A COMPARISON OF VARIOUS METHODS OF ESTIMATING THE BAKING QUALITIES OF FLOUR.

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During the past ten or fifteen years a very large amount of investigation of the chemical and physical properties of wheat flour has been carried on, by agricultural chemists in nearly every wheat producing country of the world. Most of this study has been in connection with the nitrogeneous constituents of the wheat kernel, since it is to them that wheat flour owes its characteristic bread making ability. These investigations may be roughly classified as follows: studies of the chemical nature of the proteids of the wheat kernel, as represented by the work of Osborne and Voorhees[1] in this country, Fleurent[2] in France, and others; investigations of certain physical properties of flour and of its constituents, such as water-absorption by the Jury of the Vienna Exposition[3], measurements of the elasticity of gluten by Boland[4], Heinrich[5], and Liebermann[6], etc., etc., chemical methods for estimating the baking quality of flour, as suggested by Robine[7], Girard and Fleurent[8], and others; and baking tests of various kinds, such as those suggested by Kunis[9], Sellnick[10], and Kreusler[11]. Recently several excellent articles summarizing the results of these investigations and including experiments by the authors have appeared, the most comprehensive of which are probably Hamann's "Die Bachfähigkeit des Weizenmehles und ihre Bestimmung"[12], Maurizio's article with the same title[13], and Snyder's "Testing Wheat for Commercial Purposes"[14]. Furthermore the bulletins of the various State Experiment Stations for the past five years contain many reports bearing more or less directly upon the general subject of the baking qualities of wheat flour, an extended enumeration of which would, however, unnecessarily extend the scope of this article.

The writer has recently begun an extended investigation of the chemical composition and milling qualities of the wheats grown in the State of Washington, and of the conditions which influence or determine these qualities of wheats in general. The conditions which exist in the Pacific Northwest States are now widely recognized as being very favorable to

[1] Am. Ch. J., 15, No. 6.
[2] Ann. Sci. Agr. franc. et. etrang. 2nd series, 4, (1898).
[3] Amtlicher Bericht der Wiener Weltaustellung, Bd. 1.
[4] Polytech. Jour. 111, 230.
[5] Ber. Landw. Versucht. Bostock. 1894.
[6] Zeits. Unter- Nahr-und-Genussm. 4, 22, 1009. (901).
[7] Polytech. Jour. 147, 452.
[8] Compt. Rend. 123, 227 and 755, (1896).
[9] Wie Untersucht man Getriede und Mehle? Liepzig, 1898.
[10] Das Artophon. Leipzig. no date.
[11] Die Muhle. 1887, Nr. 35.
[12] Pub. by Winter, Heidelberg, 1902.
[13] Landw. Jb. 31, 179-234, (1902).
[14] This Journal, 27, 1068, (1905).

the production of large yields per acre which is chiefly of the soft, starchy, low-protein type. A problem in connection with the wheat industry of the State which is of extreme importance is, therefore, the improvement in quality or bread-making properties of our wheats. The investigation which is now in progress has this end in view. The first requisite for such an attempt is, of course, a satisfactory method of ascertaining the comparative bread-making quality of any given sample of wheat. As was briefly mentioned in the summarized review of the literature on this subject in the preceding paragraph, a great many different methods have been suggested for this purpose. A comparison of some of the more promising of these was undertaken. The results of this comparison, while they do not afford a satisfactory conclusion as to the possibility of some single test which will show definitely the absolute or comparative value for bread-making purposes of any given flour, throw considerable light upon some of the problems now under discussion, and appear to be worthy of publication.

Description of Samples

For the purposes of the general investigation, there were collected a total of eighty-six samples of wheat, representing nineteen different varieties and coming from twenty-five different shipping points in the State. Subsamples from each of these were analyzed. A weighed portion from each was then milled in a miniature roller mill built especially for this purpose, and the percentage yield of flour, bran, and shorts ascertained; determinations of the protein content of the flour, bran, and shorts were made; and finally the moist and dry gluten test of each of the flours was determined. It should be noted that these were, in every case, "straight" flour, or the whole of the flour which the ordinary milling process would obtain from the wheat. No attempt was made to separate any "patent" grade of flour, as it was considered that the "straight" flour would more accurately represent the total milling value of the several wheats.

