Noodles. V. Determination of Optimum Water Absorption of Flour to Prepare Oriental Noodles[1]

N. H. OH,[2] P. A. SEIB,[2] K. F. FINNEY,[3] and Y. POMERANZ[3]

ABSTRACT

Cereal Chem. 63(2):93–96

A mixograph and water absorption meter were used to predict the optimum absorption of a flour for production of oriental noodles. Increments of water were added each minute to flour (10 g) in the mixograph until the width and height of the mixogram increased significantly and abruptly. The mixogram absorption was 4–8 percentage points higher than that determined by the "handling" properties of a dough to produce long, dry noodles. To predict absorption for a noodle dough, a correction curve was derived from 29 flours, which showed a linear correlation with flour protein. Compared to handling absorption, absorption predicted by the mixograph and water absorption meter gave correlation coefficients of 0.91 ($P < 0.01$) and 0.64 ($P < 0.01$), respectively. The mixograph was easier to use and gave a more accurate estimate of absorption in a dry-noodle dough than the water absorption meter. The mixograph method accurately measured the change in absorption of dry-noodle doughs caused by differences in starch damage and flour granulation.

The properties of a food made from wheat flour vary with the amount of water used in a formula. Oftentimes, high-quality food is produced within a narrow range of added water. Tolerance to deviation from optimum moisture depends on the product, the formula, the processing equipment, and the processing conditions.

Oh et al (1985a) varied absorption from 30 to 38% in the production of long, dry noodles. Absorption was shown to affect noodle color, wet strength, and dry strength. Furthermore, when absorption was varied more than 2 or 3% from optimum, sheeting, cutting, and drying of noodles became difficult.

Although several instruments are available to measure the absorption of flour in bread dough (Bloksma 1971), the authors are not aware of such a method to determine the optimum absorption of a noodle flour. Unlike moisture in bread dough, it is difficult to assess the correct moisture for noodle dough in a mixer. Irvine et al (1961) developed a modified farinograph technique to measure the rheological properties of pasta doughs at 27–36% absorption. They reported that maximum consistency and dough development time decreased in a commercial farina as water absorption increased from 28.5% to 31.5%. The authors did not describe the use of the farinograph to predict optimum absorption for pasta dough. Muller and Barron (1958) suggested that an extrusion meter could be used to measure the consistency of almost any dough. Again, no results have been reported using the meter on pasta or noodle doughs. We report here the use of the mixograph and the water absorption meter to predict the optimum absorption of flour to prepare oriental dry noodles.

MATERIALS AND METHODS

Flours

Ten soft and 48 hard wheat flours were used in the investigation. Soft wheat flours included those from two soft white wheats grown in Washington, six soft red wheats from Nebraska and Ohio, and two commercial flours. Hard wheat flours included those from 26 wheats grown in the Great Plains, 17 composite wheats from Kansas, and five commercial flours.

Five farina and two semolina samples also were used in the investigation. Farinas were from hard red winter wheats grown in Kansas, and semolinas were from durum wheats grown in North Dakota.

[1]Contribution 85-142-J, Cooperative investigation between the Agricultural Research Service, U.S. Department of Agriculture, U.S. Grain Marketing Research Laboratory, Manhattan, KS 66502, and the Department of Grain Science and Industry, Kansas Agricultural Experiment Station, Manhattan, KS 66506.

[2]Graduate research assistant and professor, respectively, Department of Grain Science and Industry, Kansas State University. Present address of N. H. Oh: Best Foods Research and Engineering Center, CPC International, Union, NJ 07083.

[3]Research chemists, U.S. Grain Marketing Research Laboratory.

Protein was measured by AACC method 46-11 and moisture by method 44-15A (AACC 1983).

