UNIVERSITY OF MINNESOTA.

Agricultural Experiment Station.

BULLETIN No. 85.

CHEMICAL DIVISION.

JANUARY, 1904.

WHEAT AND FLOUR INVESTIGATIONS.

1. Glutenous and Starchy Wheats.
2. Composition and Bread Making Value of the Different Streams of White Flour Produced by the Roller Process of Milling.
3. Relative Protein Content of Wheat and Flour.
4. Composition of an Ancient Egyptian Wheat.
5. Influence of Storage and Bleaching upon Flours.
6. Relative Food Value of Graham, Entire Wheat, and Straight Grade Flours.

ST. ANTHONY PARK, RAMSEY CO., MINNESOTA.

McGill-Warner Co., Printers, St. Paul.

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GLUTENOUS AND STARCHY WHEATS.

HARRY SNYDER.

There are great differences in the protein or gluten content of wheats. Some samples contain as low as 8 per cent, others as high as 20 per cent. For purposes of nutrition, wheats with the maximum amount of protein or gluten, provided it is in the best form for bread making purposes, are the most valuable; hence it is highly desirable to be able to distinguish wheats of high from those of low protein content by the appearance or general character. It was the aim in this investigation to study the characteristics of wheat kernels with the object of determining the physical conditions associated with high and low protein content. Because of the extensive use of wheat flour for food purposes, it is unnecessary to suggest the importance of this matter when it is recalled that wheat of maximum gluten content contains as much protein as average beef, while that of minimum content, contains no more than rice.

Marked variations have been observed in the composition of wheat produced upon the same soil during different seasons. Variations in size, color and weight of kernels grown from the same seed have also been observed, suggesting that even in the same lot of wheat, individual kernels may vary in chemical composition particularly in protein content. Analyses of wheat have often shown the lack of as close an agreement of results as could be desired, particularly when separate samples taken from a large quantity of wheat grown upon the same land were analyzed. When the analyses are made from the same sample, duplicates agree reasonably well, but they frequently fail to check when comparisons are made of different samples taken from a large quantity of wheat. This has suggested a lack of uniformity in the composition of wheat rather than error in analysis. This lack of uniformity must be due to differences in composition of individual kernels, which are known to show differences in physical characteristics. It is easy to understand how such differences can occur in the case of commercial wheat, composed of grain from different seed and different farms. In the case of wheat grown from the same seed and upon the same farm, less difference would naturally be expected and duplicate samples from such a source it would seem should agree reasonably well. The failure to obtain concordant results, led to this study of individual types of kernels. Credit is due Miss I. D. Parker for assistance rendered in carrying out the details of this work.

In any sample of wheat slight physical differences in size, color and weight of the individual kernels are discernible. In this investigation comparisons were first made of the nitrogen content of heavy and light weight kernels. Some of the results are given in table No. 1. The results as a whole are fairly concordant. In most cases the light weight seeds contained the larger percentage of nitrogen and protein while in one sample out of six the heavier weight seeds contained the larger percentage amount. There was a decided tendency for the light weight seeds to contain the larger percentage of nitrogen, but because of the greater weight of the heavier seeds a much larger amount of total nitrogen was always found in a given number of them than in the same number of light weight seeds.

In the light and heavy weight seeds, selected from six samples of wheat it was found that the light weight seeds contained 16.17 per cent protein, while the heavy weight starchy seeds contained 13.69 per cent and the heavy weight glutenous seeds 15.56 per cent.

From these and other analyses, it would appear that the light weight and shrunken kernels are deficient in starch but comparatively rich in total protein. Such seeds are known to produce a lower yield of flour, and not being well filled and perfect, although nitrogenous in character, are not suitable either for the production of the best quality of flour or for selection for seed purposes.

The comparative nitrogen content of large and of small but otherwise perfect kernels was next considered. The results are given in table No. 2. In twenty-four out of twenty-seven cases the larger sized kernels contained the greater amount of nitrogen. The difference in sample No. 65 was 9.10 per cent in favor of the larger kernels. The average difference was 1.15 per cent. From the tests made, it would appear that the large and medium sized kernels contain more protein than the small but otherwise perfect kernels.

After making comparisons on the basis of weight and size of kernels, determinations were made on the basis of color irrespective of size. The samples tested were secured from various sources, and represent the different kinds and grades of wheat found on the market. Many of the samples were from wheats which had been analyzed in connection with previous milling investigations at the Experiment Station. The list includes the standard grades of Northwestern spring wheat, also soft wheats raised in Maine, Oklahoma, Oregon, Ontario, Kansas and other localities. In most cases the wheat was grown during the years 1902 and 1903, although some of the samples were three years old, while others were from five to twelve years old. It was the object to secure as large a variety as possible of both hard and soft wheats from different sources. In many of the samples the wheat was quite uniform in appearance, but upon close inspection, slight differences were discernible, some of the kernels being of a deeper amber color than others, some uniformly colored throughout, while others showed amber tips with lighter colored central portions.

From each sample fifty each of the two types of seeds designated respectively, light colored and dark colored were selected. The terms, light colored and dark colored are used in a comparative sense. That is, in the case of each sample two kinds of seeds were selected, one of light color and the other of darker amber color, without regard to size or weight of kernels, except that in each case the kernels were reasonably perfect and well filled. The light colored seeds from the different samples were not all of the same shade; differences between the light and dark kernels were quite noticeable. In some cases there was no appreciable difference in the weight of the light and dark kernels. Occasionally the light colored were the heavier and then again the dark colored were found to be the heavier weight. In table No. 3 the weight of one hundred kernels of the two types of seeds are given and the percentage amount of protein in each. The protein was obtained by multiplying the percentage of nitrogen, as determined by the Kjeldahl process, by the usual factor, 6.25. An examination of table No. 3 shows that the percentage of protein ranges from 8.47 in sample No. 16 to 17.59 in sample No. 20. In each case it will be observed that the darker seeds contained more protein than the corresponding light colored seeds. The differences in some cases are quite pronounced while in others they are very small. In sample No. 12, a difference of 4.09 per cent in favor of the dark colored seeds was obtained; while in sample No. 18, the difference was only .35. In general, however, there was a difference of from 1 to 3 per cent between the protein content of light and that of dark colored seeds from the same sample. The average difference in the thirty-four samples from the various sources, was 2.65 per cent in favor of the dark colored seeds.

