \tag{2}$$

for flour A, and

$$M = 1.679 \times 10^{-6} s^2 - 9.533 \times 10^{-5} s + 1.496 \times 10^{-3} \tag{2a}$$

for flour B.

These equations gave accurate information for interpolated values in the experimental range of the curves.

The change in absorption corresponding to a change of 20 B.u. in dough consistency was then considered. Using equations (2) and (2a), the absorption for dough consistencies in the range 400 to 600 B.u. was calculated at intervals of 20 B.u. This was done by solving the quadratic equation (1), which by rearrangement gives

$$As^2 + Bs + C - M = 0$$

where M is the dough mobility corresponding to the particular dough consistency. The solution for the absorption is

$$s = \frac{-B + \sqrt{B^2 - 4A(C - M)}}{2A}$$

The results for flours A and B are summarized in Table I.

Constant Dough Weight Procedure. In this case varying absorptions were obtained by using different proportions of flour and water to give a total dough weight of 480 g. The dough mobilities were plotted against the corresponding absorptions calculated on dry-matter basis for both flours A and B as well as the other three flours, C, D, and E. The graphical relationships are given in Fig. 2, and it was clear that they were of the same form as those in Fig. 1.

TABLE I

THE ABSORPTION EQUIVALENT TO 20 BRABENDER UNITS OF FARINOGRAPH DOUGH CONSISTENCY IN THE RANGE 400 TO 600 BRABENDER UNITS

Consistency	Flour A		Flour B	
	Absorption, 14% Moisture Basis	Absorption Equivalent to 20 B.u.	Absorption, 14% Moisture Basis	Absorption Equivalent to 20 B.u.
B.u.				
400	62.64		65.87	
		0.78		0.96
420	61.86		64.91	
		0.73		0.89
440	61.13		64.02	
		0.70		0.84
460	60.43		63.18	
		0.66		0.78
480	59.77		62.40	
		0.63		0.74
500	59.14		61.66	
		0.60		0.69
520	58.54		60.97	
		0.58		0.66
540	57.96		60.31	
		0.55		0.62
560	57.41		59.69	
		0.54		0.60
580	56.87		59.09	
		0.51		0.56
600	56.36		58.53	

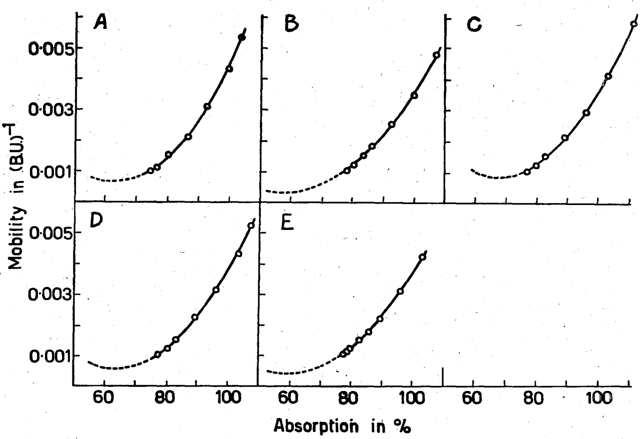

Fig. 2. Variation of dough mobility with absorption on dry-matter basis using the constant dough weight procedure. The broken portions of each curve represent extrapolation of the curves as computed from the regression equations for the experimental data for mobility and dough absorption.

Utilizing the general equation (1) and substituting for s the absorption which gives the total water content of the dough as a percentage of the dry matter, the following regression curves were obtained:

Flour A: $M = 2.719 \times 10^{-6}\ s^2 - 3.386 \times 10^{-4}\ s + 1.119 \times 10^{-2}$ (4)
Flour B: $M = 1.831 \times 10^{-6}\ s^2 - 2.109 \times 10^{-4}\ s + 6.397 \times 10^{-3}$ (4a)
Flour C: $M = 2.636 \times 10^{-6}\ s^2 - 3.547 \times 10^{-4}\ s + 1.280 \times 10^{-2}$ (4b)
Flour D: $M = 2.431 \times 10^{-6}\ s^2 - 3.083 \times 10^{-4}\ s + 1.036 \times 10^{-2}$ (4c)
Flour E: $M = 1.980 \times 10^{-6}\ s^2 - 2.342 \times 10^{-4}\ s + 7.336 \times 10^{-3}$ (4d)

The curves were extrapolated beyond their turning points by making use of the above equations. The extrapolations are shown by the broken lines in Fig. 2, where the parabolic nature of the dough mobility-absorption relationship becomes clear.

