Bulletin No. 198 - Effect of Storage Upon the Bread-Making Qualities of Wyoming Hard Wheat Flours

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Bread made from Wyoming hard wheat flour aged 6 months, 16 months, and 48 months, from left to right.

Effect of Storage
Upon the Bread-Making Qualities of Wyoming Hard Wheat Flours

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Address: Director of Experiment Station, Laramie, Wyoming.
STATION STAFF

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AVEN NELSON, Ph.D., Botanist and Horticulturist.

Chemistry:
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O. C. McCUE OR, Ph.D., Associate Chemist.
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H. F. EPSON, M.S., Asst. Chemist.

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RALPH HONESS, M.A., Asst. Research Zoologist.
EFFECT OF STORAGE UPON THE BREAD-MAKING QUALITIES OF WYOMING HARD WHEAT FLOURS

By Emma J. Thiessen

INTRODUCTION

An improvement in the baking quality of flour after having been aged for certain periods of time is generally conceded by chemists, millers, bakers, and housewives.

In the study reported here an attempt has been made to determine the optimum period of time for the storage of three brands of Wyoming hard wheat flour and, if deterioration occurs, at approximately what time it begins. Changes occurring in the flavor, texture, volume, and color of the bread from flour stored varying periods ranging from 1 month to 48 months are noted.

It is not only of value for the consumer to know the type of flour which produces optimum results under continued storage, but also to know the most favorable conditions for storage to prevent deterioration and insect infestation.

Review of Literature. A review of experimental work on the storage of flour reveals that the time of storage before improvement becomes apparent depends upon the conditions of storage, as well as upon the type of flour (1, 2, 3, 4).*

The length of time that hard wheat flours must be aged before improvement is noticeable seems to depend upon the kind of wheat used in milling and upon the temperature of the storage room. The greatest improvement in the baking qualities of stored flour occurred at the end of the first month (4, 5), and the most rapid improvement was noted in the flour which had been stored at a comparatively high temperature of 73° F., as compared with lower storage temperatures of 57° F. and 65° F. (6). However, continued storage at a warm temperature for a period of 11 months has been found to be detrimental to both common and durum wheat flours (1).

*Figures in parentheses refer to numbers in the Bibliography at the end of the bulletin.
Contradictory results have been noted in regard to a desirable storage period for flour. One investigator concluded that the highest baking strength was secured in flour aged 2 to 3 years (2), whereas in a recent investigation of Canadian flour it was concluded that deterioration was evident in stored flour after 21 to 35 months (7).

A number of investigators agree that the moisture content and absorption may either increase or decrease, depending upon the humidity of the air, the length of storage, and other conditions (4, 8, 9).

There likewise seems to be no definite agreement as to the time necessary for improvement to take place in stored flour, or whether the flour reaches a maximum quality and then deteriorates.

The extent to which such conditions as temperature, relative humidity, and exposure to atmospheric conditions are factors of importance in the deterioration or improvement of flour has been of interest in this particular study.

The most important factors which determine the character of the finished loaf of bread are gas production and gas retention by the dough. The gas producing agents in bread dough are yeast and sugar. The manner in which the dough retains the gas that is produced by yeast fermentation depends upon both the quantity and quality of the gluten, whereas the factors influencing gas production are more or less controlled by the baker and are probably secondary in importance to the factors influencing gas retention. Strong flours both tolerate and require more fermentation than do weak flours. The stronger the flour the easier it is to produce bread of uniform quality from day to day, because the dough will stand a wider range in the time of fermentation (10).

METHODS

The studies reported here involve two separate tests, namely, those concerned with baking bread from flour of certain types, and another study concerned with a few of the physical properties of the flour used in the baking tests.

A description of the flours used follows:
Flour A. This was an 80 per cent flour milled from a mixture of 30 per cent Turkey Red winter wheat and 70 per cent Marquis spring wheat from the 1928 and 1929 crops. This flour was Agene Novadel bleached and before shipping was stored in a concrete warehouse, which is well elevated and dry. The wheat had been aged 8 months before milling.

Flour B. This was a 95 per cent flour milled from the 1929 crop of wheat October 1, 1929. The milling mixture was 30 per cent Turkey Red winter wheat and 70 per cent Marquis spring wheat. This flour was Agene Novadel bleached, packed in cotton bags, and stored in a well elevated, dry concrete warehouse. The wheat had been aged one year before milling.
Flour C. This was described by the miller as a high patent flour milled entirely from Marquis spring wheat. It was milled from the 1929 crop of wheat about November 1, 1929, and stored in the laboratory on November 18, 1929. The initial moisture content when milled was secured from the mills and averaged about
The wheat used in a part of this flour had been aged 11 months before milling, and the remainder 4 months. Flour A was milled from a lower protein wheat than Flour B. Flour B was a baker's special, whereas A was principally a domestic flour.

**BAKING TESTS**

_Equipment._ The equipment used consisted of: Tin flour pans 9" x 4" x 2 ½" with covers; calibrated expansion tubes 4 ½" x 9" deep; heavy tin baking pans 6" x 2" at the bottom, 7" x 3 ½" at the top, and 5 ½" deep; and an electric mixer regulated with three speeds for mixing the dough. A well insulated electric baking oven was used (Fig. 1).

