Water-Retention Properties of Wheat Flour Fractions[1]

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ABSTRACT

Differences in the water-retention capacities (WRC) of flours of three different classes of common wheat were studied in two ways. The three major flour fractions, gluten, tailings, and starch, were obtained from a hard red winter (HRW) flour, a soft white winter (SWW) flour, and a club (soft) flour by a standard kneading fractionation, and the WRC of the individual fractions was determined. Gluten and starch from the HRW flour had moderately higher WRC than those from the soft wheat flours. The HRW tailings had much higher retentions than the other tailings. Gluten and tailings from a kneading method in which the dough was formed with dilute sodium chloride solution had lower water retentions than those from the standard fractionation. Gluten and tailings from an acetic acid extraction method had higher retentions. Starches from all three methods had about the same retentions. Flour WRC calculated from the individual fraction retentions multiplied by the fraction yields were decidedly higher than WRC determined on actual blends of the fractions. The second approach used one-fraction-at-a-time interchanges between pairs of reconstituted flours and included the water-soluble fraction. In all interchange series, the tailings caused about half of the WRC differences. SWW tailings lowered WRC of an otherwise all-HRW reconstituted flour about halfway to that of the all-soft wheat reconstituted flours. HRW tailings raised WRC of an otherwise all-soft wheat reconstituted flour about halfway to that of an all-HRW reconstituted flour. The remaining half of the WRC difference was about equally divided among the water-solubles, gluten, and starch. Water-solubles, although they had no water retention of their own, affected the WRC of reconstituted flours when interchanged. The pattern of fraction response to WRC was similar to that obtained in studies with reconstituted cookie flours.

Wheat flours have a wide range in the amount of water they will absorb or retain against a mild centrifugal force. However, information about how flour constituents affect water-holding properties is incomplete and conflicting.

Bushuk and Hlynka (1), in reviewing the water-holding properties of flour, quoted several workers as reporting the absorption of wheat starch to be 27 to 44%, while gluten absorbed about 110%. These reviewers concluded that gluten and starch absorbed most of the water taken up by flour. They acknowledged the very high absorption of pentosans and gums, but considered the total absorption of these substances to be rather small. Larsen (2) also stated that most of the water is bound by gluten and starch.

However, two years later Bushuk (3) calculated that in a dough the starch took up 46% of the water, gluten 31%, and the pentosans 23%. He pointed out that the calculated absorption would be 82%, a value higher than those found in actual determinations.

Meredith (4) stated that granular starch will hold half its weight of water, damaged starch twice its weight, gluten twice its weight, and the pentosan gums much more.

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In a different approach to the problem, Yamazaki (5), after developing the alkaline water-retention capacity (AWRC) test, went on to apply this test to gluten, starch tailings, and subfractions of the tailings. He obtained AWRC values of 122 to 137 for gluten, 55 for prime starch, and 147 to 238 for tailings.

The present study attempted to evaluate the contribution of each of the four common flour fractions to water retention through fractionation and reconstitution techniques.

MATERIALS AND METHODS

Flours

Three single-variety, straight-grade flours milled on a Buhler[2] mill were used in this study. These flours have been described (6).

Fractionation and Reconstitution Methods

These methods have been described (6). Except where another fractionation method is specifically stated, the standard method (6) was used. Flours were mixed mechanically to a dough and hand-kneaded under distilled water. The water-soluble fraction was freeze-dried, and the other fractions were air-dried. Blends of 50-g. fractions in the proportions obtained in fractionation were mixed with distilled water for 4 min. after formation of a dough. These doughs were freeze-dried and ground to flours. Moisture and retention values were determined on these reconstituted flours.

Analytical Methods

These tests have been described (6).

RESULTS AND DISCUSSION

Retention Capacities of Individual Fractions

Water-retention capacity (WRC) and AWRC values for 5-g. samples of air-dried fractions are given in Table I. Gluten WRC and AWRC values showed a small change between hard and soft wheat flours and, coupled with the relatively small yield of this fraction, indicated only a small effect of gluten on retention differences. The hard wheat flour tailings had a much higher water retention than those from the two soft wheat flours. Starch from hard wheat flour had a moderately higher retention, which, with the large yield of this fraction, would indicate a moderate effect on retention. The club wheat flour fractions had practically the same retention values as the soft common wheat fractions.

Retention values in Table I agree fairly well with those reported by Yamazaki (5) and Meredith (4). Gluten retentions in Table I are close to the gluten absorption given in the review (1), but some of the earlier workers quoted in this review obtained much lower absorptions for starch.