In order to make a more thorough test, it was deemed advisable to procure and analyze additional samples of wheat grown from uniform seed and under the best conditions of wheat culture. In order to secure such wheats, a circular letter requesting that selected samples of wheat which had been grown from one lot of seed, be sent to the Experiment Station Chemical Laboratory for the purpose of analysis with the view of obtaining more extended data as to the protein content of dark and light colored kernels. This circular was sent to fifty graduates of the School of Agriculture from whom forty samples were obtained, a number stating that they were unable to secure such samples as desired. It is believed that these wheats afford a suitable basis for making comparisons between the protein content of light and of dark colored seeds, grown from the same lot of selected seed wheat reasonably uniform in character.

A number of the samples were from special kinds of seed distributed by the Minnesota Experiment Station and grown under the best conditions. The protein content of the light and dark colored kernels from these samples (see table 4) shows the same general difference as was observed in table No. 3. The light colored seeds invariably contained less protein than the darker ones; a general difference of from 1 to 3 per cent in favor of the dark kernels being noticeable. The largest difference, 4.87 per cent, was found in sample No. 37, while the smallest difference, 1.6 per cent, was found in sample No. 53. In a number of cases it was observed that the light colored seeds from one sample contained a larger amount of protein than the darker seeds from another sample; but invariably when the light and dark seeds were selected from the same sample, which had been produced from the same lot of seed, the difference was in favor of the dark kernels. It can not be said that when light and dark seeds from different sources are compared, that the dark ones contain the larger amount of protein, because in many cases they do not. *But when the two types of seed, light and dark, were selected from the same lot of wheat, the darker seeds in all samples analyzed, were found to be richer in protein.*

Since the darker seeds are richer in protein, it must necessarily follow that the lighter seeds contain the larger amount of starch. It has been commonly believed by wheat farmers, dealers and millers, that the lighter seeds are starchy while the darker are glutenous in character. These analyses show that this belief is founded upon a rational basis, as analyses of over sixty samples, each of light and dark seeds have, without exception, shown this to be true. Occasionally a sample of wheat is found which is so uniform in character that it is not possible to select from it two kinds of seeds, viz., light and dark ones. In the course of this examination, one such sample was found where there was no appreciable difference in the color of the kernels; duplicate analyses of fifty kernels yielded 2.85 and 2.86 per cent of nitrogen. In some cases the differences were so pronounced that three distinct types could be separated, as light, medium and dark. Analyses were made of two such wheats, No. 51, a hard wheat, and No. 58, a soft wheat. The protein content of the light, medium and dark kernels of the former being respectively 14.69, 15.55 and 16.94 and of the latter 7.18, 9.89 and 9.94.

It is suggested that the darker and more amber colored kernels show a larger percentage of nitrogen because the glutenous matter which is associated with a nitrogenous coloring body is not so much diluted with starch, which is light in color. When a mechanical analysis is made of wheat flour, as in washing out the gluten, the starch is invariably white while the gluten is amber or dark in color, showing that the coloring matter is largely associated with the gluten. This is particularly noticeable in the gluten obtained from hard spring wheat flour which has a characteristic creamy color. In making transverse cuttings of dark and light colored kernels with a knife it will be found that the amber kernels are harder and more flinty, while the lighter colored ones are softer and more starchy. This difference is observed in illustration No. 120, showing the flinty character of the dark colored seeds and the starchy nature of the light colored ones from samples Nos. 56 and 35. It is not correct to state that the hard flinty portion of the darker colored seeds is pure gluten, because it is not; it simply contains a larger amount of gluten than the lighter colored and softer

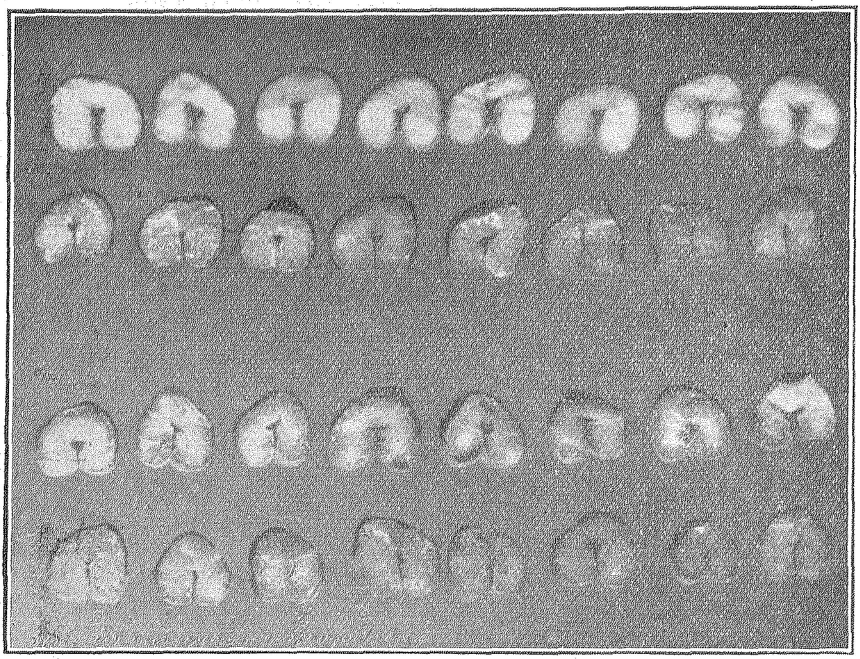


Fig. 120. Glutenous and Starchy Wheats x3¾. In rows 1 and 2 are light and dark colored seeds (cross section) from sample No. 56. The light colored starchy wheats contained 10.18 per cent protein and the dark colored glutenous wheats 14.86. In rows 3 and 4 are starchy and glutenous wheats from sample 35 containing 13.22 and 16.96 per cent respectively of protein.

portions. A physical examination of wheat kernels will often reveal their character as high or low in protein.