Based upon the results of this work, samples of the flour coming from what appeared to be the best, medium, and poorest grain of each six of the more common varieties were selected to be used in the comparative tests of their baking qualities. In the selection of these samples no attention was paid to the origin of the wheat from which they were milled. Later, in tabulating the results of the tests, it was noticed that there appears to be a very close relation between the results of the baking tests and the climatic conditions under which the grains were grown. These conditions cannot be fully shown without a complete meteorological record, which would enlarge this paper to an undesirable extent, but may be briefly summarized as follows: The wheat producing sections of the

State all lie east of the Cascade Mountains, and may be grouped into three fairly distinct areas: the first, designated as "dry" in the table below, in which the average annual rain-fall is from ten to fifteen inches, necessitating the application of the principles of "dry-land farming" in a very careful manner to insure the growth of a crop; the second, designated as "semi-arid" in the table, in which the average rain-fall is from fifteen to twenty inches; and the third, designated as "moist," in which the rain-fall varies from twenty to twenty-five inches. It will be noted at once that the annual rain--fall in all these districts is less than is usually considered to be necessary for the production of cereal crops in other parts of the United States. But the fact that the rain comes almost wholly during the winter and early spring, and that the soil is peculiarly adapted to the retention of moisture makes it possible to grow large crops of wheat with so small an amount of rain-fall. The influence which the differences in the climatic conditions in these three different sections has upon the chemical composition and baking quality of the flour from wheats grown in them is shown in the table and will be pointed out in the comments on the results of the tests.

Methods Used in the Work

The various methods of estimating the value of flour for bread-making purposes which were compared may be grouped as follows: (a) chemical tests, comprising estimations of protein, wet and dry gluten, and gliadin; (b) baker's sponge tests to show the water-absorption of the flour, and the rapidity and volume of rise of the dough under the action of the yeast; and (c) baking tests of the weight and volume of the loaf of bread from a given weight of flour. The methods of operation and signification of each process may be briefly described as follows.

(a) CHEMICAL TESTS. *Protein* was determined by the Kjeldahl method, using the conventional factor, 6.25, to calculate protein from the per cent of nitrogen found. his factor is recognized as being too high for some of the wheat proteids, the proper factor for the gluten-proteids being 5.7. But there is a great lack of uniformity among chemists in the factor which is used for this purpose, some even using one factor for calculating total proteids and another for the calculation of the individual bodies. In order that a uniform basis of comparison might be established, it was deemed best, therefore, to adopt the conventional factor and to use it throughout the investigation, and so to avoid any confusion or inaccuracy caused by change from one factor to another.

Gluten was separated from the flour by a modification of the method which is commonly used, which permitted much more rapid and accurate determinations than can usually be obtained. Twenty grams of flour were moistened with the proper amount of water (ten to twelve cc.) and worked into a smooth dough which was allowed to stand for one hour. The ball of dough was then transferred to a seive, made by stretching a piece of Schindler's Bolting Silk, No. 14XXX, over a small wooden ring such as is used by ladies as an embroidery hoop. The starch was then washed out under a thin stream of water, the dough being kneaded about with the fingers to hasten the removal of the starch, etc. In this way the starch could be washed out very rapidly without the danger of loss of any of the gluten, even with the glutens of very poor quality, such as cannot be handled at all by the usual procedure. Many careful examinations of the material which passed through the silk, both microscopically and by further washings and screening, always failed to reveal the slightest traces of gluten. There always remains on the silk a small quantity of slimy particles consisting of bits of germ, cell-tissue, etc., which will not pass through, but these are not taken up by the ball of gluten and the latter can easily be washed free of them by kneading for a few moments under water. The process thus carried out was very rapid and very satisfactory as to concordance of results. One hundred and thirty-five samples of flour, coming from nearly thirty different varieties of wheat, and varying in their yield of dry gluten from 3.65 per cent. to 17.42 per cent. were tested in duplicate by this method and in no case did the differences between duplicates amount to more than 0.5 per cent. while in most cases it was less than 0.2 per cent. and with flours of perfectly uniform composition results of very close agreement were almost invariably obtained. After thorough washing, the ball of gluten was allowed to stand under water for one hour, then carefully freed of surplus water by squeezing between the hands and weighed. This weight gave by calculation the percentage of *moist gluten*. The gluten was then dried for twenty hours at the temperature of boiling water and weighed and calculated as *dry gluten*. The loss of weight in drying was then calculated on the weight of dry gluten and the result expressed as the *water-holding capacity of the gluten*. A high water-holding capacity is usually supposed to indicate desirable physical properties in the gluten which possesses it.