Optimum Water Absorption Determined by Dough Handling

Optimum water absorption of a flour to produce long, dry noodles was determined subjectively by how well the dough could be processed into noodles during sheeting, cutting, and drying (Oh et al 1985a). Insufficient absorption formed a stiff dough that gave a dough sheet that appeared nonuniform with streaks of flour on the surface. In addition, fresh noodle strands cut from a dough that was too low in absorption contained noncohesive zones that caused the noodles to break during drying. On the other hand, excessive absorption gave a slack dough that was too extensible; the dough stuck to rolls during sheeting and cutting at 25° C, and the noodle strands stretched and sometimes broke during drying. Noodles were prepared successfully using absorptions that were ±2 percentage points from optimum. However, differences in the behavior of dough during noodle making were readily detectable when absorption varied by ±1 percentage point from optimum; the midpoint was assigned optimum absorption.

Mixograph Method of Determining Absorption of Noodle Dough

A mixograph (National Manufacturing Co., Lincoln, NE) fitted with a bowl for 10 g of flour (Finney and Shogren 1972) was used with the spring bar set at one-half strength (slot 6). Flour (10 g) was added to the bowl and the mixer started. At 1-min intervals, aliquots of NaCl solution and distilled water were added to the flour by means of a 5-ml hypodermic syringe with a no. 10 needle. The following aliquots were added: two of 10% NaCl (1.0 ml each), two of water (0.5 ml), and one to several of water (0.2 ml, or sometimes 0.1 ml) until development began.

Twenty-nine of the flours previously described (6 soft and 23 hard wheats) were tested to determine the influence of flour protein on the mixograph absorption of noodle dough. The protein in the 29 flours ranged from 8.5 to 14.8%.

Twenty-five of the flours (2 soft and 23 hard wheats) were used in a blind experiment to confirm the relationship between the optimum absorption determined by dough handling and that predicted by the mixograph method. The protein in those flours ranged from 8.5 to 14.2%, and their optimum absorption ranged from 27.5 to 33.0% as determined by dough handling.

Water Absorption Meter for Determining Absorption of Noodle Dough

The water absorption meter (Henry Simon Ltd., Stockport, England; Pomeranz et al 1956) was fitted with an extrusion die with a 22.5-mm diameter opening, and 88.8 newtons (20 lbs of load) was used for the extrusion force. Three levels of absorption were chosen to give extrusion times ranging between 30 and 120 sec at 25° C. Flour (25 g) was mixed in a 35-g bowl for 4 min using a high-speed mixograph mixer (178 rpm). After mixing, the small lumps of dough were molded by hand into a cylindrical shape, wrapped with polyethylene film, and allowed to rest for 30 min. Immediately after the resting period, the dough was packed into the sample holder of the water absorption meter and extruded. The extrusion time, in seconds, required for the plunger to move 10 mm was recorded. The log of the extrusion time was plotted against water absorption and a straight line was obtained for each flour.

Nine of the flours (2 soft and 7 hard wheats) were used to derive the theoretical extrusion time corresponding to the optimum handling absorption of noodle dough. The protein in the flours ranged from 8.5 to 13.2%, and their handling absorptions ranged from 28 to 33.5%. Twenty-one of the flours (2 soft and 19 hard wheats) were tested in a blind experiment to determine their noodle absorption using the absorption meter.

