Chemical and physical characteristics of barley flour as related to its use in baked products
by Elnor Vermeer Niffenegger

A thesis submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of
MASTER OF SCIENCE in Home Economics
Montana State University
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Abstract:
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Economics Department of Montana State College. A comparison of the physical and chemical
characteristics and the baking quality of barley flours, wheat flours and mixtures of barley and wheat
flour was made.

The starch and proteins of barley and wheat flour behave differently. The starch of barley flour has less
thickening capacity and less water absorption than wheat. The protein has less gluten-like strength.
Baked products which are dependent on gluten-like strength are made less successfully from barley
flour than from wheat flour. Appearance and flavor are usually affected by the addition of barley flour.
Methods using little manipulation are more successful with barley than those which require extensive
mixing.
CHEMICAL AND PHYSICAL CHARACTERISTICS OF BARLEY FLOUR
AS RELATED TO ITS USE IN BAKED PRODUCTS

by

ELNOR VERMEER NIFFENEGGER

A thesis submitted to the Graduate Faculty in partial
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of
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in
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Approved:

Head, Major Department

Chairman, Examining Committee

Dean, Graduate Division

MONTANA STATE COLLEGE
Bozeman, Montana
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ABSTRACT

A study of the possibilities of using barley flour as a substitute for wheat flour was made in the Home Economics Department of Montana State College. A comparison of the physical and chemical characteristics and the baking quality of barley flours, wheat flours and mixtures of barley and wheat flour was made.

The starch and proteins of barley and wheat flour behave differently. The starch of barley flour has less thickening capacity and less water absorption than wheat. The protein has less gluten-like strength. Baked products which are dependent on gluten-like strength are made less successfully from barley flour than from wheat flour. Appearance and flavor are usually affected by the addition of barley flour. Methods using little manipulation are more successful with barley than those which require extensive mixing.
INTRODUCTION AND LITERATURE REVIEW

The climate and soil composition of Montana are well suited to the raising of barley. Barley grows well where the soil is not too sandy and is well drained (22). It will also grow well on alkaline soil, because it is the most salt tolerant of the cereals (11). The cool, dry summers of Montana favor barley growth. The best conditions for barley production include average temperatures of 70°F or less, precipitation less than 35 inches and relative humidity less than 50% (11). Some varieties of barley mature earlier than other cereal crops (11). This makes it possible to harvest a mature crop where the growing season is fairly short.

Ever since man has raised cereal grains he has used the crushed or ground seeds of various grains in baked products and in other foods. Barley culture began with the earliest traces of agriculture, and barley was used for making bread, porridge and beer (21). Barley, as a food, is mentioned several times in the Bible. Moses and the Israelites ate barley bread, Ruth gleaned in the barley fields, and Jesus fed the multitud barley loaves. Until the 15th century barley was important in Europe for bread making. In more recent times it has been replaced by wheat and rye, because these cereals have superior baking qualities (16).

Barley was used in bread making in the United States during World War I. At that time wheat was being conserved and other cereals were used in bread making to extend the wheat supply. In Germany (16) and France (15) barley flour was used during World War I and in the years following World War II for much the same reason as it had been used in the United States.

Barley was brought to this country from England when the American colonies were first settled. It was introduced on the west coast when
California was settled. Gradually barley production moved inland from both the east and west and eventually the North Central Region became the most important barley producing area (21). In 1963 North Dakota, Montana and California led in barley production in the United States.

Barley ranks fourth in importance of the cereal crops in the United States (11). Over half the barley produced is used for animal feed, and it compares favorably with corn in animal weight gain. Therefore, the nutritive value appears similar (22). Barley is a favorable substitute for corn in cattle feeding, because barley grows under conditions which do not favor corn production. Barley is also used for malt, and a small amount is used for human food. Of the barley products, pot and pearl barley rank first in human consumption. Small quantities are used as barley flour and in baby food (11).

Barley flour possesses some disadvantages which make it less desirable for baked products than wheat. The barley protein, Hordein, is inferior in its ability to form dough. The high ash and raw fiber content, characteristic of barley flour, is due to the high hull portion in the flour. The hull contains tannic acid which gives the flour a bitter taste. Breads made from barley flours are crumbly. They stale quickly and give a smaller loaf volume (16).

Harlan states that barley flour can be mixed up to 20% with wheat flour without detriment to the quality of the loaf of bread. Up to 80% barley flour can be incorporated into bread when baking powder is used. However, addition of barley flour darkens the color of the loaf and alters the flavor somewhat (7).
In a German report prepared by Pelshenke (16), it is reported that breads of acceptable quality can be made if the amount of barley flour is below 30%. The following suggestions, given by Pelshenke, will produce a bread of the best quality when using 30% or less barley flour in bread making:

1. The dough should be as firm as possible.

2. The dough should rise quickly: the faster the rise, the larger the loaf.

3. The risen loaves should be held in a moist atmosphere prior to baking so as to avoid cracking.

4. The barley flour is sensitive to fermentation and the dough must be punched firmly.

5. The oven temperature should be high. It is especially advantageous to have the temperature high in the early part of the baking process.

Sour dough breads made from barley flour are quite satisfactory. A higher proportion of barley flour can be used in a sour dough bread than in a yeast bread (16).

Barley flour compares quite favorably, nutritionally, with wheat flour. Mc Elroy compared the essential amino acids in the two cereals. Lysine is slightly higher in barley than in wheat, 3.2% in barley and 2.2% in wheat. This increase in lysine is important, but barley is still considered a relatively poor source of lysine. Threonine and valine are also slightly higher in barley than in wheat (12).

Davis, et al. (2) compared the two cereals as to the relative value
of some of the B vitamins. The mean scores reported by Davis, et al. for seven barley varieties and five wheat varieties are shown in Table I.

Table I. B vitamin values found in unmalted grain.
(All values are expressed as micrograms per gram dry matter.)

<table>
<thead>
<tr>
<th>Vitamin</th>
<th>Barley</th>
<th>Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thiamin</td>
<td>5.59</td>
<td>5.63</td>
</tr>
<tr>
<td>Riboflavin</td>
<td>1.02</td>
<td>.91</td>
</tr>
<tr>
<td>Niacin</td>
<td>86.3</td>
<td>58.3</td>
</tr>
<tr>
<td>Pantothentic Acid</td>
<td>4.5</td>
<td>7.9</td>
</tr>
</tbody>
</table>

Glick found a higher choline content in barley than in oats, flax or wheat, but not as high as in soybeans (6). From these limited examples it would seem that barley can be substituted for wheat with little change in the nutritive value of the product.