AWRC values for gluten and tailings were higher than WRC values for these fractions. Starch WRC values were very close to those of starch AWRC. Bushuk (7) studied the effect of pH on water binding and found that the amount of retained water in gluten increased slowly as the pH increased above 6, but that the binding capacity of starch was independent of pH.

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

TABLE I. WATER-RETENTION VALUES FOR INDIVIDUAL FRACTIONS

	Gluten		Tailings		Starch	
	WRC %	AWRC %	WRC %	AWRC %	WRC %	AWRC %
HRW	125	135	178	189	65.4	66.2
SWW	117	129	114	117	59.8	60.0
Club	116	131	113	118	60.1	60.6

Freeze-dried starch and tailings fractions had retentions almost identical with those from air-dried starch and tailings. Freeze-dried gluten gave slightly lower retentions than air-dried gluten.

Water Retentions of Fractions from Three Flour-Fractionation Methods

WRC values for fractions from a kneading separation in which 1.75% sodium chloride solution was used for the initial dough formation (8) and from an acetic acid extraction method (9) are given in Table II. Another standard kneading separation, independent of those reported as an average in Table I, was made to accompany these two fractionations, and values for the standard fractions differ slightly from those in Table I. Only single fractionations were made of each method for each flour; WRC are averages of duplicates or more.

Tailings WRC was greatly affected by the type of fractionation, while starch values were very stable. Gluten WRC was somewhat affected. The presence of sodium chloride during the initial dough formation resulted in lower WRC of tailings than that of tailings from the standard procedure. Exposure to acetic acid solution greatly increased WRC of tailings and also of Rio gluten. WRC of starch was not affected by the acetic acid solution.

Comparison of Calculated Retentions with Actual Retentions

From the individual fraction retentions in Tables I and II and the yields of the fractions, a retention value can be calculated for the amounts of these fractions in 1 g. flour. The water-soluble fraction had no retention of its own to contribute, but the weight of this fraction must be included for a valid comparison with flour retention. Bushuk (3) in this manner estimated that flour (probably a high-protein,

TABLE II. WRC OF FRACTIONS FROM THREE TYPES OF FLOUR FRACTIONATION

	Standard Kneading Method %	Kneading with Sodium Chloride Solution %	Acetic Acid Separation %
HRW			
Gluten	125	115	133
Tailings	178	159	203
Starch	65.4	65.8	65.2
SWW			
Gluten	117	115	114
Tailings	114	102	155
Starch	59.8	59.7	60.5

TABLE III. COMPARISON OF CALCULATED RETENTIONS WITH RETENTIONS ACTUALLY FOUND FOR SIMPLE BLENDS OF FRACTIONS

		Blends of Fractions from			
		Standard kneading method		Kneading with sodium chloride	
	Normal Flours %	Calculated %	Found %	Calculated %	Found %
HRW	68.2	91	77.8	84	72.1
SWW	53.3	77	59.3	74	54.6
Club	49.2	76	55.6	67	49.6

TABLE IV. WATER-RETENTION VALUES FOR NORMAL FLOURS, RECONSTITUTED FLOURS, AND RECONSTITUTED FLOURS WITH ONE FRACTION INTERCHANGED

		Reconstituted				
	Normal Flours %	All One Variety %	Other Water-Solubles %	Other Gluten %	Other Tailings %	Other Starch %
HRW-SWW Series						
HRW	67.2	73.1	69.9	70.6	64.8	70.1
SWW	51.5	56.9	58.9	59.1	63.8	60.2
HRW-Club Series						
HRW	67.3	73.8	71.5	69.3	63.4	69.7
Club	50.6	53.9	57.9	60.0	63.5	59.3

hard wheat flour) would have an absorption of 82%. He commented that this was considerably higher than the absorption used in current breadmaking processes.

Table III gives the calculated values and the retentions actually found for such simple blends of fractions (the test was made on the amounts of fractions from 5 g. flour). Although the club wheat flour fractions and the soft white winter (SWW) flour fractions had about the same retention, the club wheat flour gave a smaller yield of tailings and therefore has a lower calculated retention. When the WRC test was applied to the actual blend, it was evident that interactions and competition among the fractions and other factors caused the actual retention to be lower than the calculated one.

Frequently conclusions about flour water-holding properties are made on the basis of the water-holding properties of the individual fractions (1–5), and some have been made in this study. That the actual retentions of both simple blends and reconstituted flours (6) are lower than those calculated from the fraction retentions may somewhat lessen the value of such conclusions.