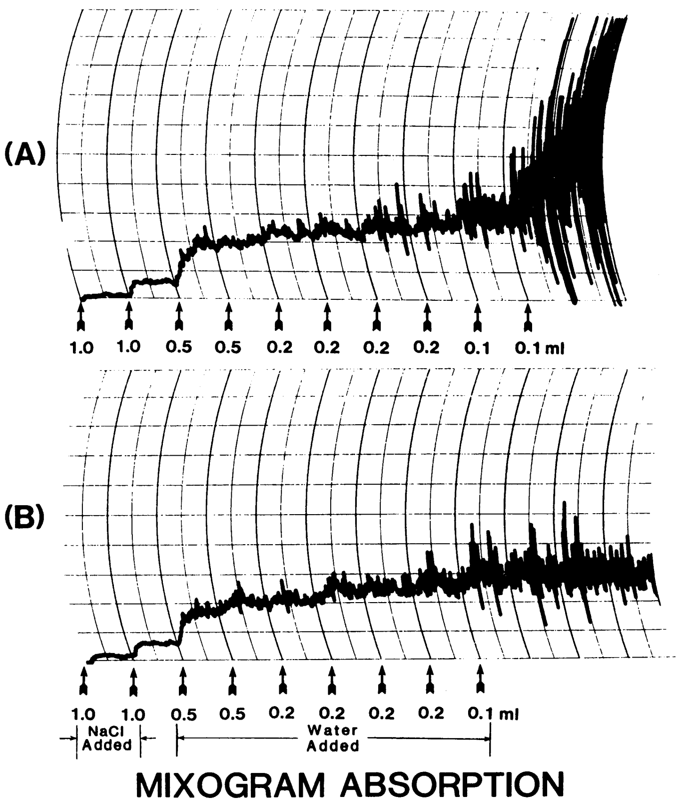

Fig. 1. Mixograms for a noodle dough mixed by the water-injection technique. At 1-min intervals an aliquot of 10% aqueous sodium chloride or water was injected up to 40% absorption (**A**) and up to 39% absorption (**B**). After the final addition of water, the mixograph was run an additional 2-4 min.

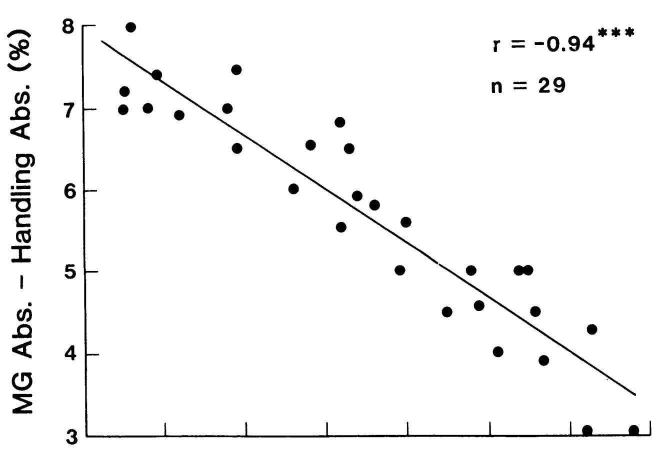

Fig. 2. Effect of flour protein content on the difference between mixogram (**MG**) and handling absorption of flour.

Absorption of Flours with Different Levels of Damaged Starch and Flour Granulation

Two of the hard and two of the soft wheat flours were ball-milled or pin-milled to produce four levels of starch damage and four different granulations for each flour. The particle size data were given by Oh et al (1985b).

RESULTS AND DISCUSSION

Mixogram Absorption of Noodle Flour

After two 1.0-ml aliquots of 10% NaCl and the first increments of water were added to flour (Fig. 1), small dough particles formed and were dispersed in a continuous powder (flour) phase that offered little resistance to mixing. As absorption increased, the dough particles increased in size, and the mixogram widened. The last 0.1 ml (1%) of water produced an abrupt change in the mixogram (Fig. 1A and B). Its width and height markedly increased because of the formation of relatively large dough pieces approximately 1 cm in diameter. For doughs containing no NaCl, the abrupt change in the mixogram occurred at approximately 2% less absorption than that for doughs containing 2% sodium chloride (data not given). The absorption that triggered the abrupt change in the mixogram was termed mixogram absorption of a noodle flour. The coefficient of variation for 10 replicated determinations of mixograph absorption on a single flour was 2.7%, so that mixogram absorption was highly reproducible.