The fact that the light colored seeds are more starchy in character, while the amber ones are more glutenous, is valuable in the selection of seed wheat. In case it is desired to select seed which is glutenous, preference should be given to the medium sized, heavy weight and dark colored flinty kernels, as they contain a larger percentage of nitrogen than the lighter colored kernels. The hand picking of glutenous kernels, is possible in selecting seed for a small area. It is believed that such hand selected seed would ultimately result in the production of wheat of high gluten content. Why there should be so large a difference as 4 per cent in the protein content of wheat grown from a uniform lot of seed is not difficult to understand when it is remembered that wheat is self fertilizing and whatever starchy or glutenous tendencies a certain type of kernel may possess, upon reproduction, make themselves manifest. That the tendency for the production of gluten has exerted itself, is evidently one reason why kernels of larger gluten content were found in all of the samples analyzed. The process of natural selection has undoubtedly taken place, and as a result the two kinds of seeds have been produced. The protein content is a matter of considerable importance in the selection of seed wheat because a given sample may show an average of 14 per cent while individual kernels of the sample may contain as low as 11 per cent and others as high as 16 per cent. It is possible by means of close selection to obtain seed of the maximum protein content. As to the comparative value of the two kinds of seed for milling and bread making purposes, there is not sufficient data at hand to form definite conclusions. It is generally considered, however, that the more amber and glutenous wheats yields a higher percentage of the patent grades of flours and less of the clear and lower grades, while the lighter colored or starchy wheats show a tendency to produce a higher percentage of total flour, but less is recovered as patent grades.

In the inspection of wheat and the establishing of grades, size, weight and uniformity of color have been the main features considered. Along with the soundness and weight, requisite to the higher grades of wheat, special emphasis is laid upon uniformity of color and size of kernels. These physical characteristics are closely associated with and dependent upon chemical composition. This investigation shows that the darker colored and flinty wheats contain more protein or gluten than the lighter colored kernels. When wheats from different localities were examined it was found that the larger kernels were the more starchy; when kernels from the same sample were compared, the medium sized contained more gluten than the small but otherwise perfect kernels. Nature herself has carried on this process of selection and has produced seeds of high and low protein content; all man has to do is to pick them out. Heavy weight, medium sized, amber colored wheat kernels, although they show a lower percentage of nitrogen than shrunken or shriveled kernels, contain a larger amount of total nitrogen because of their greater weight and are preferable for seed purposes because they supply the plantlet with a larger reserve store of food in the form of nitrogen. For human food purposes wheats with 18 per cent of protein mainly in the endosperm or floury portion are preferable to those of low protein content. Flours of high protein content require less reinforcement with expensive nitrogenous foods.

TABLE I. Composition of Heavy Weight, Plump Kernels and of Light Weight, Shrunken Wheat Kernels.

No. of Sample	Source of Sample	Light Wgt. Seeds		Heavy wgt. Seeds Protein per cent	
		Protein Per Cent	Wgt. per 100 Seeds Gms.	Light Colored	Dark Colored
40	A. L. Pfeiffer, Olivia, Renville County, Minn.	16.79	1.4914	14.42	16.24
45	T. B. Austvold, Glenwood, Pope County, Minn. Minn No. 169	16.16	2.0626	13.85	16.04
48	B. A. Kidder, Marshall, Lyon County, Minn.	16.69	1.6518	14.02	16.35
50	Oliver Dalbotten, Nansen, Goodhue County, Minn.	16.34	1.6875	13.09	14.44
52	From Willmar, Kandiyohi County, Minn.	16.69	1.6830	13.43	15.59
80	F. Clause, Spring Valley, Minn.	16.34	1.6873	13.30	14.64
	Average	16.17		13.69	15.56

TABLE II. Comparative Protein Content of Large and Small Wheat Kernels from the Same Sample.

