Relation of Distilled-Water Retention to Alkaline-Water Retention, Water Absorption, and Baking Properties of Wheat Flours[1]

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ABSTRACT

A water-retention test with distilled water was closely related to the alkaline water retention test, and the two tests were virtually identical in correlation with baking absorption, farinograph absorption, loaf volume, and cookie diameter of wheat-flour products.

An important property of wheat flour is the amount of water it absorbs or, what is often measured, the amount of water it retains against centrifugal force.

The baking-absorption and farinograph-absorption tests use distilled water (1). Retention methods with distilled water have been proposed for wheat flour (2,3,4) and have been used with wheat flour (5), wheat starch (6), and other cereal products (7,8).

Flour tests that use acid or alkaline solutions are also abundant. One of the oldest such tests is the apparent viscosity of an acidulated flour-water suspension, often called the MacMichael viscosity test (1), which uses 1N lactic acid solution. Finney and Yamazaki developed a retention test that used a dilute lactic acid solution and found it to be a reliable index of loaf-volume potentialities (9). Subsequently these investigators developed an alkaline viscosity test with the MacMichael viscometer[2] (10), and finally Yamazaki, in 1953, developed a retention test that used an alkaline solution to correspond with the alkaline medium of the cookie-baking test (11). The alkaline-water-retention capacity (AWRC) test has become a widespread, valuable tool in soft wheat flour evaluation.

A retention test that used distilled water appeared to be a logical starting point in beginning a study of the waterholding properties of wheat flour. A test using the procedure of the AWRC test would be more simple than those proposed previously with distilled water (2,3,4) and would not require a special centrifuge (2,4). Once the characteristics of distilled-water retention had been established, the results could be related to retention tests using acid or alkaline solutions. This report compares a distilled-water-retention test with the AWRC test.

MATERIALS AND METHODS

Flour Samples

A total of 122 samples was studied. They were taken from standard varieties and advanced selections grown at Pullman and Lind, Washington, in the three crop

[1]Cooperative investigations of the Plant Science Research Division, Agricultural Research Service, U.S. Department of Agriculture, and the Department of Agricultural Chemistry, College of Agriculture, Washington State University. Scientific Paper No. 3691, College of Agriculture, Pullman.

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[2]MacMichael is a trademark name of the Fisher Scientific Company, 203 Fisher Building, Pittsburgh, Pa.

years 1967–69. These wheats included HRW, HRS, HWW, SRW, SWW, SWS, and club varieties. They had a wide range in protein content, physical properties, and baking quality. Single-variety wheat samples were milled to straight-grade flours on a Buhler mill[3].

Water-Retention-Capacity Test

The procedure described by Yamazaki (11) and adapted by Medcalf and Gilles (6) was used with slight modification. Flour (5 g., as-is basis) was weighed into a tared 50-ml. centrifuge tube, 25 ml. distilled water was added, and the tube was stoppered. The tube was shaken vigorously and allowed to stand for 20 min. with shaking every 5 min. It was then centrifuged for 15 min. at 1,000 X g, the supernatant was decanted, and the tube was drained for 10 min. at a 45-degree angle. The tube was weighed, and the gain in weight was expressed as percent. Duplicate or more determinations were made until two determinations agreed within 0.1 g. retained water.

AWRC Test

This test was made exactly as described above except that 0.1N sodium bicarbonate solution replaced the distilled water.

Absorption and Baking Tests

Data for these tests were from the routine testing program of our laboratory (12,13,14) and were obtained by accepted methods (1). The values are on an 'as-is' basis and are not corrected for moisture and protein. Some samples were not baked and some were not tested with the farinograph (Table I).

The data were plotted, and the ranges and average values were calculated both for all flours and separately for hard wheat and soft wheat flours (Table II). Flours with less than 60.0% AWRC were classed as soft wheat flours, and those with 60.0% or above AWRC values were classed as hard wheat flours (15).

RESULTS

Distilled-water-retention capacity (WRC) was closely related to AWRC. The correlation coefficient was 0.99 (Table I). The two were not equal however; AWRC averaged over 3% higher than WRC for all three classes of flours (Table II). Plotting these two values showed that the soft wheat flours had a greater variation for these values than did the hard wheat flours.