The desirable mixogram absorption of a flour-water-salt dough is considered to coincide with the abrupt beginning of dough development and was found to be four to eight percentage points higher than optimum handling absorption. These results are consistent with the lack of gluten development (Matsuo et al 1978)

TABLE I
Optimum Absorption of Noodle Doughs When Determined by Handling Properties and Predicted by the Mixogram Method and the Water Absorption Meter[a]

Flour	Protein (%)	Experimental Absorption, Handling (%)	Predicted Absorption, Mixogram (%)	Mixogram Minus Handling Absorption (%)	Predicted Absorption, Absorption Meter (%)
1	10.1	33.0	32.7	−0.3	30.7
2	11.2	30.5	29.5	−1.0	30.2
3	12.5	31.0	30.9	−0.1	32.1
4	12.4	30.5	30.3	−0.2	31.3
5	12.1	30.5	30.1	−0.4	29.8
6	12.2	30.0	30.2	+0.2	29.4
7	12.3	32.5	32.3	−0.2	30.7
8	12.6	31.0	31.5	+0.5	31.6
9	12.7	29.5	29.5	0.0	27.0
10	12.5	30.5	30.4	−0.1	29.3
11	12.8	31.0	31.1	+0.1	31.3
12	13.1	30.5	30.8	+0.3	32.0
13	12.0	30.5	30.6	+0.1	30.3
14	12.6	31.0	31.5	+0.5	31.0
15	11.6	30.5	30.3	−0.2	31.8
16	11.5	30.0	29.2	−0.8	31.4
17	12.2	30.0	28.7	−0.3	30.0
18	8.5	32.5	32.5	0.0	32.8
19	11.7	32.0	31.9	−0.1	32.2
20	13.2	29.0	29.9	+0.9	29.4
21	10.8	27.5	28.1	+0.6	28.2
22	13.5	31.5	32.0	+0.5	···
23	14.2	30.0	30.1	+0.1	···
24	9.2	31.5	31.6	+0.1	···
25	13.6	31.0	31.1	+0.1	···
Correlation coefficient:			0.91 ($P<0.01$)		0.64 ($P<0.01$)

[a] 14% mb.

in a pasta dough mixed to a farinogram peak at optimum absorption (27%) for pasta making.

In commercial manufacturing of noodles, the absorption used depends on the various ingredients in the formula, processing equipment, processing variables, and on the characteristics desired in the noodle product. The mixograph method described here might be used to monitor the absorption characteristics of noodle flour from different suppliers. In this study, different flours required 27.5–33.0% water for optimum processing into long dry noodles. We found that the mixograph could be used to predict changes in absorption to make dry noodles.

TABLE II
Optimum Absorption of Ball-Milled Flour Samples When Predicted by the Mixogram Method[a]

Ball Milling Time (hr)	Starch Starch Damage (%)	Experimental Absorption, Handling (%)	Predicted Absorption, Mixogram (%)	Mixogram Minus Handling Absorption (%)
Arkan (HRW)[b]				
0	8.3	32.0	32.3	+ 0.3
8	11.5	34.0	34.2	+ 0.2
16	13.5	34.0	33.5	− 0.5
24	17.0	35.5	36.0	+ 0.5
OK 80268 (HRW)				
0	8.5	33.0	33.5	+ 0.5
8	11.0	34.0	33.7	− 0.3
16	15.1	35.0	35.2	+ 0.2
24	16.8	36.0	36.3	+ 0.3
Oasis (SRW)[c]				
0	2.9	28.5	28.1	− 0.4
8	5.5	30.0	30.2	− 0.2
16	10.1	32.0	32.5	− 0.5
24	15.9	33.5	33.5	0.0
OH 185 (SRW)				
0	3.4	30.5	30.2	− 0.3
8	5.8	30.5	30.1	− 0.4
16	10.2	33.0	32.5	− 0.5
24	16.6	35.5	35.8	+ 0.3

[a] 14% mb.
[b] HRW, hard red winter wheat.
[c] SRW, soft red winter wheat.