Sample No.	Kind of Sample	Large. Protein. Percent.	Small. Protein. Percent.	Large Wgt. per 100 Seeds Grams.	Small. Wgt. per 100 Seeds Grams.
1	Turkey Red wheat from Kansas	14.25	13.88	3.3952	1.5648
2	Turkey Red wheat from Kansas	14.09	14.50	3.1800	1.5462
3	Scotch Fife wheat from Ex. Sta. N. D.	13.94	13.13	3.6200	1.8712
4	Macaroni wheat from Ex. Sta. N. D.	12.56	11.19	5.6592	2.3496
5	Turkey Red wheat from Kansas	13.56	12.63	3.4596	1.6042
6	Turkey Red wheat from Kansas	14.31	12.50	3.6240	1.5630
7	Soft wheat raised in Maine	14.88	13.13	5.0732	2.6614
8	Soft wheat raised in Maine	14.54	12.44	5.1868	2.4844
9	Soft wheat raised in Maine	14.88	....	5.0672	2.3980
10	Soft wheat raised in Maine	16.44	12.75	5.7900	2.6224
11	Soft wheat raised in Maine	16.31	13.69	5.2800	2.1864
62	Winter wheat raised in Oklahoma	13.88	13.31	3.3616	1.7420
63	Winter wheat raised in Oklahoma	16.00	15.88	4.1452	1.8254
64	Oregon white wheat	8.69	8.06	5.2348	2.5762
65	Minn. 163	17.44	8.31	3.0284	1.3868
66	Minn. 165	17.25	15.19	2.9840	1.6868
67	Manitoba No. 1 Hard	14.19	14.31	3.5232	1.9900
68	Ontario Red	10.75	9.88	4.4588	2.4514
69	Ontario Red Reliable	12.31	12.94	4.2428	2.5806
70	Ontario White	10.75	10.56	4.5320	2.5194
71	Wheat from Goshen, Indiana	13.50	11.94	4.8960	2.1900
72	Oregon Soft Wheat	8.81	7.56	5.0540	2.6266
73	Mill Wheat, Minneapolis	15.13	15.00	3.4040	3.5898
74	Manitoba No. 1 Hard	13.38	14.31	3.2296	1.8600
75	Ontario Red	9.06	10.50	4.3920	2.9508
76	Ontario Red Reliable	10.38	12.94	4.4244	2.4674
77	Ontario White	13.19	10.63	4.6608	2.3128
	Average	13.50	12.35	....	....

TABLE III. Comparitive Protein Content of Light and Dark Colored Wheat Kernels, Miscellaneous Sources.

Sample No.	KIND OF SAMPLE.	Light. Protein. Per cent.	Dark. Protein. Per cent.	Light. Wgt. per 100 Seeds. Grams.	Dark. Wgt. per 100 Seeds. Grams.	Difference in Protein. Per cent.
12	Minneapolis Market No. 1 Hard N. W.	9.79	13.88	3.3802	3.1426	4.09
13	Minneapolis Market No 2 Hard N. W.	11.85	15.50	2.9714	3.0756	3.65
14	Minneapolis Market N. W. Rejected	12.34	15.18	3.0564	2.8830	2.84
22	Minneapolis Market Scotch Fife 3 years old	14.02	15.91	2.6794	2.8500	1.89
23	Minneapolis Market Scotch Fife 3 years old	13.53	15.53	2.7006	2,7442	2.00
26	Minneapolis Market Hard Wheat 3 years old	13.23	15.25	2.9410	3.9494	2.02
27	Minneapolis Market 3 years old, used in milling tests.	13.11	15.66	2.6834	2.6150	2.55
28	Minneapolis Market 3 years old, used in milling tests	13.39	16.62	2.6534	2.6662	3.23
29	Minneapolis Market 3 years old, used in milling tests	14.39	16.03	2.3510	2.5118	1.64
30	Minneapolis Market 3 years old, used in milling tests	13.52	15.73	2.6276	2.6894	2.20
31	Minneapolis Market 3 years old, used in milling tests	14.04	16.38	2.5788	2.6850	2.34
32	Minneapolis Market 3 years old, used in milling tests	13.33	16.17	2.4614	2.7620	2.84
7	Soft Wheat raised in Maine	12.09	15.90	3.8265	4.1100	3.81
8	Soft Wheat raised in Maine.	11.38	16.24	4.1045	4.2715	4.86
9	Soft Wheat raised in Maine	12.31	14.56	3.9725	4.1550	2.25
10	Soft Wheat raised in Maine	11.44	15.84	4.1975	4.4080	4.40
11	Soft Wheat raised in Maine	12.04	16.01	3.7680	4.1658	3.97
1	Turkey Red Wheat from Kansas City	13.29	14.75	2.7108	2.6533	1.46
2	Turkey Red Wheat from Kansas City	13.76	15.43	2.4568	2.6808	1.67
5	Turkey Red Wheat from Kansas City	11.82	14.38	2.6718	2.7840	2.56
6	Turkey Red Wheat from Kansas City	11.65	15.66	2.5958	2.7823	4.01
3	Scotch Fife Wheat from Fargo, N. Dak	12.15	14.57	2.6720	2.9605	2.42
4	Macaroni Wheat from Fargo, N. Dak	10.60	12.76	4.0703	4.0438	2.16
15	Red Reliable Wheat from Ontario, Canada	10.45	14.64	3.9476	3.8152	4.19
16	Soft Winter Wheat raised in Oregon	8.47	11.67	4.6610	4.8488	3.24
17	Minnesota 163 (several years old)	16.69	17.01	2.4508	2.4468	.32
18	Minnesota 165 (several years old)	15.42	15.77	2.5384	2.5940	.35
19	Hard Scotch Fife Wheat, crop of 1891	11.41	13.42	2.8994	2.8094	2.01
20	Hard Winter Wheat from Oklahoma	15.20	17.59	3.1604	3.1558	2.59
24	Minnesota 149 (old)	14.51	16.28	3.3342	3.2844	1.77
25	Manitoba No. 1 Hard, crop of 1891	12.11	15.03	2.8500	2.9720	2.97
	Average	12.68	15.33	....	....	2.65

TABLE IV. Showing Comparative Protein Content of Light and Dark Colored Wheat Kernels, Grown from Selected Seed Wheat.