Tests which are ordinarily employed for evaluation of physical and chemical characteristics of wheat flour were not designed with barley flour in mind. It is reasonable to believe that their application in predicting the baking quality of barley flour might be limited. The tests in question are the farinograph, sedimentation test and Kjeldahl determination.

The farinograph, invented in Europe by C. W. Brabender, was introduced into the United States in the 1930's as a visual or graphic comparison of the mixing properties of flour. The farinograph is a viscometer which blends and develops the dough. It measures mixing time, general strength and absorption of water. The farinograph curve indicates two
properties of flour: (1) the absorption or the amount of water required for a dough to reach a definite consistency and (2) a general profile of the mixing behavior of the dough. A flour of higher absorption, longer peak time and longer stability is a stronger, more tolerant flour that requires more mixing time and stands more mechanical abuse (8).

The sedimentation test was developed by Lawrence Zeleney. The principle of this test is that cereal gluten imbibes water and swells in the presence of dilute lactic acid. The amount of swelling varies with the quality of the gluten. The sedimentation value reflects protein content and gluten quality (24).

The value of the sedimentation test is controversial. Zeleney (23) points out that the test was designed to be a simple, rapid method of determining potential baking quality of wheat. Durham (4) supports Zeleney in his report. He states that repeatable results can be obtained in grain grading laboratories without highly trained chemists and elaborate equipment. The ease and simplicity of this test is important because grading can be done locally. Time and money can thus be saved.

Mattern (1) and Schesinger (17) do not agree with Zeleney. They point out that sedimentation values are correlated with loaf volume only in a general way, and they believe that some of the other tests have equal value in determining quality of wheat.

The determination of moisture of flour by drying gives results that are dependent on the details of the method used. This is because fats and water, which are chemically bound in the grain, are driven off at high temperatures. If lower temperatures are used, enzymatic reactions may
occur, and some of the free water is bound in the grain. If standardized procedures are used, the results obtained can be used as a means for comparing the moisture content of grains (1).

The Kjeldahl test is a test for nitrogen. Actual determination of protein is based on the amount of nitrogen in the sample. The amount of nitrogen times a factor of 6.25 gives the amount of crude protein present, because barley protein contains 16% nitrogen.

The practice of paying a higher price for a relatively high protein wheat is related to the fact that baking quality is dependent on a desirable proportion of protein. In wheat, the gluten producing proteins constitute 70 - 80% of the total protein. No information was found as to the amount of gluten-producing protein in barley. Neill says, "Of all the tests for quality, the amount of protein from the Kjeldahl test is still the simplest and best single indicator of wheat and flour quality" (14).

Ash determination is largely a mineral evaluation. Therefore, comparison of ash values is a comparison of the total mineral content. The minerals are concentrated mainly in the bran of cereals. The bran coat accounts for 20 - 25, and the germ 10 - 15, times as much ash as does the endosperm (9). The total mineral content of barley and wheat is very similar (13). The difference in ash of wheat and barley flours can be used as a criteria for the degree of separation of the bran and germ from the endosperm. The total ash of wheat on the average is 1.86%. The maximum limit for ash of wheat flour is set at 1/20th the protein plus .35 (9). No figures of the average or maximum ash of barley flour were found.

Starch accounts for about two thirds of the dry weight of barley. It
is composed of amylose and amylopectin. Starch granules from different sources are of varying sizes and shapes and behave differently when made into pastes (9). Starches which have more amylopectin are more viscous (1). Goering, et al. (5) state that Compana barley contains 19 - 23% amylose. According to Lowe (9), wheat contains 21 - 24% amylose. Consequently, there seems to be little difference in the amylose or amylopectin of the two starches. Lowe (9) does say that starches that have the same proportion of amylose and amylopectin may behave differently because of the variation with the fractions.

The purpose of this investigation was first to study some of the physical and chemical characteristics of barley flour and second to find uses for barley flour in baked products, either as an entire or as a partial substitute for wheat flour. Inquiries are often received from people who are allergic to wheat and who wish to know how to prepare baked products from other cereals. Since barley is an important Montana crop, the finding of new uses for barley flour would be beneficial to the economy of the state. Barley baked products would provide variety in family meals.

Barley flours, milled in Conrad, Montana, were furnished by Dr. Kenneth Goering, Professor of Chemistry, Montana State College. Flours from two different millings were available. They were milled in the spring of 1963 and the winter of 1964. Flour milled in the spring of 1963 was used for the experimental baking because it was known to be from Compana barley, the most widely grown barley variety in Montana. There was some doubt as to the variety of the barley milled in the winter of 1964.

A commercial barley flour, Cell-U brand, was provided by a friend who
purchased it in a health store in Chicago, Illinois. All-purpose wheat flour was used as the standard for comparison. All results reported in this study were obtained using the 1963 Compana barley flour milled in Conrad, unless otherwise stated.

Six hypotheses were formulated to guide the direction of the experimental work:

1. Barley is a Montana product. A new use for barley would be beneficial to the economy of the state.
2. Barley flour products will introduce variety into family meals.
3. Barley flour can be substituted for wheat flour in some baked products.
4. A partial substitution of barley flour for wheat flour can be made in products which are dependent on gluten for strength and structure.
5. Acceptable baked products can be prepared with barley flour for use in wheat-free diets for allergy.
6. Some of the tests used to determine the quality of wheat flour can be used on barley flour.

To test these hypotheses a means was necessary for judging the general acceptability of the prepared food products. According to Lowe (9), the organoleptic panel is the best method as yet available for judging the palatability of a food. This type of panel was used in the present study.

The method of smelling and tasting used by panel members is related to the reliability of the results. The panelist should inhale two to three seconds, with both nostrils open (9). Odors are perceived in the
upper nasal cavity, making it necessary to sniff or inhale, and are best detected when the air is moist and warm. Tasting, slowly, is done after smelling. After one sample has been tasted, tepid water can be taken to aid in the removal of tastes before another sample is evaluated. Tastes may be enhanced or depressed by the presence of other tastes. Flavor is defined as the over-all sensations obtained by odor, taste and touch of the tongue. Acceptance or rejection of the products is based largely on the stimulus of the sense organs. These are classified as sight, odor, taste, and flavor. The sight or appearance of the product may be affected by attractive coloring or discoloration. The shape, size and surface also affect the appearance to the observer (9).