The proofing cabinet for the fermentation of the dough was electrically heated and was devised so that steam might be introduced during the fermentation period (Fig. 2.)

The color, volume, texture, and character of the bread produced from the fresh and stored flours were determined by baking tests made every four months from three kinds of Wyoming flour stored for varying periods of time. The following formula for bread was used (11):

<table>
<thead>
<tr>
<th></th>
<th>Weight</th>
<th>Approximate Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flour</td>
<td>340 gms.</td>
<td>3 cups</td>
</tr>
<tr>
<td>Fat</td>
<td>9 gms.</td>
<td>2 teaspoons</td>
</tr>
<tr>
<td>Sugar</td>
<td>11 gms.</td>
<td>2 ½ teaspoons</td>
</tr>
<tr>
<td>Salt</td>
<td>5 gms.</td>
<td>1 teaspoon</td>
</tr>
<tr>
<td>*Water</td>
<td></td>
<td>½ to 1 cup</td>
</tr>
<tr>
<td>Compressed yeast</td>
<td>7 gms.</td>
<td>½ cake</td>
</tr>
</tbody>
</table>

Absorption tests were determined by the method advocated by the American Association of Cereal Chemists (12). Twenty-five grams of flour were placed in an evaporating dish and water added from a burette until the dough began to get sticky when pressed lightly in the hand or perpendicularly against the side of the dish. Four times the number of cubic centimeters of water used gave the per cent of absorption. This measurement is to some extent dependent upon the personal judgment of the individual operator,

*According to absorption tests, varied with time and method of storage.
but has been considered accurate to within about 1 per cent by other investigators (13). More accurate mechanical methods for determining water absorption of flour are being developed at present at Kansas State College (14). If the absorption averaged 66 per cent, the amount of water needed to produce a dough of the proper consistency from 340 grams of flour would equal 224.4 cubic centimeters.

In the case of flours which had been stored in sacks for some time and left exposed in a room of low humidity, it was frequently necessary to add more water than the absorption test called for. However, the absorption tests usually indicated a proportion of water sufficient to make a dough of the right consistency, especially from the flour stored in metal cans.

**Mixing and Baking Procedure (11).** Salt, sugar, and fat were weighed and placed in a bowl. Yeast was dissolved in the required amount of water, which had been heated to 90° F. or 32° C., and was added to the above mixture in the mechanical mixer and mixed at low speed for ten minutes. The dough was then kneaded slightly by hand until it appeared smooth and silky, after which it was placed in a warmed and oiled expansion tube. The tubes of dough were placed in a proofing cabinet warmed to 83° F. or 28° C. Steam was introduced into the cabinet until the relative humidity of the cabinet averaged around 75 to 80 per cent. The dough was allowed to rise from 1,800 to 2,000 cc. in the expansion tubes of given diameter. It was then removed, kneaded lightly five or six times to expel most of the gas, and returned to the proofing cabinet for a second rising. The second punch followed the first in about 90 to 100 minutes, or when the dough had risen from 1,400 to 1,600 cc. It was then kneaded slightly, panned, and placed in the proofing cabinet at 95° F. or 35° C. and proofed until it had acquired two and one-half times its bulk, or until an indentation with the finger did not “spring back” but remained in the dough. The bread was baked in an oven at 410-425° F. for 35 minutes.

**Fermentation.** That Wyoming hard wheat flour has excellent strength is made evident by the fermentation tolerance of the dough. The best results were obtained when a long fermentation period was given the dough. The dough was allowed to rise until
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It had expanded to four times the original bulk for the first fermentation period, and three times the original bulk for the second fermentation period. The expansion of the dough, as measured in a calibrated expansion tube, was from 1,800 to 2,000 cc. for the first fermentation and from 1,500 to 1,600 cc. for the second, although the usual method is to let the dough rise until doubled in bulk.

A variable range in fermentation time was secured in the bread making tests reported in this bulletin in spite of precautions taken in closely following a standardized procedure for the method of mixing, the temperature of the ingredients, and the humidity of the proofing cabinet.

It appears from these tests that the chief variables bringing about differences in the fermentation time for the rising of the dough are the quality of the yeast and the handling of the dough. The yeast used was not always of uniform strength and its freshness was also a variable factor, since it was necessarily obtained from local grocery stores at each baking. There were but minor differences in the time required for the fermentation of the dough of old and new flours of different brands when baked on the same day, if the absorption of the flour was between ordinary limits. The time the dough was allowed to rise was gauged by the amount of gas produced. The Wyoming hard wheat flour stood a rather variable range in fermentation time and still produced bread of a good quality, if a sufficient amount of carbon dioxide gas had been produced before punching down the dough. An average of 150 minutes was required to allow the dough to rise to four times its bulk, the proper stage for the first fermentation period.

The second fermentation period, when the dough was allowed to treble its bulk, averaged approximately 100 minutes. The time for pan proofing averaged from 90 to 95 minutes.