Sample No.	SOURCE OF SAMPLES.	Light. Protein. Per cent.	Dark. Protein. Per cent.	Light. Wgt. per 100 Seeds. Grams.	Dark. Wgt. per 100 Seeds. Grams.	Difference in Protein. Per cent.
33	G. W. Schrepel, Le Sueur, Le Sueur Co., Minn	12.93	14.46	2.3814	2.6906	1.53
34	A. J. Goodal, Bathgate, North Dakota	10.74	13.64	3.4350	2.6788	2.90
35	G. M. Emmons, St. Francis, Anoka Co., Minn. Minn. 163	13.22	16.96	2.6626	2.7536	3.74
36	Alfred Larson, Winthrop, Sibley Co., Minn	13.35	15.24	2.3312	2.3756	1.89
37	E. E. Boutwell, Mankato, Blue Earth Co., Minn	11.98	{ 14.62 } { 16.85 }	2.4290	2.8310	4.87
38	O. M. Olson, Monticello, Chippewa Co., Minn. Minn. 169	12.99	14.11	2.7090	2.7340	1.12
39	J. W. Aiton, Grand Rapids, Itasca Co., Minn	9.50	12.73	3.3850	3.5090	3.23
40	A. L. Pfeiffer, Olivia, Renville Co., Minn	14.42	16.24	2.1358	2.3120	1.82
41	H. B. Wasson, Belview, Redwood Co.. Minn	14.92	16.15	2.1770	2.2630	1.23
42	O. O. Enestvedt, Belview, Redwood Co., Minn. Minn. 169	14.47	15.73	2.2444	2.5382	1.26
43	W. C. Roberts, Western, Otter Tail Co., Minn	14.21	15.77	2.7628	2.9184	1.56
44	H. H. Chapman, Grand Rapids, Itasca Co., Minn	9.28	11.32	3.5350	3.4374	2.04
45	T. B. Austvold, Glenwood, Pope Co., Minn. Minn. 169.	13.85	16.04	2.6144	2.4672	2.19
46	Paul Ferch, Odessa, Big Stone Co., Minn	14.66	16.61	2.5150	2.6486	1.95
47	George Henderson, Halstad, Norman Co., Minn	10.84	13.74	3.4032	2.9798	2.90
48	B. A. Kidder, Marshall, Lyon Co., Minn	14.02	16.35	2.4134	2.3586	2.33
49	J. F. Cross, Childs, Wilkin Co., Minn	13.37	16.14	3.1132	2.8922	2.77
50	Oliver Dalbotten, Nausen, Goodhue Co., Minn	13.09	14.44	2.5588	2.3906	1.35
51	Carl Olstad, Hanska, Brown Co., Minn	15.43	16.49	2.4566	2.5852	1.06
52	E. Swensen, Willmar, Kandiyohi Co., Minn	13.43	15.59	2.2674	2.6480	2.16
53	E. Swensen, Willmar, Kandiyohi Co., Minn	14.31	15.89	2.6004	2.5766	1.58
54	Robert Dailey, Flandreau, S. Dak. Minn. 163	14.25	15.84	1.9940	2.0504	1.59
55	Mathew Frame, Castle Rock, Dakota Co., Minn	12.20	14.19	2.3844	2.4800	1.99
56	A. T. Campion, Angus, Polk Co., Minn	10.18	14.86	2.9250	2.3002	4.68
57	Albert Bratrud, Spring Valley Fillmore Co., Minn. 10 per cent of sample is Minn. 13, 1891; remainder Dak. wheat 1896.	11.90	14.14	2.3314	2.5840	2.24
58	H. C. R. Scott, Pasadena, Cal. Western soft winter wheat	7.63	8.87	3.7710	4.0064	1.24
59	H. M. Johnshoy, Starbuck, Pope Co., Minn. Minn. 169	14.02	15.99	2.7268	2.8570	1.97
60	J. N. Holmberg, Renville, Renville Co., Minn	14.41	15.29	2.4176	2.9216	.98
61	C. O. Gilfillan, Morgan, Minn	12.78	14.68	2.2774	2.2820	1.90
78	A. T. Baker, Kenyon	12.82	14.66	2.2428	2.3316	1.84
79	E. A. King, Chatfield	12.15	13.95	3.2014	3.2024	1.80
80	F. Clause. Spring Valley	13.30	14.64	2.2642	2.6120	1.34
	Average	12.83	14.93	....	....	2.10

Sample No.	SOURCE OF SAMPLE.	Light. Protein. Per cent.	Meduim. Protein. Per cent.	Dark. Protein. Percent.	Light. Wgt. per 100 Seeds. Grams.	Medium. Wgt. per 100 Seeds. Grams.	Dark. Wgt. per 100 Seeds. Grams.
51	Carl Olstad, Hanska. (Hard Wheat)	14.69	15.55	16.99	2.2574	2.5450	2.4888
58	H. C. R. Scott, Pasadena, Cal. (Soft Wheat)	7.18	9.89	9.94	2.9220	4.5510	4.1194
	Average	10.94	12.72	13.47	....	....	....

[NOTE.—In sample No. 37 separate analyses of the dark colored seeds were made by different analysts who obtained the results as noted, suggesting a material variation in composition of the dark colored seeds.]

COMPOSITION AND BREAD MAKING VALUE OF FLOUR PRODUCED BY THE ROLLER PROCESS OF MILLING.

HARRY SNYDER.

During the roller process of wheat milling, a number of streams of flour, depending upon the system employed, are produced which, after purification and reduction, are united to form the standard grades, as: 1, First patent; 2, Second patent: 3, Straight grade; 4, First clear; 5, Second clear; and 6, Red Dog. These various flour streams may also be combined to form special brands of flour.

The different flour streams forming the standard grades of flour have different chemical composition and bread making value. In order to determine the comparative values of the different constituent streams produced by the roller process of wheat milling, an investigation was undertaken involving analysis of the wheat, of the various break and middlings flours, and of the bread made from the different flour streams. The Minnesota Flour Milling Company of Stillwater, Minnesota, supplied the samples for this investigation. The mill had recently been equipped with modern machinery and has a capacity of two hundred and fifty barrels per day. The samples were taken by Mr. M. A. Gray, a practical head miller, who was at the time a special student of the Minnesota College of Agriculture. Some of the technical and analytical tests involved in this work also were made by Mr. Gray.