TABLE III
Optimum Absorption of Pin-Milled Flour Samples When Predicted by the Mixogram Method[a]

Flour and Granulation	Experimental Absorption, Handling (%)	Predicted Absorption, Mixograph (%)	Mixogram Minus Handling Absorption (%)
Arkan (HRW)			
Coarse[b]	32.0	32.0	0.0
Medium	34.0	33.7	+ 0.3
Fine	36.5	36.0	− 0.5
Very fine	39.0	39.5	+ 0.5
OK 80268 (HRW)			
Coarse[b]	33.0	33.5	+ 0.5
Medium	35.0	34.1	− 0.9
Fine	38.0	37.0	− 1.0
Very fine	40.0	39.2	− 1.8
Oasis (SRW)			
Coarse[b]	28.5	28.2	− 0.3
Medium	30.5	30.3	− 0.2
Fine	33.0	32.2	− 0.8
Very fine	35.0	34.0	− 1.0
OH 185 (SRW)			
Coarse[b]	30.5	30.2	− 0.3
Medium	32.5	31.5	− 1.0
Fine	33.5	33.2	− 0.3
Very fine	36.5	36.5	0.0

[a] 14% mb.
[b] Flours with no pin-mill treatment (controls).

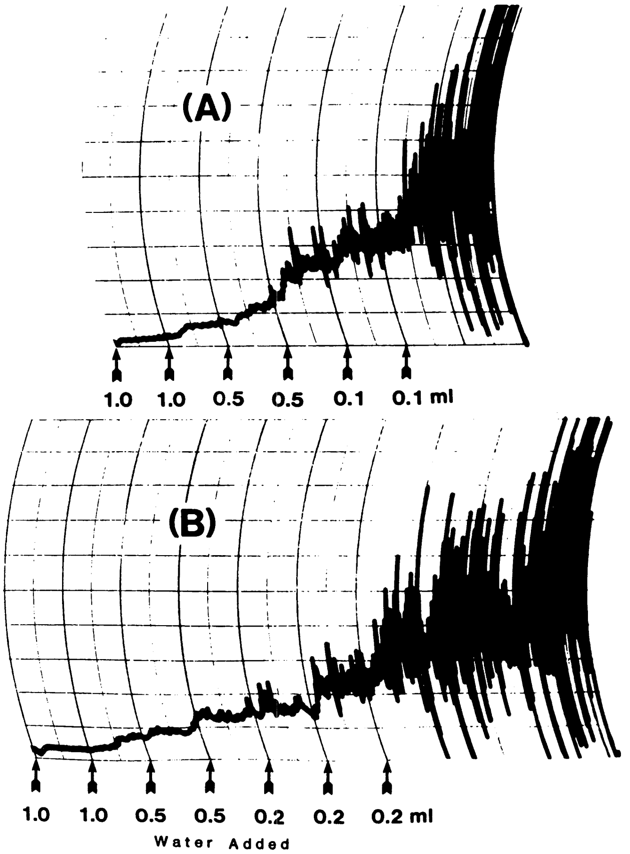

Fig. 3. Typical mixograms for pasta doughs from semolina (**A**) and farina (**B**) when using the water-injection technique without NaCl.