An example of the average time schedule for the straight dough method, using 340 grams of Wyoming hard wheat flour and 7 grams of yeast, was as follows: Time mixed, 8:30 a. m.; ready for first punch, 11:00 a. m.; ready for second punch, 12:40 p. m.; placed in the pan, 12:45 p. m.; and ready for the oven, 2:15 p. m. The bread was removed from the oven at 2:50 p. m. Total time, 6 hours, 20 minutes.
In general the total time required for the fermentation, proofing, and baking of the bread, using the straight dough method, ranged from 5 hours to 7 hours for the patent flours of highest grade, with an average of 6 hours. It was noted in using the better grades of hard wheat flour that a longer fermentation period produced bread of the best quality.

The lower grades of flour took slightly less time for the total fermentation period, averaging 5 hours. Shorter fermentation periods produced the best bread when using the lower grades of hard wheat flour.

Scoring of Loaves. The difficulty of recording the characteristics of a loaf of bread by objective measurements is recognized. Volume was measured by seed displacement. In this experiment, other properties, such as texture and grain, have been scored on the basis of observations involving the flavor, feel, and appearance of the crumb.

The following standard score card was used as a basis of comparison in these tests:

<table>
<thead>
<tr>
<th>EXTERNAL APPEARANCE</th>
<th>INTERNAL APPEARANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Symmetry of loaf</td>
<td>Grain</td>
</tr>
<tr>
<td>Volume</td>
<td>Crumb</td>
</tr>
<tr>
<td>Color of crust</td>
<td>Flavor</td>
</tr>
<tr>
<td>Form</td>
<td>Taste</td>
</tr>
<tr>
<td>Even bake</td>
<td>Texture</td>
</tr>
<tr>
<td>Character of crust</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>Total</td>
</tr>
<tr>
<td>30</td>
<td>70</td>
</tr>
</tbody>
</table>

Humidity Control Before Baking. The problem of preventing the drying and crusting of the surface of the exposed dough during the fermentation and proofing period proved to be a difficult one, due to the low moisture content of the Wyoming atmosphere, which was lessened still more in the heated laboratory during the winter months. The laboratory in which the tests were made averaged but 27 per cent in relative humidity throughout the entire year, with an average of 18 per cent during the winter months. If the dough was left exposed to this atmosphere, hard, dry sur-
faces quickly formed on the top, resulting in hard lumps and streaks when kneaded. Frequently shell tops resulted while baking the loaf, owing to rapid browning and a separation of this crust layer from the more compact grained cells just below the crust. There was also a tendency, when crusting occurred before baking, for ragged breaks to appear on the sides of the loaf. This was probably due to the too rapid hardening and browning of the crusts, which did not allow for the expansion of gases and resulted in a breaking at the sides of the loaf (11). The breaks were preventable if the dough was allowed to rise in a proofing cabinet into which sufficient moisture had been introduced to raise the relative humidity from 75 to 85 per cent.*

RESULTS OF EXPERIMENTS

In the first part of this study the data show the results of baking tests made with three brands of Wyoming flour stored by two different methods through a storage period varying from 1 month to 48 months. The age of the wheat before milling ranged from 3 months to 1 year. Flour A and Flour B were milled from a combination of Turkey Red winter wheat and Marquis spring wheat. Flour C was milled from Marquis spring wheat.

The purpose of the other part of the study was to note changes which occur in the weight and moisture content of flour stored in a steam heated laboratory of high temperature and low relative humidity. Three-pound lots of flour were weighed from the newly milled flour of the 1929 crop of Wyoming wheat and placed in cotton bags. These bags were stored in a cabinet for a period of twelve months. The flour was weighed once each week. The temperature of the cabinet was recorded each week. The relative humidity of the cabinet was also measured by the use of a wet and dry bulb and recorded weekly. The moisture content of the flour was ascertained by means of the air oven method, as described by the American Association of Cereal Chemists (12).

BAKING TESTS

Baking tests are generally regarded as the best measure of the quality of bread flours. With all of their practical difficulties the experimental baking tests may furnish valuable information with regard to the strength and many other properties of flour, which together constitute baking quality, thereby making it possible to foretell what will happen when the flour tested is used for bread making on a larger scale.

General Effect of Two Storage Methods. A quantity of each of the three types of flour was stored (1) in cans tightly closed and (2) in cotton bags exposed to room atmosphere. The quality of the bread was measured by the loaf scoring method.

Flour A. The 80 per cent patent flour previously described was made from wheat which had been aged 8 months before milling.

In cans the optimum period for storage was 1 to 24 months, during which period the bread scores ranged from 92 to 89. A gradual deterioration occurred after this period, but no insect infestation was noted at any time during a total period of 48 months.

In bags the optimum period of storage was from 1 to 19 months, during which the score of the bread ranged from 89 to 90. After 19 months, deterioration was gradual but constant. Some insect infestation was observed in a part of this sack-stored flour at the end of 9 to 12 months. The infested flour was discarded.