The absorption at the minimum of the curve is given by

$$s = -\frac{B}{2A},$$

and by using this expression, the absorptions corresponding to the extrapolated minimum mobilities were evaluated. The results are given in Table II.

TABLE II
ABSORPTION CORRESPONDING TO EXTRAPOLATED MINIMUM MOBILITY

Flour	Absorption Dry-Matter Basis
	%
A	62.25
B	57.57
C	67.29
D	63.43
E	59.13

Discussion

In view of the experimental results obtained in the present investigation, a modified presentation of the findings by Hlynka (3) becomes necessary. The latter's findings were based on experimental results obtained in the range 300 to 900 B.u. of the farinograph consistency scale. Even in that range the authors found a definite curvature trend which was emphasized by extending observations from 200 to 950 B.u. It therefore appears that dough mobility is not a linear function of absorption. Furthermore, the result of a linear relationship is that extrapolation leads to an intercept on the absorption axis where the dough mobility is zero. The implication is that consistencies of infinite value can be obtained, whereas such situations are never realized within the system under consideration.

The parabolic relationship, although of limited quantitative applicability when extrapolated to low absorption values, seems to give a rendering of the correct form for the behavior of the system. On decreasing the absorption in practice, a maximum dough consistency (minimum dough mobility) is reached beyond which homogeneous mixing of the flour and water is not attainable, but in the extreme case of dry flour the consistency decreases to a very low value.

A significant feature of the parabolic relationship is that a minimum mobility is characteristic of the relationship. Furthermore, this minimum can be interpreted in terms of the explanation advanced by Hlynka for the intercept value obtained by the linear relationship. The absorption value at the minimum dough mobility may be regarded as the quantity of water absorbed by the starch granules and bound by the hydration of the proteins. Qualitatively these processes would be expected to decrease the dough mobility. After maximum absorption and hydration have been obtained, the further addition of water should increase the mobility, as is also shown by the parabolic relationship.

It must be pointed out, however, that the structure of the flour-water system changes during the hydration process and is further modified by the mechanical treatment. This can be responsible for the breakdown of the quantitative rendering of the behavior of the system by the parabolic relationship at low absorption values, for, when merely 480 g. of flour with approximately 14% moisture content were mixed in the mixing bowl, a consistency of about 30 B.u., corresponding to a dough mobility of 33.3×10^{-3} reciprocal B.u., was obtained irrespective of the flour. It therefore appears that this change in structure opens to criticism any continuity sought between the behavior in the farinograph of a flour-water system at a low water content and its behavior at a high water content. It is possible to trace the discontinuity to the point where the water content of the system is insufficient to form a homogeneous dough. The parabolic relationship deduced from a system with a dough structure should therefore be expected to be valid for flour-water systems only if the systems consist of such a structure. It was found for the flours with low absorption at their minimum mobilities, namely flours B and E, that a very stiff though homogeneous dough structure could only just be obtained by manual manipulation of a dough with a water content corresponding to the respective absorption at minimum mobility. The flours with higher absorption values at minimum mobility could be more readily worked into doughs of which the water content corresponded to their absorption values at minimum mobility. In this connection it is perhaps of significance that a comparison of the curves in Fig. 2 shows that the doughs with higher absorption values at their minimum mobilities had higher minimum mobilities than the doughs with lower absorption values. The parabolic relationship would therefore appear to be applicable, quantitatively at least, up to the turning point of its extrapolation.

According to the results in Table II the absorption value at a minimum dough mobility varies from flour to flour with an average value in the region of 62%. This figure is evidently dependent upon protein content and quality, starch behavior, and rate of extraction. Thus it is improbable that a constant figure is obtainable even for flours of the same rate of extraction. The average value of 62% differs by 7% from the single value of 69% reported by Hlynka (3). The value obtained by the linear relationship, however, depends upon the range of consistencies used which determines the slope and thus the intercept of the regression line.

This investigation also shows that the absorption which is equivalent to a given change in dough consistency depends upon the particular flour. This is borne out in the figures given in Table I. This quantity, however, does show the general trend of decreasing in going from low to high consistencies for any given flour, but the dependence on the flour used excludes the deduction of identical values for different flours for this trend.

The parabolic relationship between dough mobility and absorption gives a more accurate expression of dough behavior than a linear relationship, in that it lends itself to a more accurate rendering of the dough behavior in the experimental portion of the curve and to a more feasible interpretation of its extrapolated form.

Further investigations necessary to relate the relationship to more fundamental concepts are in progress.

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