Reliability of the judging of palatability by a taste panel member is dependent on the individuals of the group. Methods are naturally fraught with error, for each person tastes things differently. Precautions must be taken in the selection and indoctrination of the panel member so that the minimum amount of error will enter into the results. Taste panel members should be healthy and cooperative. Lowe lists characteristics of panel members as: Sensitivity, integrity, ability to concentrate, intellectual curiosity and willingness to spend time (9). Usually it is best to use the same panelists throughout the experiment. Lowe states that four is the minimum number of panel members, but she also mentions that there are others who think eight to ten members are better (9). Dawson says three to ten members is usually adequate (3). In this experiment four panel members were used. Three were faculty members in the Home Economics department and one was a senior student in Foods and Nutrition
at Montana State College. All members had had considerable previous experience on taste panels and conscientiously carried out their duties.

The bread, muffins and pastry crust were evaluated for appearance, texture, moistness, flavor and odor. Appearance in this case referred to outside appearance. When compiling the final results of the test, the word, appearance, is used to include the composite scores of outside appearance, the texture and moistness, because it was felt that this would summarize the entire appearance of the product. The flavor and odor values were averaged in the final compilation and called flavor. More accurately, the term, taste, should have been used on the score sheet, for as Lowe states, flavor is the combination of taste and odor (9).

Cookies were evaluated for the same characteristics as the other products with the addition of tenderness. When compiling the scores for cookies, tenderness scores were averaged in with the flavor and odor scores because these characteristics were all discerned by the flavor senses. In addition to evaluation of the characteristics of each product, comments were also sought.

Numerical scores from 0 to 10 were used in evaluating the characteristics of the products in this investigation. In using numerical scores, the number of gradations used is important. The scoring scale should not have an excess, or too few, gradations. The trend at present is to use 9, 10 or 11 gradations (9).

The instruction sheet used in this experiment listed the numerical values to be used and a descriptive term for each value as taken from Lowe (9):
10 perfect (fancy)
9 excellent
8 very good
7 good
6 slightly good
5 average
4 fair
3 borderline
2 bad
1 very bad
0 inedible
PHYSICAL AND CHEMICAL CHARACTERISTICS OF BARLEY FLOUR

Moisture Determinations

Moisture determinations of the barley flours, the all-purpose flour, and mixtures of barley and all-purpose flour were made in the Cereal Quality Laboratory at Montana State College. The percentage of moisture was determined by dividing the difference in flour weight after drying and flour weight before drying by the weight of the undryed flour. Drying was done by placing the flour in a drying oven at 130° C. for 30 minutes.

The amount of moisture in a flour affects the results of several of the chemical and physical tests. Ash, Kjeldahl, sedimentation, and Farinograph results were corrected to the 14% moisture level. This is a standard procedure which is used in wheat testing so that results are uniform throughout the world.

All flours used in this experiment contained approximately 11% moisture (Table II). This is about average for Montana flours.

Ash Determination

Ash determinations were made in the Cereal Quality Laboratory, Montana State College. The three barley flours were tested. Five gram samples were placed in ashing dishes and put into an electric muffle furnace and incinerated overnight. The samples were cooled in a dessicator and weighed soon after room temperature was attained. Results, corrected to the 14% moisture level, are given in Table III.

The total ash content of whole wheat kernels and whole barley kernels are very similar. Shaffer (18) gives mineral content of barley as 3.1% and wheat as 3.02%. Yet the ash percentage in the barley flour tested
Table II. Percentage of moisture in barley flours, all-purpose flour and mixtures of barley and all-purpose flour.

<table>
<thead>
<tr>
<th>Type of Flour</th>
<th>Moisture %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conrad Plant, Spring, 1963</td>
<td>10.7</td>
</tr>
<tr>
<td>Conrad Plant, Winter, 1964</td>
<td>11.0</td>
</tr>
<tr>
<td>Cell-U Brand</td>
<td>11.1</td>
</tr>
<tr>
<td>75% Barley flour, 25% Wheat flour</td>
<td>10.8</td>
</tr>
<tr>
<td>50% Barley flour, 50% Wheat flour</td>
<td>10.8</td>
</tr>
<tr>
<td>All-Purpose flour</td>
<td>11.0</td>
</tr>
</tbody>
</table>

Table III. Percentage of ash in three different barley flours.

<table>
<thead>
<tr>
<th>Type of Flour</th>
<th>Ash %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conrad Plant, Spring, 1963</td>
<td>1.07</td>
</tr>
<tr>
<td>Conrad Plant, Winter, 1964</td>
<td>1.18</td>
</tr>
<tr>
<td>Cell-U Brand</td>
<td>1.48</td>
</tr>
</tbody>
</table>

(Table III) is much greater than the values of 0.39% to 0.42% reported for wheat flours (9). The greater percentage of ash in barley flours could be due to a less complete separation of the bran and germ from the endosperm in barley. This has been described as a common situation when barley flours have been used in Germany (16). The Cell-U brand barley
flour was the highest in ash content of the barley flours tested (Table III). This flour appeared coarse and less finely milled than the two barley flours milled at Conrad. The average weight per cup of the Cell-U brand flour was also higher than weight per cup of other flours.

Since barley bran contains tannic acid (16), the high bran content of barley flours may account for the bitter flavor sometimes found in barley products.

Kjeldahl Tests for Determination of Protein

The Kjeldahl determinations were made by personnel in the Grain Inspection Laboratory, Montana State College. The Gunning Method (14), with slight modifications, was used. Copper sulfate was used as the catalyst rather than mercury. A slightly longer time is needed for complete digestion with this catalyst. The indicator used was 3/4 methyl red and 1/4 methylene blue, because the operators felt that by using the mixture it was easier to determine the end point than if methyl red was used alone.

The barley flours all had a higher percentage of protein than the wheat flour or the mixtures (Table IV). Using standards commonly applied to wheat flours, this percentage of protein would indicate that the flour should produce a loaf of good volume.

Sedimentation Tests

The three barley flours, mixtures of barley and all-purpose flour, and all-purpose flour were tested for sedimentation rate. The procedure outlined by the Grain Branch of the USDA Production and Marketing Administration (20) was followed. Four tests of each of the flours were made.
Table IV. Protein content of barley flours, all-purpose flour and mixtures of barley and all-purpose flour.

<table>
<thead>
<tr>
<th>Type of Flour</th>
<th>Protein Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conrad, Spring, 1963</td>
<td>12.83</td>
</tr>
<tr>
<td>Conrad, Winter, 1964</td>
<td>13.66</td>
</tr>
<tr>
<td>Cell-U Brand</td>
<td>13.27</td>
</tr>
<tr>
<td>75% Barley flour, 25% All-purpose flour</td>
<td>12.40</td>
</tr>
<tr>
<td>50% Barley flour, 50% All-purpose flour</td>
<td>11.97</td>
</tr>
<tr>
<td>100% All-purpose flour</td>
<td>11.10</td>
</tr>
</tbody>
</table>

The amount of flour used was corrected to the 14% moisture level.