The wheat used was of good quality, weighing fifty-eight pounds per bushel, and graded by the State Grain Inspector as No. 1 Northern. Before milling, the wheat was thoroughly screened, scoured and tempered. It was then passed on to the first break which flattened some of the softer kernels, splitting them along the longitudinal groove, the harder kernels being broken up by the rolls into segments. A small amount of flour known as first break flour was separated by means of a fine bolting cloth as were also some of the granular middlings called first middlings, which were then passed on to other rolls for reduction. At each of the breaks, a break flour and granular middlings were obtained. In the gradual reduction process of milling, the aim is to remove the fine flour as rapidly as it is reduced, and to subject both the break flours and middlings to purification while the reduction is taking place. The process admits of more effectual removal of the bran, shorts, germ, dust, dirt, wheat hairs and other forms of debris than would be possible were the wheat kernel ground directly into a fine meal. The middlings, tailings and chops are passed from roll to roll until all the fine flour particles are reduced, removed and purified. Each break affects a mechanical separation of the chop into break flour, middlings flour and tailings. This process is repeated until finally the flour stock is practically all removed from the wheat offals. The different streams of break and middlings flour are blended so as to form either standard grades or special brands of flour. At the time the samples used in this investigation were taken two kinds of flour were being produced, a ninety per cent patent, and a clear grade sometimes called bakers'.

Chemical analyses and technical and baking tests were made of the two finished flours and of seventeen of the break and middlings flours. The chemical analyses included mainly those determinations which are of most value in ascertaining the commercial value of the flour, namely: moisture, ash, total nitrogen, gliadin and acidity. The technical determinations included dry gluten, absorption, expansion of the gluten and color of the flour. The baking tests included size of the loaf, color, texture and quality of the bread product.

COMPOSTION OF SAMPLES.

Moisture. The moisture is determined by drying a weighed amount of the flour in a water oven and determining the loss of weight in drying. An excess of moisture, over thirteen per cent in the freshly milled samples, is undesirable as it has a tendency to cause the flour to become unsound by fermentation. Ordinarily flour contains from 10 to 12.50 per cent water.

The moisture content of the flour samples used in this investigation ranged from 9 to 11.68 per cent. The first break flour contained most and the tailings least moisture. It is quite noticeable that as the stock passes from roll to roll there is a tendency for the moisture to decrease. The break flours contain more moisture than those obtained from the corresponding middlings. A part of the moisture in flour comes from the water used in tempering the wheat. The tempering of wheat is an important operation in milling as it prevents the bran from becoming brittle and pulverizing, and also secures a better separation of the flour from the offals. The moisture content of the air perceptibly influences the moisture content of the flour. The per cent of moisture in these flours is quite similar to that found in other samples produced by the gradual reduction process of milling. Differences in flour yield when similar wheats are milled in different mills are often due to differences in moisture content of the flours. For example, a yield of 70 per cent flour containing 11 per cent moisture is equal to 71.1 per cent flour containing 12.5 per cent moisture.

TABLE V. Chemical Composition of Samples.

NAME OF SAMPLE.	Water. Per cent.	Ash. Per cent.	Gliadin Number.	Acidity. Per cent.	Protein (Nx6.25) Per cent.	Carbohydrates and Fat. Per cent.
90 per cent Patent	10.89	.48	60.75	.09	13.38	75.25
Clear grade	10.53	.85	54.63	.13	14.19	74.43
First break	11.68	.61	60.83	.09	13.56	74.15
Second break	11.10	.52	59.17	.09	15.00	73.38
Third break	10.97	.49	59.09	.10	16.50	72.04
Fourth break	11.14	.71	58.31	.11	18.44	69.71
First germ	10.90	.48	54.17	.08	12.00	76.62
Second germ	10.37	.59	56.44	.10	12.63	76.41
First middlings	10.37	.42	57.43	.08	12.63	76.57
Second middlings	10.69	.42	63.85	.08	13.31	75.58
Third middlings	10.29	.37	66.67	.08	12.56	76.78
Fourth middlings	11.08	.38	64.29	.07	12.25	76.29
Fifth middlings	10.21	.42	62.44	.09	12.81	76.55
Sixth middlings	10.15	.37	57.97	.09	12.94	76.53
Seventh middlings	10.30	.47	59.16	.10	13.31	79.92
First tailings	9.01	.77	50.00	.12	13.50	76.72
Second tailings	9.54	.65	57.94	.10	13.38	76.43
Second tailings cut	9.32	.83	54.88	.11	13.44	76.42
Shorts duster	9.36	1.61	39.51	.18	15.19	73.84
Shorts middlings	9.79	4.03	....	....	17.47	....
Wheat	13.07	1.82	....	....	14.25	....

Ash. The ash is determined by burning a weighed amount of flour and weighing the mineral residue. Uniform conditions for complete volatilization of the flour at a low temperature can be secured by an electric muffle. The percentage amount of ash in different wheat crops varies but little from year to year. The ash determination is of value in establishing the grade of a flour. The more completely the bran, shorts, and germ particles are removed, the smaller is the ash content. There is a definite relationship between the ash content and the grade of the flour. The ash is more constant in amount and composition than any other class of compounds found in wheat, consequently the ash content of the different grades of flour is quite

CORRECTIONS TO BULLETIN No. 85.