Flour B. The 95 per cent patent flour previously described was made from wheat which had been aged one year before milling.

In cans the optimum period of storage ranged from 2 to 8 months, during which the bread scores ranged from 90 to 94. No insect infestation occurred in cans.

In sacks the optimum storage period was 1 to 8 months. Insect infestation was observed.

Flour C. This high grade patent flour was made partly from wheat aged 11 months before milling, and the remainder 4 months. This difference in aging of the wheat prior to milling apparently had little effect on the quality of the bread.
In cans the optimum period of storage ranged from 2 to 24 months. Deterioration in the quality of the bread was noted after this period. Deterioration of the quality of the bread was definitely noted after it had been stored 28 months.

In sacks the optimum period of storage ranged from 1 to 18 months, after which deterioration was very rapid. Insect infestation also occurred.

Additional tests were made from the flour milled in 1930 and 1931. There were changes in the wheat specifications for Flour A and Flour B for these two years. Good ratings were secured for both flours over a period of storage of 6 and 16 months when the experiment closed.

TABLE I
Rating and Average Factors Affecting Baking Qualities of Three Brands of Flour Used at Varying Ages.

<table>
<thead>
<tr>
<th>Brand of Flour</th>
<th>Absorption (per cent)</th>
<th>Weight of Loaf (grams)</th>
<th>Volume of Loaf (cubic centimeters)</th>
<th>Texture Score (Basis of 15)</th>
<th>Baking Value (Basis of 100)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age of Flour when Racked (Months)</td>
<td>In cans</td>
<td>In sacks</td>
<td>In cans</td>
<td>In sacks</td>
<td>In cans</td>
</tr>
<tr>
<td>A (80% Flour)</td>
<td>1-3</td>
<td>66</td>
<td>67</td>
<td>473</td>
<td>470.5</td>
</tr>
<tr>
<td></td>
<td>5-9</td>
<td>67</td>
<td>74</td>
<td>488</td>
<td>484</td>
</tr>
<tr>
<td></td>
<td>11-20</td>
<td>67</td>
<td>74</td>
<td>488</td>
<td>501</td>
</tr>
<tr>
<td></td>
<td>22-28</td>
<td>67</td>
<td>78</td>
<td>501</td>
<td>494</td>
</tr>
<tr>
<td></td>
<td>32-40</td>
<td>67</td>
<td>81</td>
<td>481</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>42-48</td>
<td>70</td>
<td>...</td>
<td>467</td>
<td>...</td>
</tr>
<tr>
<td>B (95% Flour)</td>
<td>1-3</td>
<td>65</td>
<td>67</td>
<td>495</td>
<td>487</td>
</tr>
<tr>
<td></td>
<td>5-9</td>
<td>68</td>
<td>72</td>
<td>479</td>
<td>478</td>
</tr>
<tr>
<td></td>
<td>10-20</td>
<td>70</td>
<td>75</td>
<td>487</td>
<td>481</td>
</tr>
<tr>
<td></td>
<td>22-28</td>
<td>70</td>
<td>77</td>
<td>493</td>
<td>506</td>
</tr>
<tr>
<td></td>
<td>32-40</td>
<td>70</td>
<td>...</td>
<td>489</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>42-48</td>
<td>72</td>
<td>...</td>
<td>484</td>
<td>...</td>
</tr>
<tr>
<td>C (Patent)</td>
<td>1-3</td>
<td>69</td>
<td>67</td>
<td>500</td>
<td>471</td>
</tr>
<tr>
<td></td>
<td>5-9</td>
<td>70</td>
<td>71</td>
<td>486</td>
<td>517</td>
</tr>
<tr>
<td></td>
<td>12-21</td>
<td>70</td>
<td>75</td>
<td>498</td>
<td>501</td>
</tr>
<tr>
<td></td>
<td>22-28</td>
<td>74</td>
<td>...</td>
<td>485</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>32-42</td>
<td>76</td>
<td>...</td>
<td>496</td>
<td>...</td>
</tr>
</tbody>
</table>

Table I shows the results more in detail. The changes in the quality of the bread and the absorption of the flour are shown graphically in Figure 5. It will be noted that in all cases a definite deterioration took place after two or more years of storage. In 4 out of 6 cases this deterioration was associated with a definite rise in the water absorption power. However, in the case of Flour A
and Flour B stored in cans there was very little change in absorption at the point where the marked fall in quality came.

The extreme aridity of the laboratory from November until March, when the relative humidity ranged from 10 to 30 per cent, resulted in a 50 per cent decrease in the moisture content of the flour which had been stored in cotton bags. The flour reabsorbed moisture when the average relative humidity of the room increased from 25 per cent to 60 per cent during the period from April to September, the percentage increasing from 6 per cent to 10 per cent. Apparently the fluctuations in the moisture content of the flour had very little effect upon the quality of the bread during the first year the flour was stored, provided correct proportions of liquid were used in mixing the dough. The increases in the amount of liquid needed were often surprisingly large, however.