WRC of Reconstituted Flours with One Fraction Interchanged

Table IV lists the water retentions for two reconstituted series, in which one fraction at a time was substituted for the corresponding one of the opposite member of the pair. In the first series, the substitution of SWW water-solubles and

TABLE V. ALKALINE WATER-RETENTION VALUES FOR NORMAL FLOURS, RECONSTITUTED FLOURS, AND RECONSTITUTED FLOURS WITH ONE FRACTION INTERCHANGED

		Reconstituted				
	Normal Flours %	All One Variety %	Other Water-Solubles %	Other Gluten %	Other Tailings %	Other Starch %
HRW	70.5	76.0	72.9	73.0	66.6	73.1
SWW	53.7	60.4	59.9	61.5	67.6	61.6

TABLE VI. WATER-RETENTION VALUES FOR FLOURS RECONSTITUTED FROM FRACTIONS OF A SEPARATION IN WHICH THE DOUGH WAS FORMED WITH SODIUM CHLORIDE SOLUTION

		Reconstituted				
	Normal Flours %	All One Variety %	Other Water-Solubles %	Other Gluten %	Other Tailings %	Other Starch %
HRW	68.1	71.0	66.7	68.7	61.6	69.2
SWW	52.7	54.9	51.8	50.9	65.8	53.7

SWW starch in the otherwise all-HRW reconstituted flour caused the retention to drop from 73 to about 70, and substitution of SWW gluten lowered the retention to 70.6. However, the substitution of SWW tailings caused the HRW flour retention to drop from 73 to 65. Thus, of the difference between the retention of the all-HRW reconstituted flour and the all-SWW reconstituted flour, the tailings accounted for about half of the difference, while the remainder was divided rather evenly among all three of the other fractions, with perhaps here the gluten being slightly less effective.

Only minor deviations from this pattern were evident when one HRW fraction was substituted in the otherwise all-SWW reconstituted flour. Here HRW water-solubles and HRW gluten caused the retention to rise from 57 to 59, while HRW starch raised the retention to 60. Again the tailings effected the largest response, retention going from 57 to 64.

Retentions for the HRW-club wheat flour reconstitution series are given in the second part of Table IV. Here the substitution of club wheat tailings for HRW tailings in the HRW blend lowered the retention from 73 to 63. Likewise, the substitution of HRW tailings for club wheat tailings in the otherwise all-club wheat blend raised the retention from 54 to 63.5. All three of the other fractions, when substituted, also affected the difference in water retention. In this series, the gluten interchanges caused larger retention differences than did the starch interchanges, and the water-solubles here were less effective than either gluten or starch.

AWRC for a HRW-SWW reconstitution series exhibited much the same pattern (Table V). Substitution of SWW tailings into the HRW blend caused retention to drop from 76 to slightly below 67. Substitution of each of the other three SWW fractions into the HRW blend lowered the retention from 76 to 73.

Substitution of HRW fractions into the SWW blends showed some deviations from the usual pattern. HRW water-solubles consistently lowered AWRC slightly below that of the all-SWW reconstituted flour. HRW gluten and starch caused AWRC to rise only about 1% while HRW tailings effected a raise of 7%.

Table VI gives the WRC for a HRW-SWW reconstituted series in which fractions from separations of doughs formed with sodium chloride solution were used. This series was unusual in that substitution of SWW fractions into the otherwise all-HRW blend gave results very similar to those already listed, while substitution of HRW fractions into the SWW blend gave very different results. HRW water-solubles, gluten, and starch, when substituted in the SWW blend, caused the reconstituted flours to have lower WRC than the all-SWW reconstituted flour. HRW tailings substituted into the SWW blend did raise the retention 11%.

CONCLUSIONS

All four fractions proved to be contributing to the water-retention differences between hard and soft wheat flours. The tailings fraction invariably had the largest effect, however, and usually caused about half of the difference when interchanged. This was true for both the hard wheat flour tailings substituted into the soft flours and the soft wheat tailings substituted into the hard flours.

The evidence from fraction interchanges in reconstituted flours was somewhat different from that based on individual fraction retentions. The water-solubles proved to have an effect when interchanged. Gluten generally had about the same effect as starch, a conclusion that might not be reached from the smaller amounts of gluten present in flour and the small retention differences between glutens.

The pattern of fraction responses to water retention showed a striking similarity to similar work with reconstituted cookie flours (5,10) and adds additional support to the hypothesis that cookie-baking quality may be a matter of flour-water relationship (5).

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