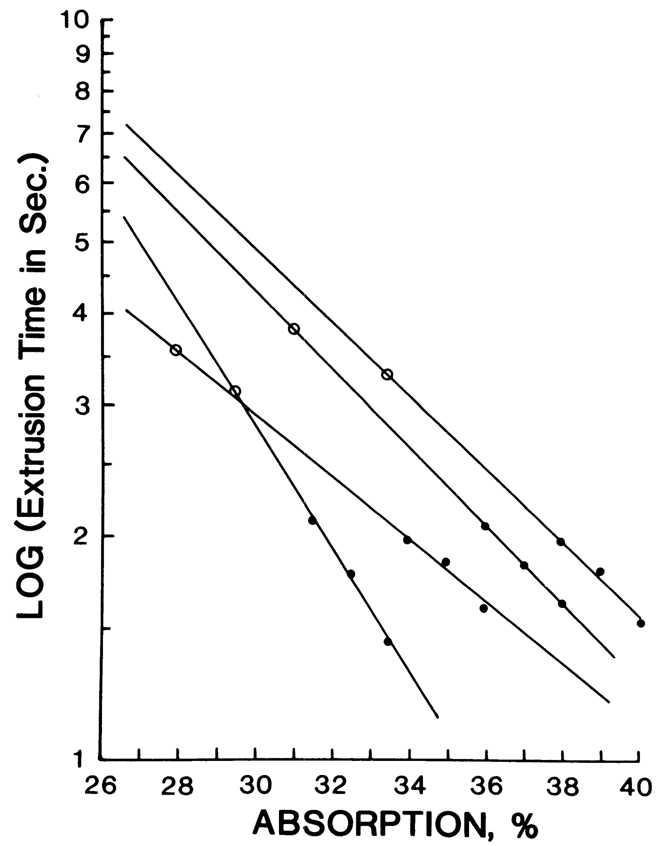

Fig. 4. Relation of the log of extrusion time in seconds measured by the water absorption meter and absorption. ● = Experimental data; o = optimum handling absorption.

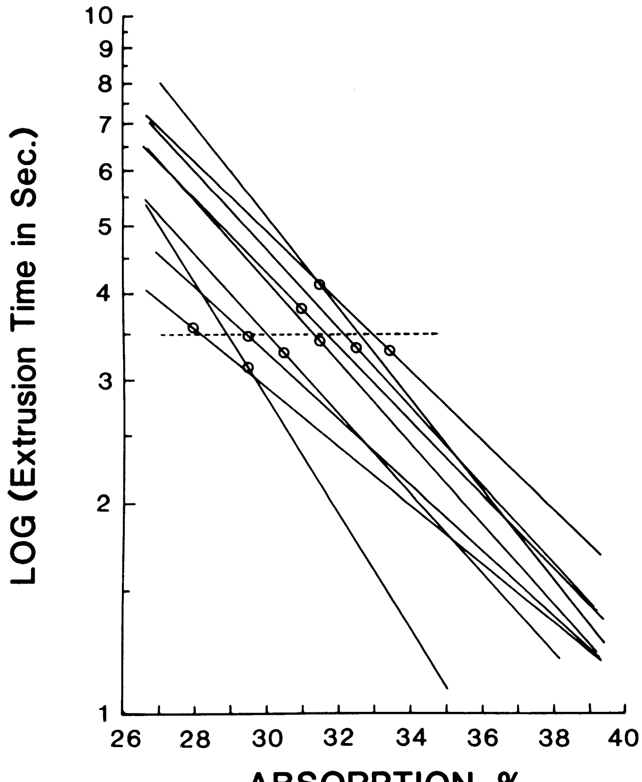

Fig. 5. Log of extrusion time in seconds measured by the water absorption meter vs. absorption for nine flours. o = Optimum handling absorption.

Effect of Flour Protein Content

When the difference between mixogram absorption and handling absorption was plotted against flour protein content of 29 flours (Fig. 2), there was a highly significant negative linear relation ($r = -0.94$, $P > 0.01$). Substituting MA − PA for D (difference) in the regression equation D = −0.66 P + 13.2, gives the equation:

$$PA = MA - (13.2 - 0.66\ P),$$

where PA is the predicted absorption of a flour to produce dry noodles, MA is the mixogram absorption, and P is the flour protein content, all values in percent and expressed on a 14% mb.

It is postulated that the higher the flour protein content, the more rapidly dough cohesiveness develops to exert resistance on the mixer pins. Irvine et al (1961) reported that pasta dough developed more rapidly in the farinograph as the protein content of semolina increased from 9.5% to 16.2% at a constant absorption of 31.5%.

When we used our equation to predict the noodle making absorption of 25 additional flours, the predicted absorptions agreed well ($r = 0.91$, $P > 0.01$) with the experimental values for optimum dough handling (Table I). The mixogram method estimated the optimum absorption of 20 of 25 noodle doughs with an accuracy of 0.5%. The greatest difference was 1.3%.

Effect of Starch Damage and Reduced Particle Size on Absorption Mixogram Method

Previous work demonstrates that starch damage and flour granulation influence the optimum absorption of flour to produce oriental dry noodles (Oh et al 1985b). Tables II and III indicate that increased optimum absorptions associated with variations in starch damage and particle size of flours were predicted accurately by the mixogram method. The regression of the difference between mixogram and handling absorption on flour protein content (Fig. 2) was still applicable regardless of starch damage or flour granulation.