In the Kansas experiment already mentioned in the section on History and Literature (4) the score of the bread made from flour stored in sacks and sealed jars in both heated and unheated rooms was about the same. The ratings of the bread made from flour stored under these varied conditions were about the same. The loss of moisture averaged the least (1 per cent) in the sealed jars. The greatest improvement was noted after the first month of storage. It should be noted, however, that the Kansas experiment was continued for one year only, whereas the changes in the tests now being reported were most evident during the second year of storage when deterioration was most rapid for the flour which had been stored in sacks.

Quality of Bread. The improvement in the quality of the bread made from flour aged for several months was evident in a softer and more velvety texture of the crumb, as well as in a more symmetrical shape of the loaf (Figs. 3 and 4 and cover illustration).

As the storage period extended into the second year, the texture, color, and general quality of the loaf were higher when made from flour which had been stored in the containers, as compared with flour stored in the muslin bags.

Loss in the quality of the flour which had been stored too long was shown by the loss of the sweet, nutty aroma and flavor evident
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Figure 3. Bread made from 95 per cent flour aged 6 months (No. 1), 16 months (No. 2), and 48 months (No. 3). The differences in volume, the symmetrical shape noted in No. 2, and the close, compact texture of No. 3 are characteristic of this flour when aged.

Figure 4. Bread made from 80 per cent Wyoming flour aged 6 months (No. 4), 16 months (No. 5), and 48 months (No. 6). The differences indicated in Figure 3 are also characteristic of this brand of flour when aged.
in bread made from the newer flour, and also in a compact, moist, gummy texture of the crumb. A breaking at the top of the loaf was often evident in bread made from the old flour and occurred either in pan proofing or in baking (Figs. 3 and 4). It will be noted from the illustrations that the ragged breaks did not occur in loaves made from the newer flour.

The flour stored in metal containers for 48 months still produced edible bread, although very evident deterioration had occurred (Figs. 3 and 4).

**Loaf Volume.** The loaf volume must be judged in connection with absorption, maximum volume of dough, rise in the oven, and texture of the loaf.

The volume of the bread made from the flour in these tests averaged around 2,100 cubic centimeters, which is well above the standard volume of 1,800 cubic centimeters for a one-pound loaf of bread.

It was possible to obtain a loaf of larger volume as a result of over-proofing. The large volume was then obtained at a sacrifice of other desirable qualities. Large loaf volume, when associated with a good texture, is a desirable quality. Texture and loaf volume are closely associated in that one may be improved at the expense of the other.

There was not a constant relation between the volume of the loaves and the length of the storage period, but in general the volume was reduced when the flour had been stored long enough for deterioration to begin. The deterioration was evident especially in a smaller response to oven-spring while baking. The lack of oven-spring was observed by watching the baking process in an oven with glass doors, as well as by measuring the volume of the baked loaf by seed displacement. The loaves having the best oven-spring indicate a stronger, stiffer gluten. The decrease of oven-spring may indicate some deterioration in gluten quality in the old flour.

In spite of precautions taken to eliminate variables, some discrepancies in loaf volume were evident in duplicate loaves of bread baked from the same brand of flour under the same standard procedure.
ABSORPTION TESTS

Table I shows the changes in the water absorbing capacity of the flour during storage. It was found that an excessive amount of liquid was needed for the flour which had been stored in sacks. It was found necessary to increase the amount of water 6 to 10 per cent to make a dough of the right consistency during the storage period of the first 12 months. The absorption rate increased from 10 to 18 per cent for the different brands of flour stored in sacks during the second year of storage. In contrast, the absorption of duplicates of these samples stored in tightly closed cans increased only 0 to 2 per cent after a storage period ranging from 1 to 21 months and 6 to 10 per cent after a storage period of 48 months. The 10 per cent increase was evident in but one brand of flour, which had been stored in smaller quantities and in a can made of thinner metal than the others. It would, therefore, seem that the increased absorption rate for the flour stored in sacks can be attributed to some extent to the excessive drying out of the flour. A modification of the gluten seems to have occurred in flour stored by both methods, but more rapidly in the flour stored in sacks.

As previously pointed out, there appears to be a relationship existing between the quality of the bread and this great increase in water absorption. When it was necessary to use such excessive amounts of water in order to make a dough of the proper consistency, there was then a decided lowering in the quality of the loaf of bread (Fig. 5). When the absorption rate took a decided upward trend, the quality of the bread took a decided downward trend. The low quality was due in a large part to the close, compact texture and moist, sticky feeling of the bread. These qualities were especially evident in the old flour to which it had been necessary to add such excessive amounts of water. The close, compact texture will be noted in Figures 3 and 4. That deterioration after long periods of storage does take place without any marked change in absorption is evident from the cases of Flour A and Flour B, which had been stored in cans. (See Fig. 5.)

Other investigators of this problem have shown that the proportion of water used affects the tenacity and extensibility of the gluten, and hence the resulting dough. An increase of water be-
Beyond the optimum amount decreases the extensibility of the dough, the gluten becomes more tender and less tenacious, and evidently some of the walls collapse and coalesce, thus giving a smaller volume to the loaf. Bailey observed this increase of absorption and was of the opinion that it cannot be attributed to a simple drying
out of the flour. He believed that some modification of the colloidal condition of the gluten must have occurred with the lapse of time, which brought about this increased absorbing quality of the flour (6). However, the tests reported here were not conducted in a way to give specific information about the nature of the change.