Gliadin was determined by treating five grams of flour with 250 cc. of 70 per cent. (by weight) alcohol, shaking frequently and allowing to stand for twenty hours, after which an aliquot part was filtered off and the nitrogen in it determined by the Kjeldahl method. Gliadin was calculated, using the factor 6.25 for the reasons already pointed out. Several attempts were made to use the polarimetric method suggested by Snyder[1] but without success, it being found impossible to get satisfactory readings from flours of this type. From the percentage of gliadin found, the per cent. of *gliadin in the protein*, or so-called "gliadin number," and the per cent. of

[1] This Journal, 26, 263, (1904).

gliadin in the gluten were calculated. It is stated by nearly every investigator who has made a study of wheat gluten that the bread-making quality of flour depends both upon the quantity of gluten which it will yield and upon the quality of the gluten as determined by the proportions of gliadin and glutenin which it contains. But a great difference of opinion exists as to what proportion of the total proteids must be gliadin in order to insure flour of the highest baking quality. Fluerent[1] holds that the proportion of gliadin in the gluten should be 75 per cent., and that a variation of 2 per cent. either way from this typical composition may easily be detected in the quality of the bread produced. Snyder[2] states that gliadin constitutes from 55 per cent. to 70 per cent. of the total protein of wheat flours, and that flours of good quality should have from 55 per cent. to 65 per cent. of their protein in the form of gliadin. Shutt[3] points out, however that later work of Snyder's leads to the conclusion that flours of excellent baking quality often show only 41 per cent. to 46 per cent. of their protein in the form of gliadin, and confirms this by his own analyses of flours from Manitoba wheats. Dr. de Sigmond, of the University of Budapest, told the writer in a recent personal conversation that the flours of Hungary, which are noted throughout Europe for their excellent bread-making qualities, usually contain less than 50 per cent. of their protein as gliadin. Hence, it appears that the suggested standards of 55 per cent. to 75 per cent. are higher than is oftentimes found in high grade flours. Both the percentage of gliadin in the protein and in the gluten are recorded in the table below, as a means of comparison with the suggested standards of Snyder and Fleurent respectively.

(b) Baker's Sponge Tests. These are certain tests of physical, or dough-making, properties of flour which have been suggested by Mr. John Koelner, of Milwaukee, an expert in flour testing, as a result of a tour of inspection and investigation of the mills and bakeries of Europe. Although wholly empirical in the details of their operation, they would appear to be capable of yielding comparative results of practical value. They were carried out as follows.

Water-absorption. A dough of standard stiffness was first prepared by kneading thirty grams of "standard" Spring wheat flour (a Minnesota Spring wheat flour was used) with 55 per cent of its weight, or 17.5 cc. of water. Equal weights of the flour to be tested were treated in the same way, differing only in the amount of water used, in each case varying the amount by 0.5 cc. That amount of water which gave a dough of the same stiffness as the standard was taken as the correct water-absorption of the flour and calculated as percentage as reported in the table below.

For the expansion tests of the dough, a sponge was prepared by mixing

[1] Compt. rend. **123**, 755, (1896).
[2] This Journal, **26**, 263, (1904).
[3] Central Exp. Farm of Canada, Bull. No. 50, pt. II, 17.

100 grams of flour, 5 grams of compressed yeast, 5 grams of sugar, and the proper amount of water, as shown by the absorption test. The yeast and sugar were dissolved in the water which had previously been warmed to 90° F. The warmed flour and this solution were thoroughly mixed and kneaded to a smooth sponge in a Koelner's "Scientific Dough Kneader" (a machine so constructed that the dough is constantly worked against the surface of a tank which contains water at any desired temperature). The dough was thus kept at a temperature of 90° F. during kneading. When thoroughly kneaded, the dough was transferred to a graduated cylinder which had previously been warmed to 90° and slightly oiled on the inside. The cylinder was then placed in an "expansion box," or air-oven provided with a glass door through which the rising of the dough in the cylinders could be observed. The temperature of the box was kept at 90 per cent. F. The rise of the dough was observed frequently, and when it reached its greatest height the volume of the dough and the time required for the rise were noted. The cylinder was then taken out of the box, the dough cut down from the sides of the cylinder and kneaded down gently. The cylinder was then replaced in the expansion box, and the time and maximum height of the second rise of the dough noted. From these two readings the *average time of rise* and *average volume of rise* of the dough from 100 grams of flour were calculated.