Both retention tests were closely related to baking absorption, with correlation coefficients of 0.92 and 0.89. Soft wheat flours had AWRC values that averaged the same as baking absorptions, whereas WRC values for these flours averaged 3.5% less. For hard wheat flours, however, AWRC values averaged 3.3% higher than baking absorptions, whereas WRC values were practically the same as baking absorptions. Hard wheat flours had as much variation between retention values and baking absorptions as soft wheat flours.

Both retention tests were also closely related to farinograph absorption (Table I). For the soft wheat flours, farinograph absorptions averaged 7.1% higher than

[3]A trademark name of The Buhler Corporation, 8925 Wayzata Blvd., Minneapolis, Minn. 55426.

TABLE I. CORRELATION COEFFICIENTS FOR WATER-RETENTION CAPACITIES, WATER ABSORPTIONS, LOAF VOLUMES, AND COOKIE DIAMETERS

Relationship	n	r
WRC vs.		
AWRC	122	0.99
Baking absorption	120	0.92
Farinograph absorption	110	0.88
Loaf volume	108	0.06
Cookie diameter	119	−0.87
AWRC vs.		
Baking absorption	120	0.89
Farinograph absorption	110	0.86
Loaf volume	108	0.05
Cookie diameter	119	−0.85
Baking absorption vs.		
Farinograph absorption	110	0.93
Loaf volume	108	0.23
Cookie diameter	119	−0.81
Farinograph absorption vs.		
Loaf volume	102	0.30
Cookie diameter	110	−0.86
Loaf volume vs.		
Cookie diameter	108	−0.06

WRC and 3.6% higher than AWRC. For the hard wheat flours, farinograph absorptions averaged only 2.4% higher than WRC and slightly lower than AWRC.

Baking absorption had a correlation coefficient of 0.93 with farinograph absorption, but farinograph absorptions averaged 2.6% higher for soft wheat flours and 3.4% higher for hard wheat flours (Table II).

The two retention tests were very poorly correlated with loaf volume (Table I), and the two absorption tests were only slightly better.

All four water-holding tests had good negative correlations with cookie diameter. Coefficients ranged from −0.81 to −0.87. In the routine data compiled in this laboratory for the 21 crop years, 1947–67 (12), covering hundreds of samples, AWRC vs. cookie diameter had a coefficient of −0.85 and farinograph absorption vs. cookie diameter had a coefficient of −0.89. Yamazaki (16) reported for 448

TABLE II. RANGES AND AVERAGE VALUES FOR WATER-RETENTION CAPACITIES, WATER ABSORPTIONS, LOAF VOLUMES, AND COOKIE DIAMETERS

	Water Retention %	Alkaline-Water Retention %	Baking Absorption %	Farinograph Absorption %	Loaf Volume ml.	Cookie Diameter cm.
No. of samples	122	122	120	110	108	119
Range	45.2–78.3	49.2–81.4	49.5–72.5	51.0–75.4	578–1107	7.00–9.17
Average value						
All flours	59.1	62.4	60.5	63.2	849	8.12
Soft wheat flours	51.8	55.3	55.5	58.9	838	8.48
Hard wheat flours	64.3	67.4	64.1	66.7	857	7.87

samples for 5 years that AWRC vs. cookie diameter had a correlation coefficient of −0.86 and baking absorption vs. cookie diameter had a coefficient of −0.87.

Loaf volume and cookie diameter were very poorly correlated, with a coefficient of −0.06.

DISCUSSION

In recent years there has been a trend towards the use of distilled water in determining waterholding properties of cereal products (2,3,4,5,6,7,8). However, Fifield (2) used a Sharples Supercentrifuge[4], and Miller (4) used a specially modified centrifuge. The method proposed by Sosulski (3) is time-consuming and requires oven-drying. Larsen (5) and Medcalf and Gilles (6) determined water retention by using distilled water with the relatively simple method and commonly available equipment that Yamazaki used for the AWRC test (11). In the present study, distilled water was used with the method and equipment of the AWRC test. Thus it was necessary to establish the relation of distilled-water retention to other evaluation tests.

Since Yamazaki (16) investigated three of these properties – baking absorption, AWRC, and cookie diameter – in much greater detail (448 samples covering 5 years), the present study was limited to enough samples (122 for 3 years) to establish a sound relation.