Because the degree of fineness in milling affects sedimentation rate, all flours should be passed through a 100 mesh sieve. The flours from the Conrad plant and the all-purpose wheat flour were milled finely enough so that no pre-sieving of these flours was necessary for this experiment.

The sieve of the Cell-U barley flour was not known and the results indicate it was too coarse and should have been sieved before the sedimentation test was made.

The barley flours always took longer to wet with alcohol than the wheat flour. Some flour would stick to the bottom and shaking it 6 - 10 times was necessary to get the flour into complete suspension. It was difficult to read the sedimentation values of the barley flours. The supernatant fluid remained cloudy and a distinct line of separation was diffi-
cult to ascertain. The Cell-U barley flour sedimentation was especially cloudy. In spite of these difficulties the replicates of each test varied no more than 1.0 ml. Results are given in Table V.

Table V. Sedimentation values of barley flours, all-purpose flour, and mixtures of barley and all-purpose flour.

<table>
<thead>
<tr>
<th>Type of Flour</th>
<th>Value (ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barley Flour</td>
<td></td>
</tr>
<tr>
<td>Conrad Plant, Spring, 1963</td>
<td>19.1</td>
</tr>
<tr>
<td>Conrad Plant, Winter, 1964</td>
<td>19.5</td>
</tr>
<tr>
<td>Cell-U Brand</td>
<td>42.6</td>
</tr>
<tr>
<td>75% Barley, 25% All-purpose flour</td>
<td>29.5</td>
</tr>
<tr>
<td>50% Barley, 50% All-purpose flour</td>
<td>37.3</td>
</tr>
<tr>
<td>100% All-purpose flour</td>
<td>40.5</td>
</tr>
</tbody>
</table>

When comparing the sedimentation values in Table V with the standards described by Zeleney (23), the two barley flours milled in Conrad would be classified as being exceptionally weak in gluten-like quality. The Cell-U barley flour rated much higher, but this probably was due to the fact that it was more coarsely milled. Its value is not indicative of its gluten strength. The all-purpose flour would be considered good quality for bread making. The values of the two mixtures of all-purpose and barley flour indicate the gluten strength to be intermediate between the all-purpose flour and the barley flour. The gluten quality appeared to be related to the amount of all-purpose flour present. One would expect to
be able to make a bread of good volume from the all-purpose flour and one of much less volume from the barley flours. The breads made from the mixtures would be expected to be intermediate in volume. This was found to be true, as will be explained in the description of baking experiments.

Farinograph Curves

Farinograph curves were made on a Brabender farinograph in the Cereal Quality Laboratory, Montana State College. Barley flours absorb less moisture than do wheat flours and the amount of water ordinarily used for wheat flours made the barley flour dough too soft and sticky so that the curve produced was not in the proper range to be meaningful. By using less water it was possible to produce a barley flour dough of sufficient strength to bring the peak of the farinograph curve up into the desirable range of wheat flours (Figure 1, top and middle). The fairly dry barley flour doughs were stiff, yet easily broken. They were not elastic as were the wheat flour doughs. The farinograph was designed to measure gluten strength of wheat flours. It is possible that the farinograph curve of the barley flours measured the stiffness of the dough rather than the gluten strength, which is necessary to make good quality bread. Using the techniques developed to measure wheat flour quality, the farinograph determination appears to be of little value for determining strength of barley flour doughs. Curves produced did not show a peak and they failed to indicate optimum mixing time.

A farinograph curve was made from the all-purpose flour used in this experiment. The farinograph curve of this flour (Figure 1, bottom) indicates that the dough will produce a loaf of acceptable volume because its
Figure 1. Farinograph curves of three different flours. Top: Barley flour, 1963; Middle: Barley flour, 1964; Bottom: All-Purpose flour.
peak and mixing time are in the desirable range.

**Thickening Capacity**

A comparison of the thickening capacity of barley and all-purpose flour was made. A ratio of 2 tablespoons flour (14 grams all-purpose flour and 12 grams barley flour) per cup of water (244 grams) was used. A small amount of the water was used to hydrate the flour and the rest of the water was heated rapidly to boiling. When the water began to boil, the hydrated flour mixture was poured slowly into the boiling water and stirred rapidly. When the mixture again came to a full rolling boil it was removed from the heat. The peak temperature attained was 93°C. When the mixture had cooled to 50°C, it was poured into a glass tube, one inch in diameter and 23 inches long, with a lower tip measuring 0.107 inches. After the tube was filled the mixture was allowed to run out and the height of the remaining column was marked at five-second intervals. The relative thickening capacity of all-purpose and barley flours was expressed as the distance from the top of the tube to the pastes in the glass tube at five-second intervals (Table VI).

The barley flour paste height was not recorded at the 25 and 30 second intervals because the column was so short that the figures would not be representative of the flow of the paste. The all-purpose flour dropped 4 inches in the same 5 second interval that the barley flour paste dropped 5 5/8 inches (Table VI). Volume for volume, all purpose flour was the better thickening agent.
Table VI. Distance from the top of glass tube of all-purpose and barley flour pastes at five-second intervals.

<table>
<thead>
<tr>
<th>Time from Beginning of Test (seconds)</th>
<th>Type of Flour Paste</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All-Purpose inches</td>
<td>Barley inches</td>
</tr>
<tr>
<td>5</td>
<td>4</td>
<td>5 5/8</td>
</tr>
<tr>
<td>10</td>
<td>8</td>
<td>10 5/8</td>
</tr>
<tr>
<td>15</td>
<td>11 1/8</td>
<td>14 3/8</td>
</tr>
<tr>
<td>20</td>
<td>13 1/2</td>
<td>17 1/2</td>
</tr>
<tr>
<td>25</td>
<td>15</td>
<td>Not recorded</td>
</tr>
<tr>
<td>30</td>
<td>17</td>
<td>Not recorded</td>
</tr>
</tbody>
</table>
EVALUATION OF BAKED PRODUCTS CONTAINING BARLEY FLOUR

General Methods for Baked Products

One hundred percent barley flour, designated as (A), 75% barley and 25% all purpose flour (B), 50% barley flour and 50% all-purpose flour (C) and 100% all-purpose flour (D), were used in the baking of breads, muffins, cookies and pastry crust. In the breads some whole wheat flour was used in place of the all-purpose flour. This is designated when necessary. Mixtures of less than 50% barley were not used because the time and inconvenience involved in using smaller percentages of barley flour would not be justified under home conditions.

