HYDRATION AS A FACTOR IN BREAD FLOUR QUALITY[1]

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ABSTRACT

A study was made of the rate of water-absorption of starch and the rate of water-absorption of protein of a bread flour, with a farinograph as the testing device. The techniques used to separate the starch and protein prior to the rate studies avoided water as a separating agent. The results indicate that the water-absorption by flour starch is more rapid than the water-absorption by flour protein. It is hypothesized that a determinant of the quality of a bread flour for breadmaking is the relative rates of hydration of water by the starch and the protein of a particular bread flour.

Over the years, numerous papers have been published concerning differences in bread flours. In spite of the many advances, there remains some mystery surrounding this question.

On one point there is general agreement. The quantity of protein in a bread flour is important; the greater the amount of protein, the better is the flour's potential for the baking of bread. The work of Aitken and Geddes (1) on this subject is typical.

While there is general agreement on the importance of protein in a

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bread flour, it is also generally agreed that factors other than protein also play a part in the breadmaking performance of a flour. This proposition is clearly demonstrated by the studies of Finney and Barmore (2), which showed that the quality of bread made of flours from different varieties of wheat, all having the same amount of protein, did indeed differ and quite significantly.

These unexplained differences are generally described as variations in protein quality. The term *protein quality* is used in spite of the fact that the chemical compositions of proteins from different flours are apparently similar. For example, Lewis and Elvehjem could find no differences in the amino acid make-up of glutens from different flours (3). Pence (4) has looked at the albumin and globulin contents of wheat flours without finding important variations. Hess (5) and Grosskreutz (6) have studied the lipoprotein complex, but differences among flours are not striking.

Laboratory and commercial experiences with high-protein flours produced by air-classification techniques also argue against the concept of protein quality. Some high-protein flours used in conjunction with weak bread flours to improve their bread-baking qualities are produced from soft wheat flours. These high-protein flours, which come from typical cake flours, have all the characteristics associated with extremely strong bread flours. In this usage, they are as good as similar high-protein flours derived by air-classification from normal bread-type flours.

These studies, as well as others, seem to indicate that protein quality, whatever the term describes, is yet to be explained. Proteins in flours that bake differently appear to be the same.

There can be no doubt that physical dough testing devices measure characteristics of flours that are related to the quality of bread, and that differences in characteristics are found in flours of the same protein content. If these differences in physical testing characteristics — which are generally attributed to protein quality — are not in fact due to protein quality or at least not to differences in protein composition, then other explanations must be found. The purpose of this paper is to present some new experimental data and an alternative suggestion. This explanation revolves around the role that water plays in the formation of a bread dough.

Materials and Methods

Two types of flours were used in this study. One was a typical cake flour milled from soft wheat and having a protein content of 7.2% (14% moisture basis) and ash content, 0.32%. The other was a bread flour made from northern spring wheat and having a protein content of 12.2% and ash content 0.40%.

All farinograph studies were made in a 10-g. bowl following the procedure of Shogren and Shellenberger (7).

Neutral water-retention measurements were made according to the procedure of Yamazaki (8), except that Yamazaki used alkaline water whereas here distilled water was used.

The flour was fractionated by density separation techniques, with a mixture of carbon tetrachloride and benzene. The first separation was made at sp. gr. 1.45. The low-protein fraction which resulted from this separation was further fractionated at sp. gr. 1.35. The high-protein fraction coming from the first separation was cut at sp. gr. 1.45.

The maltose, protein, and ash values were measured by standard AACC methods. The tailings starch, prime starch, gluten, and water-solubles described in Table I were isolated in the following manner.