The retention test with distilled water was very closely related to the AWRC test, and the two tests were virtually identical in their relation to baking absorption, farinograph absorption, loaf volume, and cookie diameter.

Evidence for the value of farinograph absorption in an evaluation program continues to grow. In this study, farinograph absorption had a correlation coefficient of 0.93 with baking absorption, of −0.86 with cookie diameter, and of 0.88 with WRC. In the data for 21 years (12), farinograph absorption had a correlation of −0.89 with cookie diameter. Miller (4) reported a correlation of 0.87 between his retention test and farinograph absorption. Shellenberger et al. (17) reported a correlation of 0.90 between farinograph and baking absorptions if their durum and Chiefkan samples were omitted and 0.83 if all samples were included.

When cookie diameter was plotted against WRC in this study, the great majority of samples fell into a narrow band, thus supporting the hypothesis that cookie diameter may be a function of water absorption or retention, as first proposed by Yamazaki (16). Nevertheless a number of samples fell outside this band, and some with essentially the same water retention had very different cookie diameters. Examples were:

WRC	*Cookie Diameter*	*WRC*	*Cookie Diameter*
47.3	9.17	56.8	8.59
47.4	8.29	56.7	7.76

Study of these atypical flour samples may provide more information about soft wheat flour baking quality.

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[4]A trademark name of The Pennwalt Company, P.O. Box 515, West Chester, Pa. 19380.

Literature Cited

1. AMERICAN ASSOCIATION OF CEREAL CHEMISTS. AACC Approved methods formerly Cereal laboratory methods, 7th ed. The Association: St. Paul, Minn. (1962).
2. FIFIELD, C. C. A mechanical method for the determination of absorption in bread doughs. Cereal Chem. 10: 547 (1933).
3. SOSULSKI, F. W. The centrifuge method for determining flour absorption in hard red spring wheats. Cereal Chem. 39: 344 (1962).
4. MILLER, H. A micro centrifuge to determine water-retention properties of wheat flour. Cereal Chem. 45: 109 (1968).
5. LARSEN, R. A. Hydration as a factor in bread flour quality. Cereal Chem. 41: 181 (1964).
6. MEDCALF, D. G., and GILLES, K. A. Wheat starches. I. Comparison of physicochemical properties. Cereal Chem. 42: 558 (1965).
7. ANDERSON, R. A., CONWAY, H. F., PFEIFER, V. F., and GRIFFIN, E. L., Jr. Gelatinization of corn grits by roll- and extrusion-cooking. Cereal Sci. Today 14: 4 (1969).
8. PEPLINSKI, A. J., and PFEIFER, V. F. Gelatinization of corn and sorghum grits by steam-cooking. Cereal Sci. Today 15: 144 (1970).
9. FINNEY, K. F., and YAMAZAKI, W. T. Water retention capacity as an index of the loaf volume potentialities and protein quality of hard red winter wheats. Cereal Chem. 23: 416 (1946).
10. FINNEY, K. F., and YAMAZAKI, W. T. An alkaline viscosity test for soft wheat flours. Cereal Chem. 30: 153 (1953).
11. YAMAZAKI, W. T. An alkaline water retention capacity test for the evaluation of cookie baking potentialities of soft winter wheat flours. Cereal Chem. 30: 242 (1953).
12. BARMORE, M. A., et al. Twentieth annual report of the Western Wheat Quality Laboratory (1969).
13. RUBENTHALER, G. L., et al. Twenty-first annual report of the Western Wheat Quality Laboratory (1970).
14. RUBENTHALER, G. L., et al. Twenty-second annual report of the Western Wheat Quality Laboratory (1971).
15. KITTERMAN, J. S., and RUBENTHALER, G. L. Assessing the quality of early generation wheat selections with the micro AWRC test. Cereal Sci. Today 16: 313 (1971).
16. YAMAZAKI, W. T. Interrelations among bread dough absorption, cookie diameter, protein content, and alkaline water retention capacity of soft winter wheat flours. Cereal Chem. 31: 135 (1954).
17. SHELLENBERGER, J. A., POMERANZ, Y., FINNEY, K. F., and WARD, A. B. Chemical, rheological and bread-making characteristics of selected varieties of various wheat classes. Baker's Dig. 44(5): 27 (1970).

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