Barley flour muffins were made in a preliminary trial to determine the amount of barley flour to use in recipes calling for all-purpose flour. For each cup (115 grams) of all-purpose flour called for in the recipe, substitutions of 1 cup plus 2 tablespoons (88 grams), 1 cup plus 3 tablespoons (93 grams) and 1 cup plus 4 tablespoons (98 grams) barley flour were made. Since the substitution of 1 cup plus 3 tablespoons (93 grams) barley flour for 1 cup (115 grams) all-purpose flour resulted in the best product, this substitution was used in all subsequent baking trials.

The baking of the products was done over a two month period. Only one product was baked on any given day. Products made of each of the four different flours, designated A, B, C, and D, were made in duplicate each day. Unless otherwise stated, the same experiment was repeated not less than one week later. This gave a total of four replicates for each product.

Yeast breads were baked in the Cereal Quality Laboratory, Montana.
State College. The fermentation cabinet and rotating oven were used for standardizing procedures. The quick breads, cookies, pastry crust and muffins were prepared in the food laboratory in the Home Economics Department, Montana State College, to simulate home conditions and preparation procedures.

Bread

A white yeast bread was made using the basic recipe and the machinery used in the Cereal Quality Laboratory for commercial testing. A whole wheat yeast bread was made with hand mixing methods. Recipes for both yeast breads are given in the appendix, numbers 1 and 2. Flours designated as A, B, C, and D were used for both the white and the whole wheat bread.

The yeast bread doughs were put into a fermentation cabinet with a relative humidity just under 100% and held at 82°F. After fermentation, 175 grams of dough were put into each pan and returned to the fermentation cabinet to raise. The bread was baked in 5 X 2½ X 3 inch baking pans in a rotating oven at 425°F for 25 minutes. After the bread was cooled it was weighed and the volumes were measured by the rape seed displacement method.

The white yeast bread made with 100% all-purpose wheat flour ranked high, with an average organoleptic rating of 8.5 in flavor and 9 in appearance (Figure 2). There was a definite step-wise reduction in rating of flavor and appearance with the addition of barley flour. This reduction was proportional to the amount of barley flour used. The barley breads did not brown well, and they were pale in appearance. The surface of the crusts was not smooth and tended to crack. The texture of the barley bread...
was more coarse and the loaf was quite compact.

Figure 2. Average organoleptic rating of yeast breads made from a white yeast bread recipe and using barley flour, all-purpose flour and mixtures of barley and all-purpose flour.

The whole wheat bread recipe produced a barley bread of slightly better appearance than did the white yeast bread recipe. The barley bread made from the whole wheat yeast bread recipe rated 2.6 while the barley bread made from the white yeast bread recipe rated only 2.1 in average organoleptic rating (Figures 2, 3). The appearance of the breads made from the whole wheat bread recipe was slightly better because the whole wheat flour and molasses gave a darker color. The flavor scores for this bread are very similar to the flavor scores given to the breads made from the white yeast bread recipe. The addition of molasses
in this bread did not appear to improve the flavor of the barley breads as had been anticipated.

Figure 3. Average organoleptic rating of yeast breads made from a whole wheat yeast bread recipe and using barley flour, wheat flours and mixtures of barley and whole wheat flour.

The volume of the white and whole wheat breads was good. Volume decreased progressively as the substitution of barley flour for wheat flour was increased (Table VII). The machine-mixing employed with the white yeast bread recipe reduced the volume of the loaves more than the hand-mixing employed with the whole wheat yeast bread recipe.

All loaf weights were very similar (Table VIII). Loaf weight did not appear to be affected by the substitution of barley flour for wheat flour or by the mixing method employed.
Table VII. Loaf volumes of yeast breads made from barley flour, wheat flours, and mixtures of barley and wheat flours.

<table>
<thead>
<tr>
<th>Flour Used</th>
<th>100% Barley (cc.)</th>
<th>Purpose (cc.)</th>
<th>Purpose (cc.)</th>
<th>Wheat (cc.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recipe Used</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White Wheat Bread (Machine Mixed)</td>
<td>230.</td>
<td>278</td>
<td>355</td>
<td>770</td>
</tr>
<tr>
<td>Whole Wheat Bread (Hand Mixed)</td>
<td>274</td>
<td>359</td>
<td>502</td>
<td>657</td>
</tr>
</tbody>
</table>

Table VIII. Loaf weight of yeast breads made from barley flour, wheat flours, and mixtures of barley and wheat flours.

<table>
<thead>
<tr>
<th>Flour Used</th>
<th>100% Barley (grams)</th>
<th>Purpose (grams)</th>
<th>Purpose (grams)</th>
<th>Wheat (grams)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recipe Used</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White Wheat Bread (Machine Mixed)</td>
<td>151</td>
<td>155</td>
<td>152</td>
<td>155</td>
</tr>
<tr>
<td>Whole Wheat Bread (Hand Mixed)</td>
<td>152</td>
<td>154</td>
<td>154</td>
<td>153</td>
</tr>
</tbody>
</table>

Because loaf weights were nearly the same while loaf volumes were much larger for the wheat breads than the barley breads, one would expect that the barley breads would be compact and heavy. This was true of the breads made in this experiment.

Although the organoleptic scores indicate that the yeast breads made with barley flour were not of high quality (Figures 2, 3), they still have
possibilities in allergy diets. They certainly were edible.

It was difficult to cut a slice of the barley bread because the loaf was very crumbly and pieces tended to fall away from the edges of the slice. The tendency to crumble increased as the amount of barley flour was increased.

The appearance and texture of the doughs of barley flour were quite different from the appearance and texture of the wheat flour doughs. Barley flour dough broke easily and had little elasticity or strength. Wheat doughs felt plastic, yet firm in the hand, whereas the barley doughs were soft and fragile. The shaping of the loaf of barley bread was difficult and it was almost impossible to form a smooth loaf.

The preparation of the yeast breads was time consuming, and it was necessary to judge them on the day following the baking. The breads were wrapped after they were cooled so that they did not dry out excessively.

**Quick Breads**

Because the yeast barley breads were difficult to handle and were adversely affected by manipulation, it seemed logical to assume that quick breads, which require little manipulation, might be successful.

A white quick bread was made using a muffin recipe (Appendix #3) and using the muffin method of mixing. The average organoleptic scores of the white quick bread (Figure 4) show that there was little difference in the rating of the products made using the A, B, and C flour substitutions. All of these breads were quite acceptable products.