Inasmuch as the expansive power of dough depends both upon the quality and the quantity of the gluten present in it, the *average rise per gram of gluten* may be considered as giving a probable measure of the quality of the gluten as shown by the expansive power of the flour.

(c) BAKING TESTS. In preparing the sponge for the baking tests the same general procedure was followed as in preparing that for expansion tests, except that the amount of ingredients taken was that commonly used for making a one-pound loaf of bread, *viz.*, 340 grams of flour, 10 grams of compressed yeast, 12 grams of sugar, 5 grams of salt, and the proper amount of water . The sponge was maintained at a uniform temperature of 90° during the mixing and kneading, which were continued for twenty minutes. The dough was then transferred to a greased bake-pan and placed in the expansion box and allowed to rise until it just touched a tin strip laid across the top of the pan, thus giving a uniform rise for all the samples which were tested. The pan was then transferred to an electric oven, heated to 400° F., and baked for forty minutes. This oven gave a very uniform and constant temperature and the conditions of mixing, kneading, raising and baking were identical in the case of each sample tested. Variations in the yeast were guarded against by tests of the fermenting power of each new batch of yeast, and by running duplicate baking tests on the same flour with different lots of the yeast. After baking, the loaves were turned out on a table to cool for thirty minutes, after which their *weight* and *volume* were determined. The volume was determined by placing the loaves in a cylindrical box of known cubical content and then pouring in fine seeds until the box was filled, carefully striking off the seeds level with the top of the box. The seeds which filled all the space around the loaf in the box were then poured into a graduate and their volume ascertained. This subtracted from the volume of the box gave the volume of the loaf. By dividing the volume of the loaf by its weight the *apparent specific gravity* is obtained. The writer believes that the apparent specific gravity, or comparative "lightness," is the best numerical basis of judgment as to the quality of bread. Color, flavor, texture, and ability to remain moist, etc., are, of course, qualities which most consumers of flour take into consideration, but these are very difficult, or impossible, of exact measurement. Commercial bakers would, perhaps, consider the weight of the loaf from a given weight of flour as a more satisfactory basis of judgment as to the value of flour for their purposes. But the last Census Report estimates show that only 16 per cent. of the bread of this country is made by bakers, the remainder being home-baked. "Lightness" is probably the greatest requisite for flour for home bread-baking. Furthermore Prausnitz[1] and Lehmann[2] have shown that more highly porous bread is more easily digested than heavier bread. Hence it seems probable that the apparent specific gravity is the best basis of comparison of the quality of different loaves of bread.

It is at once apparent that these baking tests were not carried out under the conditions which obtain either in home practice or in commercial bake-shops. They were, however, carried on under conditions which it was possible to control, and thus to secure uniformity of treatment of each sample, an absolute essential, if comparable results are to be obtained. The results on the different samples are, therefore, perfectly comparable with each other, but not necessarily the same as would have been obtained on the same flours in other laboratories or under other conditions of treatment.

Results of the Comparative Tests.

The final results of each of the tests on each sample are included in Table I. Fuller details of this work and of other analytical data of these samples will be issued shortly as a bulletin of this Experiment Station. Only a summary of these results is presented in the table below, with the purpose of making the article as brief as possible. In the table the samples are arranged in the order of the specific gravity of the loaves of bread which they produced, as shown in the last column. This is done on the assumption that the lightest loaves of bread are those of highest quality.

Aside from the comparison of the results of the different tests, the

[1] Arch. für Hygiene. 17, 639.
[2] Ibid. 21, 241.

table shows some valuable general facts to which attention may be called. One of the first, and perhaps the most significant, of these is the relation which is shown to exist between the quality of the bread and the climatic conditions under which the grain is grown. It will at once be noticed that the samples from grain grown in the dry section produced the best quality of bread, and those from the moist section the poorest bread. The first, or better half of the samples show eight from the dry section, five from the semi-arid and none from the moist section; while the second, or poorer half show none from the dry, five from the semi-arid, and eight from the moist sections. So far as the writer can discover there is no single definite effect of the climate upon the chemical compounds of the grain, at least as shown by any or all of the analytical tests which were made on these samples, which will fully account for this relationship. In general the samples from the dryer sections are higher in protein, gluten, and gliadin than those grown in moister localities, but there are many striking exceptions to this statement. In fact there are a considerable number of these samples in which the good or poor quality of the bread seems impossible to explain on any other grounds than some as yet undetermined effect of the climatic conditions under which the grain was grown.