In Saunders' work on the storage of flour an enormous absorption increase was evident over a storage period of 14 years. However, there was only about 1 per cent increase in absorption each year which could not be accounted for by the drying out of the flour (6, 2).

The optimum amount of water used with the flour being studied varied with the brand and the time and condition of storage, but for flour that had been stored not longer than a few months 66 to 70 per cent of water seemed to give the best loaf and texture.

This is in line with numerous tests by other workers, showing that the hard spring wheats grown in the Northwest have excellent gluten strength and produce the strongest flours (6).

The storage of both pastry and bread flour in tightly closed containers to prevent drying out seems to be the best method in arid regions or in steam heated rooms where the relative humidity is extremely low. It also appears from these tests that recipes which are the result of careful experimentation may be more accurately followed for the proportion of liquid to flour when the flour has been stored so as to prevent undue loss of moisture.

As the flour lost moisture it gained in weight per given volume and vice versa. This would indicate a physical change in the size of the flour particles. The loss in moisture and change in weight both adversely affect the ratio of flour to liquid; consequently there is a resulting error in proportions in that an increased amount of dried-out flour is used when measured by volume (15). A surplus of flour results in a dry, hard product. This is consistent with the findings of housewives in arid regions, who have found through trial and error procedure that it is usually necessary to add slightly larger amounts of liquid than recipes call for when volume measurements are indicated. In this connection it is suggested that milling companies can assist their customers in arid areas by mak-
ing modifications in their recipes to care for changes in relative humidity.

*Weight of Bread Related to Absorption.* It will be noted from Table I that there is a fairly well defined relationship existing between the weight of the loaf of bread produced and the water absorption of the flour.

From a commercial standpoint the percentage of absorption is very important, for other things being equal the more water that can be worked into a given amount of flour, the greater the weight of the bread. To the baker the bread yield or number of pound loaves produced per barrel of flour is an important measure of flour quality. The extent of the water loss during baking is dependent upon the quality of the gluten. A loaf containing gluten of good quality absorbs and holds the added water against the heat of the oven. Consequently, the weight is greater.

The yield from a 48-pound sack for Flour A averaged 68 one-pound loaves, and for Flour C 70 one-pound loaves. The usual yield is 64 pound loaves for this amount of flour.

**Table II**  
The Weight and Moisture of Flour in Small Cotton Sacks in Relation to Temperature and Relative Humidity.

<table>
<thead>
<tr>
<th>Date Tested</th>
<th>Temperature of Room</th>
<th>Relative Humidity of Room</th>
<th>Weight of Sample (grams)</th>
<th>Moisture Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>Nov. 14</td>
<td>80.6</td>
<td>22</td>
<td>85</td>
<td>1,361.0</td>
</tr>
<tr>
<td>Dec. 10</td>
<td>85.0</td>
<td>18.5</td>
<td>48</td>
<td>1,310.7</td>
</tr>
<tr>
<td>Jan. 12</td>
<td>80.6</td>
<td>13</td>
<td>44</td>
<td>1,298.0</td>
</tr>
<tr>
<td>Febr. 12</td>
<td>79.0</td>
<td>30</td>
<td>95</td>
<td>1,292.5</td>
</tr>
<tr>
<td>March 23</td>
<td>78.0</td>
<td>17</td>
<td>85</td>
<td>1,289.3</td>
</tr>
<tr>
<td>April 22</td>
<td>78.0</td>
<td>17</td>
<td>50</td>
<td>1,302.5</td>
</tr>
<tr>
<td>May 21</td>
<td>76.0</td>
<td>25</td>
<td>34</td>
<td>1,313.3</td>
</tr>
<tr>
<td>Jun 19</td>
<td>74.0</td>
<td>46</td>
<td>78</td>
<td>1,316.5</td>
</tr>
<tr>
<td>July 15</td>
<td>78.0</td>
<td>31</td>
<td>47</td>
<td>1,320.5</td>
</tr>
<tr>
<td>Aug. 15</td>
<td>70.0</td>
<td>39</td>
<td>80</td>
<td>1,334.0</td>
</tr>
<tr>
<td>Sept. 15</td>
<td>73.0</td>
<td>34</td>
<td>42</td>
<td>1,352.0</td>
</tr>
<tr>
<td>Oct. 17</td>
<td>76.0</td>
<td>20</td>
<td>72</td>
<td>1,311.3</td>
</tr>
<tr>
<td>Nov. 14</td>
<td>80.0</td>
<td>15</td>
<td>44</td>
<td>1,294.2</td>
</tr>
<tr>
<td>Dec. 13</td>
<td>84.0</td>
<td>18</td>
<td>69</td>
<td>1,276.0</td>
</tr>
</tbody>
</table>
EFFECT OF RELATIVE HUMIDITY ON MOISTURE IN FLOUR

A record was kept of the weight and moisture content of the 3-pound samples (1,361 grams) stored in the sacks. A summary is shown in Table II. The weight of the samples decreased rapidly when the flour was first put in the dry laboratory. However, during the summer period when the relative humidity of the room increased, due to the absence of artificial heat, the flour again regained weight. Flour C showed the greatest and most rapid loss of weight of the three varieties tested. There was a loss of 7.2 per cent in 2½ months during the first part of storage. Flour B lost 4.9 per cent and Flour A 5.3 per cent during the same period. The weight never remained exactly constant.