Although these quick breads are not a substitute for yeast breads, they can be made successfully for meal variety. The shape of the loaf is
Figure 4. Average organoleptic ratings of quick breads made from a muffin recipe and using barley flour, all-purpose flour, and mixtures of barley and all-purpose flours.

such that the bread could be toasted if desired. This quick bread was made only on one baking day and was not repeated because there seemed to be little advantage—except for shape—over the muffins which were made.

A whole wheat quick bread was made (Appendix #4) using the quick bread method of mixing. The average organoleptic scores (Figure 5) were all fairly low. Average appearance scores were 3.4, 4.1, 4.7, and 6.2 for flours A, B, C, and D, respectively. Average flavor scores for flours A, B, C, and D were 4.2, 5.5, 5.7, and 7.1, respectively. The scores decreased as the amount of barley flour increased. The barley flour breads made from this recipe did not rate as well as the barley breads made from the
Figure 5. Average organoleptic rating of quick breads made from a whole wheat quick bread recipe and using barley flour, wheat flours, and mixtures of barley and whole wheat flour.

-28-

A: 100% Barley
B: 75% Barley
   25% Whole Wheat
C: 50% Barley
   50% Whole Wheat
D: 100% Wheat

white quick bread recipe. The instructions given with the recipe called for more mixing than did the instructions in the muffin recipe. The extra manipulation may have affected the quality.

The loaf volumes of all the quick breads were similar (Table IX). The whole wheat quick bread dough weighed 175 grams and was baked in a pan 5 X 2½ X 3 inches. The white quick bread was baked in a smaller pan with less dough because these were the pans that were available. The volumes for the quick breads made from the white quick bread recipe were corrected to the value for the larger pans so that a comparison could be made more easily. Loaf volumes of quick breads did not appear to be affected
appreciably by the substitution of barley flour for wheat flour.

Table IX. Loaf volumes of quick breads made from barley flour, wheat flours, and mixtures of barley and wheat flours.

<table>
<thead>
<tr>
<th>Recipe Used</th>
<th>Flour Used</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>100% Barley</td>
</tr>
<tr>
<td>White Quick Bread</td>
<td>cc</td>
</tr>
<tr>
<td>Whole Wheat Quick Bread</td>
<td>cc</td>
</tr>
</tbody>
</table>

The loaf weights of all of the breads made from the whole wheat quick bread recipe were very similar (Table X). The substitution of barley flour for wheat flour did not appear to affect loaf weight of the quick breads. Loaf weights were not recorded for the white quick breads, due to an error in carrying out of plans.

Quick breads of good quality can be made using all or part barley flour. The method employing the least manipulation is recommended when barley flour is used.

Table X. Loaf weights of quick breads made from barley flour, wheat flours, and mixtures of barley and whole wheat flour.

<table>
<thead>
<tr>
<th>Flour Used</th>
</tr>
</thead>
<tbody>
<tr>
<td>100% Barley</td>
</tr>
<tr>
<td>grams</td>
</tr>
<tr>
<td>149</td>
</tr>
</tbody>
</table>
Muffins

Raisin spice muffins and bran muffins (Appendix, #5 and #6) were made from the flours A, B, C, and D previously described. All-barley muffins were also made in a comparative test of the three different barley flours. The muffin method of mixing was used. A quantity of 40 grams of dough was weighed into paper muffin cups. All muffins were mixed and weighed before any were put into the oven so that they would be done at the same time and could be sampled while hot by the panel. All muffins were baked in gas ranges.

Muffins were left in the paper cups for judging and taking of volume measurements. Volumes were determined by the rape seed displacement method. It was realized that the volume would be slightly in error with the paper cups left on, but all the cups were the same size and weight and this was better than having the muffins crumble while being measured.

Bran muffins made from 50% barley flour and 50% all-purpose flour (C) ranked higher in flavor than did muffins made from flours A, B, or D (Figure 6). The average flavor score of C was 7.9. Flour D scored 7.4 while A and B both scored 6.9. The average organoleptic score for appearance of C and D was 7.4. Average appearance score for A and for B was 6.9.

Spice raisin muffin evaluations were similar to those for bran muffins. The appearance of the muffins made with 50% barley and 50% all-purpose flour (C) ranked highest with a score of 7.4. Flours A, B, and C scored 6.4, 6.7, and 7.2, respectively, for appearance (Figure 7). The spices blended with the barley flavor and made a very acceptable product. The
Figure 6. Average organoleptic rating of bran muffins made with barley flour, all-purpose flour, and mixtures of barley and all-purpose flour.

The addition of raisins was also helpful in improving the flavor.

There was very little difference in volume due to substitution of barley for all-purpose flour either in bran muffins or in raisin spice muffins (Table XI).

Results of the comparative test of the three barley flours are shown in Figure 8. Muffins made from the flour milled in the spring of 1963 ranked highest in flavor while muffins made from flour milled in the winter, 1964 were highest in appearance. There was very little difference in quality of the muffins made from these two barley flours. The muffins made from the Cell-U barley flour ranked lowest in both appearance and flavor.
Figure 7. Average organoleptic rating of raisin spice muffins made with barley flour, all-purpose flour, and mixtures of barley and all-purpose flour.

Table XI. Volume of bran muffins and raisin spice muffins made from barley flour, all-purpose flour, and mixtures of barley and all-purpose flour.

<table>
<thead>
<tr>
<th>Type of Muffins</th>
<th>Flour Used</th>
<th>75% Barley</th>
<th>50% Barley</th>
<th>100% All-Purpose</th>
<th>50% All-Purpose</th>
<th>100% All-Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>100% Barley</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bran Muffins</td>
<td>cc</td>
<td>97</td>
<td>100</td>
<td>95</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Raisin Spice Muffins</td>
<td>cc</td>
<td>96</td>
<td>105</td>
<td>98</td>
<td>103</td>
<td></td>
</tr>
</tbody>
</table>
They were quite dry and coarse. This flour appeared more coarse. It weighed more per cup and evidently had greater water absorbency.

![Barley Flour Comparison Chart]

**Figure 8.** Average organoleptic rating of muffins made from barley flour of 1963 and 1964 milling and from Cell-U brand barley flour.

All muffins made were of good quality. Barley flour in muffins has possibilities as a variety food or for wheat-free allergy diets.

**Cookies**

Applesauce cookies and brown sugar cookies were selected for baking because it was hoped that spices and brown sugar would make barley flour cookies more palatable.

A Hamilton Beach Mixer with a small bowl was used to mix the cookies. Recipes are provided in the appendix (#7, #8). After mixing, 10 grams of dough were weighed for each cookie. All cookies were baked in a gas
range oven.