Page 191, 7th mds. carbohydrates read 75.92, not 79.92; page 208, dry matter: No. 79, read 89.10, not 89.18; No. 86, 85.68, not 87.68; No. 79, 87.85, not 87.89; protein, No. 83, read 16.44, not 16.40; No. 87, 14.07, not 14.17; No. 100, 16.43, not 16.33.

uniform. The patent grades of flour almost invariably contain less than .50 per cent ash. The range in ash content of the different grades of spring wheat flour is approximately as follows:

	Per Cent Ash.
First Patent	.35 to .40
Second Patent	.40 to .48
Straight Grade	.48 to .55
First Clear	.60 to .90
Second Clear	.90 to 1.80

Flour made from fully matured wheat has the minimum ash content, because high maturity is usually accompanied by a low ash. The ash determination cannot be used to establish the comparative value of two samples of flour belonging to the same grade, for example, if two samples of flour contain respectively .36 and .40 per cent ash, the one with the lower per cent is not necessarily the better flour. If, however, two samples of flour contain respectively .42 and .55 per cent ash, the former is a patent grade and the latter a straight grade flour. In grading Hungarian flours, the ash determination has been used successfully by Virodi. When making comparisons, however, too strict an application of the results is not admissible, particularly when the ash determinations are made in different laboratories and by different analysts as the results then are not always strictly comparable. When the ash determinations are made under similar conditions, the results are of much value in determining the grade of a flour, as will be observed in examining the results in table No. 1.

The ash content of the flour samples used in these tests ranged from .37 to 1.61 per cent. The middlings flours contained the least and it is these streams which constitute the main portion of the stock forming the patent grades. The break flours contain appreciably more ash than the middlings and constitute the main source of the stock which forms the lower grades. Only slight variations are found in the ash content of the first six middlings flours. The seventh, however, contains somewhat more ash. The ash in the break flours varies more in amount than in the middlings, the third break contains the highest. It is noticeable that the bread making value of the different streams varies with the ash content, those with high ash percentages producing a poorer loaf than streams low in ash. Good flour stock occasionally contains a high per cent of ash due to imperfect removal of the offals.

Total Nitrogen and Crude Protein. The protein represents the nitrogenous matter of the flour and is obtained by multiplying the per cent of nitrogen by 6.25. In wheat and flour, the protein is composed largely of gluten, but contains small amounts of nitrogenous bodies other than gluten. The percentage of gluten in the higher grades of flour is directly proportional to the amount of protein present. However, in drawing comparisons between the nutritive values of different samples of flour, it is not possible to reach definite conclusions on the basis of the protein content alone, but the other nutrients and their digestibility must also be considered. The total nitrogen is of special value as a check on the gluten and also for determining the gliadin number of the flour.

The variations in proteid or glutenous material of the different flour streams of this experiment were quite noticeable. The wheat used contained 14.25 per cent, and the finished flour, 90 per cent patent, contained 13.38 per cent. Slight variations were observed in the protein content of the middlings, the fourth middlings contained 12.25 per cent and the second and seventh 13.31 each. From the fourth to the seventh middlings, there was a gradual increase in protein content. The break flours showed an increase from 13.56 per cent protein in the first break to 18.44 per cent in the fourth break. It is noticeable that the break flours, except the first break, all contained more protein than the original wheat. In the fourth break there was 4.20 per cent more than in the wheat and about 1 per cent more than in the shorts. The parts of the wheat kernel except the germ which contain the largest percentage of protein find their way into the break flours, and not into the offals. The break flours contain more protein than the middlings, but the protein is not as valuable for bread making purposes.

Judged on the basis of protein content alone as a measure of food value without regard to digestibility, the break flours, particularly the fourth break, would be considered the most valuable, and the fourth middlings the least valuable, this, however, would be an erroneous valuation because the fourth break flour produced the smallest sized, darkest and poorest loaf physically of any of the break or middlings flours, while the fourth middlings flour produced the largest, lightest and best loaf physically. A high protein content in a flour is desirable provided it is accompanied with physical properties suitable for bread making purposes.

Gliadin is the glue-like body of wheat gluten which binds the flour particles and enables the dough to expand when gas is generated by the action of yeast or by chemicals. The bread making value of flour in a large measure is dependent upon the amount of gluten and the proportion of gliadin which the gluten contains. Either an excessive or scant amount of gliadin may cause a flour to have poor bread making qualities. The best grades of hard wheat flour contain from 56 to 68 per cent of proteids in the form of gliadin. The per cent of total nitrogen in the form of gliadin varies in different flours. In a flour with a gliadin number of sixty, 60 per cent of the gluten is gliadin and the remaining 40 per cent is composed mainly of glutenin. For convenience the percentage of total protein in the form of gliadin is called the gliadin number of the flour. The gliadin is extracted from the flour with a 70 per cent solution of alcohol, and the amount is determined by the polariscope* or from the nitrogen content of the extract. The gliadin content of a flour is only one of the factors in determining its bread making value. Poor bread making qualities may be due to other causes than either an excess or a deficiency of gliadin; it is, however, due more frequently to an unbalanced condition of the gluten than to any other cause.

The gliadin numbers of the different flours ranged from 39.5 to 66.67. The highest gliadin content was found in the third and fourth middlings and the lowest in the tailings. Four of the middlings flours contained a relatively larger amount of gliadin than the break flours, one contained about the same and two a somewhat less amount. In the finished flour (90 per cent patent), 60.75 per cent of the total nitrogenous material was in the form of gliadin. The flours which produced the best quality of bread were, in order of excellence: fifth, fourth, third, second and first middlings. The differences in bread making value between some of the middlings flours, as to color, size of loaf and texture, were not large. The gliadin numbers of the middlings flours which produced the best quality of bread were: 62, 64, 67, 64 and 57, and the per cent of protein of which 62 to 67 per cent was in the form of gliadin ranged from 12.25 to 13.31. A good quality of bread was produced from the first germ containing 12 per cent protein, of which 54 per cent was gliadin. Such flours, however, produce a smaller sized

*Journal Am. Chem. Society, March, 1904.