Flour (1 lb.) was placed in a Hobart (Model N50) mixing bowl, 300–325 cc. of distilled water added, and a dough formed. The dough hook was removed and a regular blade paddle inserted in its stead. Then 250–300 cc. of distilled water was added and mixing was continued for 3–4 min. on speed 1. The major part of the dough was removed and the liquid was strained from the small fragment remaining, through a cloth strainer. The dough, plus the small fragment, was replaced in the mixer, rewashed, and re-strained as described above. This was repeated eight to ten times or until the wash-water came out clear. Hand kneading the last few times helped remove the last of the starch from the gluten ball. The gluten ball was cut into small pieces and air-dried with a fan.

The combined washings settled overnight in the cold. The clear water was decanted and the remainder centrifuged. The well-defined upper layer of tailings starch was mechanically removed from the prime starch. Both layers were air-dried.

The water-washings were collected and concentrated in a glass circulatory evaporator. The concentrate was then freeze-dried. Regrinding of flour was done on the smooth rolls of an Allis experimental mill.

Experimental

Water-Adsorptive Capacity of a Bread Flour. A measure of the water-attractive capacity of flour can be obtained by calculating the hydration capacity of a bread flour and then comparing this capacity to the amount of water normally used in bread; see table below.

A typical bread formula has about 54% flour and about 35% water. Together, these two ingredients make up about 89% of a normal bread

	Percent in Formula		*Percent Water-Binding Capacity (ref. 9)*		*Percent Water-Bound*
Starch (dry basis)	40.8	×	70	=	28.6
Protein (dry basis)	5.6	×	180	=	10.1
Water	42.6				38.7

formula. Since a bread flour contains moisture, the amounts of water and dry flour in a bread formula are 42.6% water and 46.4% dry flour.

Given the water-binding capacity of starch and of protein (9), it is possible to calculate, as shown in the table above, that most of the water (38.7%) in a normal bread dough is bound by these two ingredients alone.

Rate of Water-Absorption of Starch and Protein. In spite of the limited amount of water available in a bread dough, it would seem, since the gluten protein can absorb so much more water than starch, that the gluten would be able to attract all the water it requires to form gluten strands. Such a conclusion, however, assumes that because gluten can absorb more water than starch, it can also do it at a faster rate than starch. Such is not the case, as the following experiments show.

Farinograph curves for solvent density-separated soft wheat flours of 4.8, 23.3, and 87.3% protein are shown in Fig. 1; see table below. These products were prepared from the same parent flour by density classifi-

Protein %	*Water Absorption* %	*Peak Time* *min.*
4.8	77.5	0.5
23.3	114.0	17.0
87.3	216.0	20.0

cation in the nonpolar organic solvent mixture described under "Materials and Methods."

While the water-absorption greatly increased with increasing protein, the rate of absorption as measured by the farinograph peak consistency decreased. Apparently, the starch absorbs the water much more rapidly than gluten.

The same relative picture is true of similar products prepared in the same manner from a solvent density-separated spring wheat, bread-type flour; see table below.

The differences in the rates of absorption can be better appreciated

Protein %	*Water Absorption* %	*Peak Time* *min.*
6.6	96	1.5
23.1	129	29.0
85.6	220	50.0

by examination of actual curves. Farinograph traces are shown in Fig. 1. The high-protein flour resists water until suddenly a dough begins to form. Apparently, there must be a mechanical rearrangement of the gluten structure before water can be adsorbed. Until this mechanical work is done on gluten, gluten is largely hydrophobic in character.

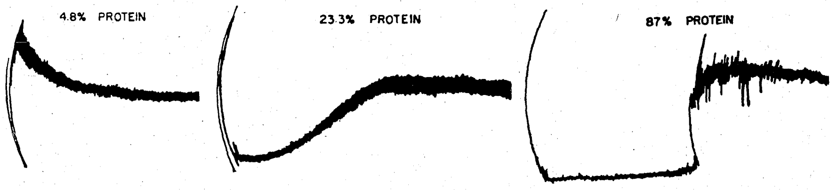

Fig. 1. Farinograph curves of a flour adjusted to different protein contents by density separation techniques.