Since the applesauce cookie dough was soft and would have been difficult to transfer quantitatively, the dough was weighed on a piece of aluminum foil and placed on the cookie sheet. Organoleptic ratings of the applesauce cookies are given in Figure 9.

![Average organoleptic rating of applesauce cookies](image)

Figure 9. Average organoleptic rating of applesauce cookies made from barley flour, all-purpose flour and mixtures of barley and all-purpose flour.

Three cookies from each batch, giving a total of 12 cookies of each kind in the four replications, were sketched around the periphery. Later the planimeter was used to determine the areas of spread. Cookies are considered undesirable if their areas of spread are excessively large. Average areas of the applesauce cookies are given in Table XII.
Table XII. Average area of applesauce cookies made from barley flour, all-purpose flour, and mixtures of barley and all-purpose flour.

<table>
<thead>
<tr>
<th>Kind of Flour Used</th>
<th>Area square cm.</th>
</tr>
</thead>
<tbody>
<tr>
<td>A: 100% Barley</td>
<td>27.7</td>
</tr>
<tr>
<td>B: 75% Barley 25% All-Purpose</td>
<td>27.6</td>
</tr>
<tr>
<td>C: 50% Barley 50% All-Purpose</td>
<td>25.9</td>
</tr>
<tr>
<td>D: 100% All-Purpose</td>
<td>23.7</td>
</tr>
</tbody>
</table>

The cookies made from 100% barley flour spread most and those made from 100% all-purpose flour spread least during baking. The range from the least to the most area spread was not large. None of the cookies spread enough to detract from their appearance.

Brown sugar cookies were made from the barley flour, all-purpose flour, and the mixtures of barley and all-purpose flour. The brown sugar cookies were mixed as the applesauce cookies were except that they were weighed on a piece of wax paper and transferred from the wax paper to the cookie sheet.

As shown in Figure 10, the appearance of the all-purpose flour cookies rated highest, with a reduction in rating as the amount of barley flour increased. The flavor scores show that 100% all-purpose flour cookies rated slightly higher than the 75% barley flour cookies. The 100% barley flour cookies rated lowest in flavor.
Appearance Flavor

Figure 10. Average organoleptic rating of brown sugar cookies made from barley flour, all-purpose flour, and mixtures of barley and all-purpose flour.

The brown sugar cookies were more adversely affected by the addition of barley flour than were the applesauce cookies.

Brown sugar cookie spread during baking, as determined by the planimeter, was proportional to the amount of barley flour used (Table XIII). The difference from the least to the most area spread was greater for brown sugar cookies than it was for applesauce cookies.

The appearance of some of the cookies was rated low because the shape of the cookies was not uniform. The techniques employed in the weighing and transferring made uniform shaping of the cookies a difficult task. Because eight batches of cookies were being made each day, lack of time
Table XIII. Average area of brown sugar cookies made from barley flour, all-purpose flour, and mixtures of barley and all-purpose flour.

<table>
<thead>
<tr>
<th>Kind of Flour Used</th>
<th>Area square cm.</th>
</tr>
</thead>
<tbody>
<tr>
<td>A: 100% Barley</td>
<td>29.1</td>
</tr>
<tr>
<td>B: 75% Barley 25% All-Purpose</td>
<td>26.6</td>
</tr>
<tr>
<td>C: 50% Barley 50% All-Purpose</td>
<td>24.8</td>
</tr>
<tr>
<td>D: 100% All-Purpose</td>
<td>21.2</td>
</tr>
</tbody>
</table>

was also a factor in not shaping the cookies uniformly.

The 100% barley flour cookies had a pronounced barley flavor. This flavor was less noticeable in cookies made from the mixtures of the flours. The distinct barley flavor was more noticeable in cookies that were a day or two old than in freshly baked cookies. None of the cookies rated very high. A score of 8 was the highest score represented in Figures 9 and 10. Possibly different recipes or techniques might have been better than those employed. More experimentation might produce a cookie made from barley flour or mixtures containing barley flour which would be more acceptable.

**Pastry**

Plain pastry and egg and vinegar pastry were made using the usual pastry method. The pastry was rolled on a pastry cloth to a uniform thickness of 1/16th inch. Metal strips which gave 1/16th inch clearance between the rolling pin and the pastry cloth were used on each side of the
crust. Recipes are recorded in the appendix (#9, #10).

Egg and vinegar pastry crust was made using flours A, B, C and D. Pastry crust made from all-purpose flour ranked high with a score of 8.1 in appearance and 9.0 in flavor (Figure 11). There was a step-wise reduction in rating as the percentage of barley flour was increased. Pastry crust made from 100% barley flour rated lowest with scores of 4.2 in appearance and 5.1 in flavor.

![Figure 11. Average organoleptic rating of egg and vinegar pastry crust made from barley flour, all-purpose flour, and mixtures of barley and all-purpose flour.](image)

Plain pastry was made only once. The barley flour crusts made using the plain pastry recipe were extremely fragile. Since the egg and vinegar crust had better structure, no further experimentation was done with the
plain pastry crust. Organoleptic ratings of the plain crust are given in Figure 12.

![Graph showing organoleptic ratings of plain pastry crust](image)

Figure 12. Average organoleptic rating of plain pastry crust made from barley flour, all-purpose flour, and mixtures of barley and all-purpose flour.

The appearance and flavor values of the plain pastry crust were very similar to those for the egg and vinegar pastry crust (Figures 11, 12). The color of the barley flour pastries was darker than that of the wheat flour pastries. The color was not objectionable, but it was easy to see which pastry contained barley flour before any testing was done.

The barley flavor in pastry is not as pronounced as in some products and was not considered objectionable. The flavor of the barley flour pastries was affected by the apparent excess of shortening in these crusts. Barley flour pastry might be made quite satisfactorily if the shortening
were reduced. More experimentation should be done to determine the optimum amount of shortening for barley flour pastry.
DISCUSSION AND SUMMARY

An interest in using barley flour came about because barley is an important Montana crop and there is a need for developing recipes for wheat-free allergy diets.

Physical and chemical tests ordinarily used for testing wheat for suitability for baking were made with barley flour and the all-purpose wheat flour used in this experiment.

Moisture. The moisture content of the barley and wheat flours used in this experiment was about 11%.

Ash. The ash percentage of barley flour was higher than in wheat flour. This suggests an incomplete separation of bran from the endosperm which may have affected the flavor of the barley flours.

Kjeldahl. The protein content of barley flours was in the desirable range for wheat, but the gluten-forming proteins were not as evident. However, there seemed to be some substance present which gave a little strength and elasticity to barley baked products.