Pasta Absorption Determined by the Mixogram Method

Figure 3 shows typical mixograms of pasta doughs (no NaCl) from semolina (Fig. 3A) and farina (Fig. 3B). All farina and semolina samples behaved the same in the mixograph. Pasta doughs responded like noodle doughs, although the dramatic change in curve width and height occurred at much lower absorption, probably because of the larger particle size of semolina and farina compared to flour (Irvine et al 1961). The limited data suggest that the mixogram method may be used to predict the optimum absorption of semolina or farina to produce pasta.

Water Absorption Meter

Three moisture levels were used to derive each straight line for the semilog plot of extrusion time versus moisture level of doughs from four flours (Fig. 4). Each line was extrapolated past the known optimum handling absorption indicated by the open circle on each line.

Figure 5 shows the extrapolated lines obtained for nine flours with optimum handling absorptions that varied from 28% to 33%. The experimental points for the different moisture levels were left off the graph for clarity. The mean extrusion time (log value in seconds) of the handling absorptions of the nine flours was 3,160 sec (log value 3.5). This time was used to predict the optimum noodle absorption of 21 unidentified flours. Absorption predicted by the water absorption meter was significantly correlated ($r = 0.64$, $P > 0.01$) with the optimum handling absorption (Table I). The water absorption meter was not as effective in predicting optimum absorption of noodle doughs as was the mixogram method, because it accounted for only about 41% of the variation in the absorption of noodle doughs.

CONCLUSIONS

The mixogram method was more reproducible and more accurate than the research absorption meter in predicting flour absorption to produce oriental dry noodles (Table I). The amount of flour and the time required for one determination on the mixograph were 10 g and less than 15 min, respectively, whereas 75 g and 30 min were required by the water absorption meter. Furthermore, the mixogram method was convenient to use.

ACKNOWLEDGMENT

Authors N. H. Oh and P. A. Seib thank the Kansas Wheat Commission for financial support.

LITERATURE CITED

AMERICAN ASSOCIATION OF CEREAL CHEMISTS. 1983. Approved Methods of the AACC. Method 44-15A, revised October 1981; Method 46-11, revised October 1982. The Association: St. Paul, MN.

BLOKSMA, A. H. 1971. Rheology and chemistry of dough. Page 523 in: Pomeranz, Y., ed. Wheat: Chemistry and Technology. Vol. 3. Am. Assoc. Cereal Chem.: St. Paul, MN.

FINNEY, K. F., and SHOGREN, M. D. 1972. A ten-gram mixograph for determining and predicting functional properties of wheat flour. Bakers Dig. 45(2):233.

IRVINE, G. N., BRADLEY, J. W., and MARTIN, G. C. 1961. A farinograph technique for macaroni doughs. Cereal Chem. 38:153.

MATSUO, R. R., DEXTER, J. E., and DRONZEK, B. L. 1978. Scanning electron microscopy of spaghetti processing. Cereal Chem. 55:744.

MULLER, H. G., and BARRON, L. F. 1958. Some modifications of the design and use of the research water absorption meter in relation to consistency measurements of single doughs. J. Sci. Food Agric. 9:638.

OH, N. H., SEIB, P. A., and CHUNG, D. S. 1985a. Noodles. III. Effects of processing variables on quality characteristics of dry noodles. Cereal Chem. 62:437.

OH, N. H., SEIB, P. A., WARD, A. B., and DEYOE, C. W. 1985b. Noodles. IV. Influence of flour protein, extraction rate, starch damage and granulation on the quality characteristics of dry noodles. Cereal Chem. 62:441.

POMERANZ, Y., HALTON, P., and PEERS, F. G. 1956. The effects of flour dough and bread quality to molds grown in wheat and those added to flour in the form of specific cultures. Cereal Chem. 33:157.

[Received March 25, 1985. Revision received August 29, 1985. Accepted August 29, 1985.]