Since it appears that the water-adsorption capacity of starch is important, a study was done on the changes in the water-adsorptive capacity of starch caused by regrinding flours. The results are summarized in Table I.

TABLE I
WATER ABSORPTION OF REGROUND FLOUR FRACTIONS

	Maltose Value	Recovery	Neutral Water Absorption
	mg./10 g.	%	%
Control flour	190	. . .	81.1
Prime starch	13	53.3	87.7
Tailings starch	404	19.7	146.6
Gluten	29	15.5	114.6
Water-solubles	2,345	7.1	. . . .
Once-reground flour	271	. . .	91.7
Prime starch	85	49.9	59.3
Tailings starch	578	24.2	127.0
Gluten	42	15.3	126.7
Water-solubles	3,590	8.3	. . . .
Four-times-reground flour	480	. . .	119.4
Prime starch	158	45.8	66.1
Tailings starch	1,076	25.6	130.4
Gluten	75	15.6	126.0
Water-solubles	4,013	11.4	. . . .

As a flour is reground, there is a conversion of prime starch, which absorbs less than its weight as water, to tailings starch, which absorbs more than its weight as water, and to water-solubles, which are extremely water-adsorptive. While the percentage increase in the tailings starch fractions and water-soluble fractions are not large, these changes, when the limited amount of water available in a bread dough is considered, could be quite significant.

Discussion

The basic structure of bread is formed during the dough mixing stage (Baker and Mize, 10), when the protein fiber strands, in which starch is imbedded (Sandstedt, 11), are created and provide the strength and structure of bread. In order for a bread dough to form, the gluten of the flour must be hydrated. If the amount of water in a bread dough is at a minimum, there may be times when the water needs of a bread flour protein are not fulfilled, the gluten structure of the bread dough is not properly formed, and the quality of the resulting bread is therefore substandard.

Data presented in this paper indicate that there is indeed a limited amount of water in a bread dough formula, since it appears that most of the water is bound (see first unnumbered table). The fact that so little water is lost during baking (a bread dough formula contains about 42% water and bread normally contains 37% water) is additional evidence of the small amount of free water in bread. The fact that Botulinum bacteria cannot grow in canned bread having a moisture content of 36% or less even though other environmental conditions are favorable (Wagenaar and Dack, 12) indicates that the available water is firmly attached to the hydrophilic substances that are part of the bread formula. Bacteria must have free water in their environment to grow.

Along with limited water supplies, the problem of meeting the hydration needs of gluten is apparently complicated by the fact that starch can adsorb water much more rapidly than can gluten. Data reported herein support this assertion. Consequently, if for some reason the water-adsorptive capacity of a bread flour starch is unusually high, the starch might capture more than its normal share of water during the dough mixing stage and at the expense of the flour protein.

It is well known that the water-adsorptive nature of starch can be varied. This has been accomplished by disruption of the crystalline structure of starch by heat (Alsberg and Rask, 13), by enzymes (Kirschner and Hoppe, 14), and by mechanical forces (15). Furthermore, there is evidence that different varieties of wheat of similar protein content vary in their absorptive nature. Zeleny (16) uses the swelling of flour in a highly polar mixture of water, isopropyl alcohol, and lactic acid as a test of flour quality. Finney and Yamazaki (17) suggest the water-absorptive capacity of a bread flour as a test of the quality of hard red winter wheats. Yamazaki (8), working with cookie flours, has indicated that water-absorption is a quality factor and has related the differences in absorption to the amount of tailings starch. Gilles and

Smith (18) have studied the highly water-absorptive carbohydrate gums of flour.

Thus, there is reason to hypothesize that the water-adsorptive characteristics of starches of bread flours can vary and that, under some circumstances, gluten does not get enough water to properly form a bread dough. This may be a cause of the differences in the bread-baking quality of two bread flours of the same protein content. It suggests a starch quality factor that perhaps can be specified by rates of hydration or by some chemical constituent such as amount of tailings starch.

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