Sedimentation. The sedimentation test was designed to measure gluten strength of wheat flours, and its application to barley flour is limited. There is a possibility that the sedimentation test could be used for determining baking quality of barley flour if some modifications were made in the test.

Farinograph. The farinograph measures dough strength and mixing time of wheat flours. Its use for measuring strength or mixing time of barley flour is questionable. It appeared that the
farinograph was measuring stiffness of the barley flour doughs rather than strength.

**Thickening Capacity.** Barley flours did not possess as great a thickening capacity as did wheat flours. The total amylose and amylopectin content of the two cereals is similar (5, 9). Because the thickening capacity is different, there is evidently some molecular difference within the fractions of the two cereals. Baked products were made from barley flours, all-purpose flour and/or whole wheat flour, and mixtures of barley and wheat flour. An organoleptic panel of four members was used to evaluate the baked products for palatability. Four categories of baked products were tested.

**Bread.** Yeast breads are dependent on gluten strength for structure and volume. Yeast breads became more compact and coarse as the proportion of barley flour in them was increased. Barley yeast breads were very undesirable, but certain mixtures of barley and wheat were more satisfactory.

Breads using baking powder and requiring little mixing (Quick Breads) were made quite successfully from barley flour and mixtures of barley and wheat flours.

**Muffins.** Muffins made from barley flour and mixtures of barley and wheat flours were acceptable products. Little mixing was necessary, thus eliminating the adverse effects inherent in the mixing of barley products.

**Cookies.** The barley flavor appeared quite pronounced in the cookies made in this experiment, especially after a day or two.
The appearance of cookies was affected very little by the addition of barley flour, but they did spread a little more during baking.

**Pastry Crust.** Pastry crusts made from barley flour broke easily and appeared to need less shortening than did wheat flour pastries. The addition of egg to pastry crust was helpful in improving structure.

Some people like the barley flavor. Others object to it. It appeared with this panel that those who initially disliked the barley flavor intensified their dislike during the period of the experiment. The products in which the presence of barley could be seen were ranked in step-wise fashion, with a lower score for each increase of barley flour content. If booths with special lights which mask color had been available, more objective evaluation might have been possible.

Barley flour products do have possibilities for those seeking food variety and in wheat-free allergy diets. More experimentation with recipes would no doubt produce baked products of better quality than those discussed in this paper. It would be interesting to try cookie recipes using molasses, pastry crust with less shortening, and hot cakes.

Varieties of barley other than Compana might make a flour of better flavor and baking qualities. Variations in the milling process might also produce a better quality flour.
APPENDIX

#1. White Yeast Bread

Flour..........................100 grams (14% moisture basis)
Dry skim milk.....................2 grams
Crisco............................5 ml.
Salt and sugar solution........10 ml. (1100 grams sugar and 400 grams salt dissolved in 100 ml. water)
Malt...............................10 ml. (25 grams malt in 1 liter water)
Yeast..............................20 ml. (100 grams yeast in 1 liter water)
Bromate..................Flour A: 5 ml. (16 grams bromate in 1 liter water)  
                           Flour B: 3 3/4 ml. water to make stock; 25 ml. stock in 2 liters water)  
                           Flour C: 2 1/2 ml. 
                           Flour D: None
Water....................Flour A: 22 ml. 
                          Flour B: 24 ml. 
                          Flour C: 25 ml. 
                          Flour D: 27 ml.

Standard procedures and equipment for mixing and baking of bread in the Cereal Quality Laboratory were used.

#2. Whole Wheat Bread

White flour......................87 grams
Whole wheat flour.............147 grams
Yeast.............................7 grams
Shortening......................15 cc.
Molasses.........................17 grams
Water............................183 grams

The usual method of mixing and baking of yeast breads was followed.
#3. White Quick Bread

Flour ..................... 184 gm.
Sugar ........................ 19 gm.
Milk ......................... 184 gm.
Egg .......................... 36 gm.
Fat ............................. 19 gm.
Baking powder ............. 9 gm.
Salt ............................ 1½ gm.

Sift dry ingredients together 3 times. Make a hole in the center of the dry ingredients, add all liquid ingredients. Stir 8 times, just wetting the dry ingredients. Make 2 150 gm. loaves. Bake at 425° F. for 25 minutes.

#4. Whole Wheat Quick Bread

Whole wheat flour ........ 87 gm.
White flour ................ 100 gm.
Baking powder ............ 12 gm.
Shortening ................. 7½ cc.
Milk .......................... 176 gm.
Salt ........................... 2 gm.
Sugar ........................ 25 gm.
Egg ............................ 24 gm.

Stir dry ingredients into bowl, add liquid, mixing well. Add beaten egg, stir in. Add shortening and beat mixture thoroughly.
5. Bran Muffins

Flour .......................... 56 gm.
Sugar ......................... 25 gm.
Milk ............................ 92 gm.
Eggs ............................ 24 gm.
Fat ............................... 25 gm.
Baking powder .................. 6 gm.
Salt .............................. 1 gm.

The muffin method of mixing was used.

6. Raisin Spice Muffins

Flour ............................ 115 gm.
Sugar ............................ 12½ gm.
Milk .............................. 122 gm.
Egg ............................... 24 gm.
Fat ............................... 12½ gm.
Baking powder ................. 6 gm.
Salt .............................. 1 gm.

The muffin method of mixing was used.
#7. Applesauce Cookies

Sugar........................ 50 gm.
Shortening.................. 25 gm.
Egg................................ 12 gm.
Applesauce.................... 60 gm.
Flour........................... 56 gm.
Salt............................... ½ gm.
Soda............................... ½ gm.
Baking powder.................. 1 gm.
Cinnamon.......................... ½ gm.
Clove................................ ½ gm.
Raisins.......................... 15 gm.

Cookies were mixed with a Hamilton Beach Mixer.

#8. Brown Sugar Cookies

Shortening...................... 50 gm.
Brown sugar..................... 95 gm.
Eggs............................... 24 gm.
Buttermilk....................... 31 gm.
Flour............................. 101 gm.
Soda............................... 1 gm.
Salt................................ 1 gm.

Cookies were mixed with a Hamilton Beach Mixer.
#9. Egg and Vinegar Pastry Crust

- Flour: 28 gm.
- Lard: 12 gm.
- Egg: 4 gm.
- Water: 10 gm.
- Vinegar: 1 1/2 gm.

Pastry method of mixing was used.

#10. Plain Pastry Crust

- Flour: 28 gm.
- Lard: 12 gm.
- Salt: 1 gm.
- Water: 18 gm.

Pastry method of mixing was used.
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Niffenegger, E. (Vermeer)
Chemical and physical characteristics of barley flour

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