Another interesting fact is that the percentage of protein, as determined by a chemical process, and that of gluten, as separated mechanically, is in very close agreement, except in the case of those samples where the total nitrogenous matter is low. In the latter the analytical figures invariably show an unbalanced condition of the gliadin-glutenin ratio, which probably accounts for the impossibility of securing a good mechanical separation of the gluten.

The gliadin number, or proportion of gliadin in the total protein of the flour is lower in every case than that which has been supposed to be required in flour of good bread-making qualities, while the quality of the bread, so far as the writer could judge, was as good as that from the average flour from other sections of the country. The question of the comparative quality of the bread from our Washington wheats with a low gliadin number and that from Eastern wheats is now under investigation in this laboratory. We have secured samples of wheat from Minnesota, North Dakota, Nebraska, Kansas, Illinois, and Tennessee, which we are now milling and testing along with the samples of Washington grown wheats. When these tests are completed we shall be able to determine whether our wheats yield bread of different quality from those in other sections, or whether the standards which have been suggested for gliadin-number are not satisfactory for universal application.

A study of the data presented in Table I shows that no single test or

TABLE I.—RESULTS OF COMPARATIVE TESTS

			Chemical Tests							Baker's Sponge Tests.				Baking Tests.		
Lab. No.	Variety of Wheat.	Section where Grain was Grown.	Protein (N × 6.25). per ct.	Moist Gluten. per ct.	Dry Gluten. per ct.	Water-holding Capacity of Gluten. per ct.	Gliadin. per ct.	Gliadin in Protein. per ct.	Gliadin in Gluten. per ct.	Water Absorbed by Flour. per ct.	Average Time of Rise of Dough. minutes	Average Volume of Rise of Dough. cc.	Average Rise per gram Gluten.	Weight of Loaf. grams	Volume of Loaf. cc.	Apparent Specific Gravity.
716	Turkey Red...	Dry.....	13.50	43.00	13.58	2.167	6.87	50.9	50.6	52	77	390	24.5	503.1	1330	0.3783
715	Fife.........	"	11.31	30.13	10.05	2.098	5.88	51.9	58.5	48	117	380	38.0	494.0	1300	0.3800
840	Bluestem......	"	12.29	37.84	11.18	2.387	5.81	47.2	51.9	50	65	377	33.7	492.2	1220	0.4034
714	"	"	11.04	34.23	10.82	2.108	5.61	50.8	51.9	47	77	365	33.7	512.5	1270	0.4035
804	Red Russian...	Semi-arid	8.31	22.40	7.90	1.835	4.22	50.8	53.4	51	67	418	52.9	486.0	1220	0.4050
792	Bluestem......	Dry.....	13.43	40.03	13.52	1.961	6.98	51.9	51.6	52	70	365	27.0	502.0	1220	0.4115
807	Macaroni......	Semi-arid	12.20	34.93	12.11	1.885	5.75	47.1	47.5	52	80	350	28.9	491.4	1190	0.4130
791	Little Club....	Dry....	11.24	34.28	10.99	2.109	6.22	55.5	56.6	52	112	377	34.3	504.0	1220	0.4131
706	Turkey Red...	Semi-arid	9.50	25.13	8.09	2.106	4.66	49.1	57.6	52	75	405	50.1	464.0	1100	0.4279
832	Bluestem......	"	10.93	32.35	10.72	2.018	5.37	49.1	50.1	50	80	367	34.3	475.1	1090	0.4359
1018	Little Club....	Dry....	9.44	15.19	5.25	1.893	4.17	44.1	79.0	50	55	335	63.8	483.4	1100	0.4386
644	" "	Semi-arid	9.52	24.28	8.18	1.902	4.61	48.4	56.3	52	62	355	43.4	502.0	1140	0.4403
699	Red Chaff Club	Dry....	14.29	40.89	13.28	2.072	7.14	50.0	54.5	49	67	360	27.2	488.5	1100	0.4441
830	Little Club....	Semi-arid	7.40	11.88	3.97	1.993	3.36	45.4	84.6	50	115	377	94.7	490.6	1100	0.4460
707	Bluestem.....	"	11.83	35.26	11.34	2.109	5.92	50.0	52.2	50	62	377	33.3	497.5	1100	0.4523
878	"	"	10.45	31.20	10.24	2.047	5.28	50.5	51.6	51	45	365	35.6	499.4	1100	0.4540
675	Fife...........	Moist...	8.13	16.80	5.58	2.011	4.22	51.9	75.6	52	67	380	68.1	464.0	1030	0.4548
704	Red Russian...	"	9.18	25.11	8.82	1.836	4.53	49.3	51.4	51	85	355	40.6	503.9	1080	0.4665
718	Bluestem.....	"	9.32	19.98	6.79	1.943	3.78	40.6	55.6	52	72	315	46.4	511.0	1070	0.4682
682	Red Russian...	"	8.40	16.16	5.49	1.942	4.02	47.9	91.4	52	95	357	65.2	498.7	1060	0.4705
750	Macaroni.....	"	10.32	29.07	10.30	1.822	4.56	44.2	44.2	52	55	390	37.9	531.5	1100	0.4832
696	Fife.........	Semi-arid	9.69	21.38	6.58	2.249	5.16	53.2	78.4	48	85	380	57.9	492.1	1030	0.4878
865	Little Club....	"	13.04	41.78	13.30	2.134	6.49	49.8	48.8	49	75	430	32.9	508.3	1040	0.4884
702	Bluestem.....	Moist...	9.68	25.12	8.56	1.934	4.71	46.2	54.7	51	57	365	42.6	496.6	980	0.5067
858	Macaroni.....	"	10.41	23.80	8.85	1.689	4.90	47.0	54.8	54	42	315	29.5	496.6	960	0.5104
705	Fife.........	"	8.70	17.00	5.61	2.036	2.83	32.5	50.4	50	75	305	54.4	519.3	920	0.5644