The determination of the moisture content of the flour from time to time made it clear that the variations in weight were due to fluctuations in moisture content, which followed the changes in the relative humidity of the room more or less closely.

The initial moisture content for Flour A was 13.5 per cent and for Flour B 13.4 per cent, as given to the writer by the manufacturers. After the samples had been stored in the laboratory for five months the moisture content for Flour A was 6.4 per cent, for Flour B 6.3 per cent, and for Flour C 6.3 per cent. Thus the moisture content of the flour decreased one-half during this period of storage. During this time the moisture content of the room was exceedingly low, ranging from 10 to 15 per cent. An ordinary kitchen in arid regions would probably average somewhat higher in relative humidity, due to the steam from cooking. During the summer period, when the relative humidity rose and fluctuated in a range from 28 to 60 per cent, moisture was reabsorbed. On September 12 the moisture content for Flour A was 10.9 per cent, for Flour B 11.6 per cent, and for Flour C 11.6 per cent.

When the laboratory was again heated and took on the low relative humidity of winter, there was another loss of moisture in the flour. On December 13 the moisture content of Flour A was 7.4 per cent, of Flour B 7.5 per cent, and of Flour C 7.4 per cent. During October, November, and the first part of December the relative humidity of the laboratory had ranged from 10 to 40 per cent.
A study of the fluctuations showed that when the relative humidity of the laboratory ranged from 15 to 20 per cent the percentage of moisture in the flour settled to about 6.5 per cent; when the relative humidity ranged from 25 to 30 per cent the moisture of the flour became fairly constant at about 8.6 per cent; and when the relative humidity of the room ranged from 45 to 60 per cent the percentage of moisture in the flour rose to 10.6 per cent and remained fairly constant.

The changes in moisture content were gradual, with no abrupt changes from week to week. Practically all the variations in weight can be accounted for by variations in moisture content. The flour in the sacks never remained constant in weight or moisture content for more than a few weeks at a time, but showed a constant variation as the relative humidity of the room varied, indicating that flour is constantly establishing a moisture equilibrium with the atmosphere in which it is stored.* As has already been said, the changes in moisture content had a decided effect upon the absorption of the flour.

*It should be noted that comparatively small samples of flour were involved. The moisture content of flour stored in full-sized sacks or bins would be expected to change even more gradually than that of the samples studied. (See Regain of Unwashed Wool, Wyo. Expt. Sta. Bul. 132, 1929.)
Figure 6 shows the fluctuations of weight and relative humidity both indoors and out.

No record was made of the changes of weight and moisture content of the flour stored in cans. It may be inferred from the changes in absorption capacity that the moisture content fluctuated less in this method of storage.

**SUMMARY AND CONCLUSIONS**

1. Wyoming hard wheat flour stored in a warm, dry place was improved by aging 1 to 3 months and then showed little change for 2 years or more. After that, deterioration set in and increased in rapidity toward the end of the 48 months' storage. Variation in the length of time the wheat was aged had no measurable effect on the behavior of the flour in storage.

2. When deterioration in flour occurred it was characterized by the moist, gummy texture of the loaf, small volume of loaf, and by the loss of the sweet, nutty aroma and flavor evident in bread made from newer flour.

3. The moisture content of the flour stored in sacks increased or decreased, depending upon the relative humidity of the atmosphere to which it was exposed. The absorption test indicated that flour stored in containers which were practically air-tight showed very little moisture fluctuation and the loss of moisture was very slow.

4. The water-absorbing power of the flour tested increased with its age, due in a large part to a loss of moisture from the flour itself under the conditions of storage. Consequently, the water-absorbing power increased most rapidly and fluctuated most in the flour that was stored in sacks.

5. A modification in the condition of the gluten evidently occurred in the old flour with the lapse of time. This was hastened by the drying out of the flour.

6. The results of these experiments show that flour which is to be stored for considerable periods in warm, dry rooms, such as are common in the steam-heated houses of Wyoming, should be placed in containers which are air-tight or practically so.
BIBLIOGRAPHY


APPENDIX

DIRECTIONS FOR HOUSEHOLD PRACTICE
IN HOME BAKING

Recipe for Short-Process or Straight-Dough Bread (11):

- 9 cups flour,
- 3 cups liquid (approximately),
- 2 tbsp. fat,
- $2\frac{1}{2}$ tbsp. sugar,
- 3 tsp. salt,
- $1\frac{1}{2}$ cakes compressed yeast.

This recipe is sufficient for 3 one-pound loaves of bread.