process gives results from which the comparative bread-making quality of the flour can be determined. This is perhaps best shown in Tables II and III. In Table II the samples are arranged in the order of the quality

TABLE II.—COMPARATIVE VALUE OF EACH SAMPLE AS SHOWN BY DIFFERENT TESTS.

Lab. No.	Variety.	Specific Gravity.	Volume of Loaf.	Relative Rank of Samples in Protein.	Gluten.	Gliadin.	Gliadin Number.
716	Turkey Red......	1	1	2	1	3	6
715	Fife	2	2	8	13	8	3
840	Bluestem.........	3	4	5	7	9	18
714	"	4	3	10	9	10	7
804	Red Russian......	5	7	24	19	20	8
792	Bluestem.........	6	5	3	2	2	4
807	Macaroni.........	7	8	6	5	11	19
791	Little Club.......	8	6	9	8	6	1
706	Turkey Red......	9	10	18	18	16	14
832	Bluestem.........	10	17	11	10	12	15
1018	Little Club.......	11	11	19	25	22	25
644	" "	12	9	17	17	17	16
699	Red Chaff........	13	12	1	4	1	10
830	Little Club.......	14	13	26	26	25	22
707	Bluestem.........	15	14	7	6	7	11
878	"	16	15	12	12	13	9
675	Fife..............	17	22	25	23	21	5
704	Red Russian......	18	18	21	15	19	13
718	Bluestem.........	19	19	20	20	24	23
682	Red Russian......	20	20	23	24	23	17
750	Macaroni.........	21	16	14	11	18	24
696	Fife.............	22	23	15	21	4	2
865	Little Club.......	23	21	4	3	5	12
702	Bluestem.........	24	24	16	16	15	21
858	Macaroni	25	25	13	14	14	20
705	Fife..............	26	26	22	22	26	26

of the bread which they produced as shown by their comparative specific gravity, which is indicated in the first column, and in the other columns there is given the rank of each sample as shown by the several other tests. In no case do the results by different methods of testing fully agree. In Table III the effect of differences due to variety of the wheats is eliminated by arranging the samples in groups according to variety, but the same disagreement as to comparative values of the different samples, as shown by the results of the chemical estimations and the baking tests, is shown. From these results it would appear that there is no definite relation between the relative percentage of protein, gluten or gliadin which a flour contains and its comparative baking quality. Hence it would appear that it is impossible to form final conclusions as to the baking quality of a flour from the results of a chemical analysis alone. To be sure, it is apparent that as a general rule flours which contain high percentages of

TABLE III.—COMPARATIVE VALUES OF SAMPLES ARRANGED BY VARIETIES.

		Relative Rank of Samples in					
Lab. No.	Variety.	Specific Gravity.	Volume of Loaf.	Protein.	Gluten.	Gliadin.	Gliadin Number.
840	Bluestem	1	2	2	3	3	6
714	"	2	1	4	4	4	2
792	"	3	3	1	1	1	1
832	"	4	6	6	5	5	5
707	"	5	4	3	2	2	4
878	"	6	5	5	6	6	3
718	"	7	7	8	8	8	7
702	"	8	8	7	7	7	8
791	Little Club	1	1	2	2	2	1
1018	"	2	4	4	4	4	5
644	"	3	2	3	3	3	3
830	"	4	3	5	5	5	4
865	"	5	5	1	1	1	2
715	Fife	1	1	1	1	1	1
675	"	2	3	3	4	4	3
696	"	3	2	2	2	2	2
705	"	4	4	4	3	3	4
804	Red Russian	1	2	1	1	1	1
704	"	2	3	3	2	2	2
682	"	3	1	2	3	3	3

these nitrogenous constituents are more apt to show high bread-making quality, but the exceptions are much too frequent to permit a definite conclusion of wide applicability to be drawn.

The results of the baker's sponge tests when considered alone appear to be absolutely valueless. The average time of the rise of the dough to its maximum height or volume is particularly erratic in its variations, having apparently no connection whatever with any other property of the flour. The average volume of rise, or expansive power, of the dough also appears to have no definite connection with other properties of the flour. Taken in connection with the gluten content, however, it does give an important indication of the baking quality of the flour. In general, a flour with a low percentage of gluten and a high volume of rise produces a good quality of bread, but one with a low percentage of gluten and a low volume of rise gives a poor quality of bread. With high-gluten flours the effect of the volume of rise of the dough is not so noticeable, although if we eliminate sample No. 865 (the poor quality of the bread from which seems to be wholly unexplainable) a somewhat similar relation between the quality of the bread and the expansive power of the dough to that which exists in the case of the low-gluten flours, is apparent.

In the results of the baking tests the largest loaves were usually also the "lightest," or those with the lowest specific gravity. Loaves of the same volume did not always have the same specific gravity, however, because of variations in weight, due to the greater or less loss of water during baking. From the standpoint of the commercial baker greater weight for the same volume of loaf would probably be desirable, since a one-pound loaf could be made from less flour. Whether this same property of greater capacity to hold moisture during baking, giving a heavier loaf of the same size, is a desirable one in flour for home-baking will depend upon whether a moist or a dry bread is preferred. If capacity to hold moisture during baking gives similar capacity to hold moisture after baking and so prevent the rapid drying-out of the bread, this would be a desirable quality. Experiments to determine whether this be true are planned and will be carried out in this laboratory at an early date.

Conclusions

From the results of these comparative tests, we must conclude that no single test which was tried is capable of giving conclusive evidence as to the baking quality of flour. Any of the processes which have yet been suggested for testing flour must be supplemented by a baking test if final and accurate conclusions are to be reached.

The baker's sponge tests appear to afford little evidence of value except in the case of low-gluten flours. In as much as these tests require nearly as much actual work and fully as much care and attention as the complete baking tests, it appears that they may well be abandoned in favor of the latter.

The writer is indebted to Mr. A. L. Glover and to Mr. H. B. Berry for assistance in this study, in carrying on the nitrogen determinations and the sponge and baking tests respectively.

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CORN OIL—ITS POSSIBLE USE AS AN ADULTERANT IN LARD AND ITS DETECTION.

BY WM. MCPHERSON AND WARREN A. RUTH.
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The statement is frequently made that corn oil is used as an adulterant in lard. On what authority this claim is made, we have not been able to ascertain. Both Lewkowitsch[1] and Allen[2] state that the oil is used for this purpose and it is probable that American authors have accepted these statements. Although I have conferred with a great many food analysts, I have never yet found one who has found a definite case of such adulteration. There may be two reasons for this : In the first place it may not be used for this purpose ; or, in the second place, the chemist may have failed to recognize it, although present, because no accurate method has been worked out for its detection. The following work was carried out with a view to determining whether corn oil may be so used and if so to determine some method for its detection.

To determine the effect of the presence of corn oil in lard, three samples

[1] Chemical Analyses of Oils, Fats and Waxes, 373.
[2] Commercial Organic Analysis, 2, I, 144.