Mixing. Heat the liquid until lukewarm ($90^\circ$ F. or $32^\circ$ C.) and add to a mixture of the salt, sugar, and fat. Reserve one-half cup of the liquid for softening the yeast. Add the dissolved yeast to the above mixture. The flour should be added gradually, since the amount needed varies with the absorptive qualities of the flour. Reserve one-half cup of flour for the bread board. The experienced breadmaker tells by the “feel” of the dough when sufficient flour has been added. With hard wheat flour the dough should be of medium stiffness.

Kneading and First Rising of Dough. The first mixing and kneading, when gluten is developed, should be thorough. The dough is turned out on a clean floured board and kneaded with the palms of the hands until the dough feels soft and pliable. It is then rounded, greased lightly, and placed in an oiled bowl to rise until it is four times its original bulk.

Punching Down. This kneading is done with light pressure and is not continued for too long a period. Only a thin dusting of flour is used on the board, or the first kneading may be done without removing the dough from the bowl by punching in the center, pulling the sides over and pressing into the center, then turning the ball of dough with the smooth side up and greasing lightly. The dough is returned to a warm, moist place for the second rising.
Second Rising, Molding of Loaves, and Panning. The dough is allowed to treble in bulk, and is then removed from the bowl, divided, and molded into loaves. Treatment is also light at this time to prevent the reuniting of the thin gluten strands, which results in coarseness. No flour is needed on the board, since the gluten has now developed to the extent that the dough will not stick. Inexperienced bread makers usually add too much flour in kneading. If added at this stage it may produce streaks in the bread.

To mold the loaves flatten the dough on the board, fold from the outer edges toward the center, and press together tightly. Repeat, folding from the opposite sides. Then roll the dough quickly into a smooth loaf. Place the loaves preferably in individual tins for baking, and let rise until two and one-half times its bulk. A good test for sufficient rising of the loaf is made by touching the dough lightly with the fingers. If it has risen enough, a slight depression remains, while if the indentation disappears quickly it should rise a little longer.

Bake the loaves in a hot oven (410° F. to 425° F.) for 35 minutes. Remove from the pan and let cool on a wire rack before storing.

The use of milk and a slightly larger proportion of fat than the recipe specifies is to be recommended when the bread is to be kept for several days, to prevent a crumbly texture and rapid stalting.

Recipe for Long-Process or Sponge Bread (16).

2½ tbsp. sugar,
2 tbsp. fat,
4 tsp. salt,
1 cake yeast foam,
2 cups potato water,
½ cup mashed potatoes,
2-2½ cups water (dependent upon the absorption of the flour),
12 cups sifted flour.

Cut three medium-sized potatoes into small pieces and cook until tender. Pour off the water and let cool until lukewarm.
Then add the yeast, sugar, and one-half cup of mashed potatoes to the desired amount of potato water.

This ferment or starter should be set at noon previous to the day for baking. If kept in a warm place it will be light and frothy the following morning.

Make a sponge by adding to the ferment one cup of water, which has been heated until lukewarm, and a sufficient amount of flour to make a fairly stiff batter. Beat the batter until smooth and let stand until light. Then add the remainder of the water, the melted fat, salt, and flour, and knead until the dough is smooth and elastic. This kneading should be very thorough and will take approximately 40 minutes if kneaded by hand. The dough should be of medium stiffness.

Allow the dough to treble its bulk for the first fermentation period and to double its volume for the second fermentation period. Otherwise proceed in the same manner described in the straight-dough process in handling the dough and baking the loaves. This recipe yields approximately 4 one-pound loaves of bread.

*Prevention of Crust Formation on Dough.* Precautions must be observed in arid sections to prevent crusting of the top surface of the dough during the fermentation periods. If a warm, moist place is not available for the rising of the dough the bowl of dough may be placed in a pan of warm water and covered with a clean, moist towel, so supported that it is not in direct contact with the dough.
The following publications of the Wyoming Experiment Station may be had upon request: (Revised list, May, 1933.)

No.  CIRCULAR—
17.  Feeding Yearling Steers.
18.  Abortion Disease in Wyoming.

No.  BULLETINS—
92.  The Value of Fiber Testing Machines for Measuring the Strength and Elasticity of Wool.
101.  Zygadenine, the Crystalline Alkaloid of Zygadenus intermedius.
110.  Sweet Clover.
113.  The Effect of Alkali upon Portland Cement.
116.  Winter Grains.
134.  Wintering Range Calves.
139.  Chemical Examination of Three Delphiniums.
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182.  Grain Mixtures Supplementary to Wyoming Native Hay for Milk Production.
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185.  Barley Tests at the Sheridan Field Station.
188.  Studies with Hampshire Sheep No. II.
189.  Two Poisonous Vetches.
190.  Drifting of Honeybees.
193.  Arrow Grass—Chemical and Physiological Considerations.
194.  Three Species of Zygadenus (Death Camas).
195.  Grasses, Alfalfa, and Sweet Clover at the Archer Field Station.
196.  Wool Inheritance in Hampshire-Rambouillet Crossbreds.


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