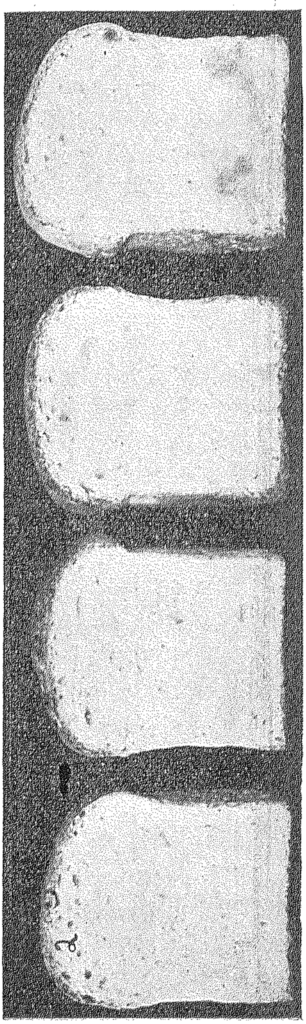
loaf and the glutens are deficient in expansive power, as will be observed from the figures given in table 2. The gliadin content appears to bear a close relationship to the expansion of the gluten, to its physical properties, as hard or soft, and to the size of the loaf produced. Exceptions, however, will be observed as in the case of the fourth break flour which had a low gliadin number, a high expansion of gluten and produced a medium sized loaf. But the bread was of poor quality. The protein and gliadin content alone cannot be taken as a basis for determining value, but when considered jointly with other determinations, as ash, moisture, acidity and the technical and baking tests, they are of material value.

Acidity. The acidity of a flour indicates the amount of water soluble free acid bodies which can be neutralized by an alkali. When flour is made from sound, normal wheat, the patent grades contain less than .10 per cent of acid. High acidity may be due either to lack of complete maturity of the wheat or to unsoundness caused by fermentation, as in sprouted grain. A flour may have a low acidity and be unsound, but a high acidity usually indicates an unsound flour and one of poor keeping qualities. Germ, bran, and debris, as wheat hairs, contain the organized ferments, and hence flours which are not well cleaned and purified have poorer keeping qualities than those from which the offals are more completely removed. A noticeable difference in the acidity of the various streams is observed in table 1.

Of the samples tested, the fourth middlings flour had the lowest and the tailings and shorts duster the highest acidity. The middlings flours showed a slightly lower acidity than the corresponding break flours. The acidity of all of the streams was low. It is to be noted that the flours with the higher acidity were less valuable for bread making purposes than those of lower acidity. The finished flour, 90 per cent patent, contained .09 per cent of acid calculated as lacti acid. The middlings and break flours contained from .07 to .11 per cent.

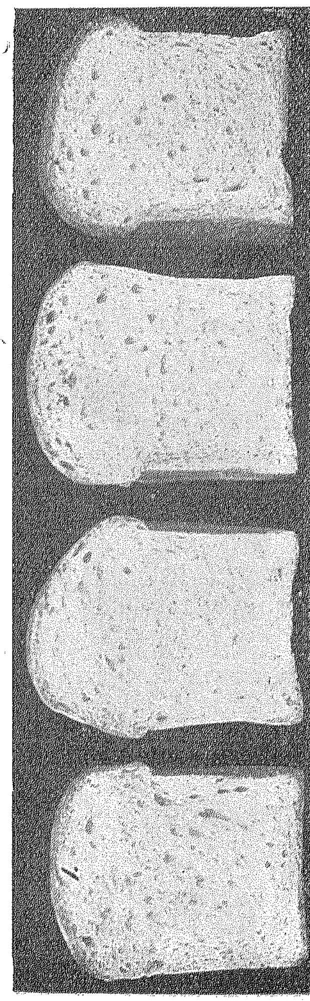
TECHNICAL AND BAKING TESTS.

Dry Gluten. The dry gluten was obtained by making a stiff dough of 10 grams of flour and removing the starch mechanically with water as described in Bulletin No. 54, Minn. Ex. Station; this wet gluten was then washed, dried and weighed. All of the flours showed a high per cent of gluten. The glutens ranged on the average a little higher than the crude protein content of the flour. The same general relationship which was observed in the protein results was also noticeable in the gluten determinations. The glutens from the middlings were elastic, creamy in color and of good quality. The glutens from the break flours were slightly darker in color, that from the fourth break flour being the darkest. The color of the glutens was more characteristic, as light cream, dark cream and gray, than the color of the flours themselves. The quality of the gluten ap-



1 First Break 2 Second Break 3 Third Break 4 Fourth Break

Fig. 121. Bread from Break Flours.

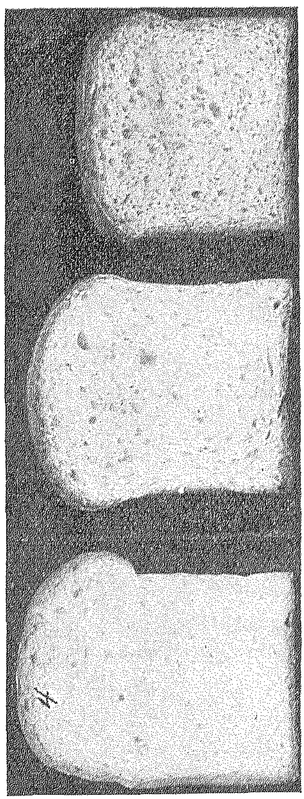


5 90 Per Cent Patent 6 First Germ 7 First Middlings 8 Second Middlings

Fig. 122. Bread from Patent and Middlings Flour.

pears to be equally if not more important than the quantity in determining the bread making value of a flour. A high gluten content does not necessarily imply a large loaf or good bread making qualities. The sample with the largest gluten content was the fourth break flour which produced a rather small loaf, and one of poor quality. A high gluten content is desirable provided the gluten is of good quality.

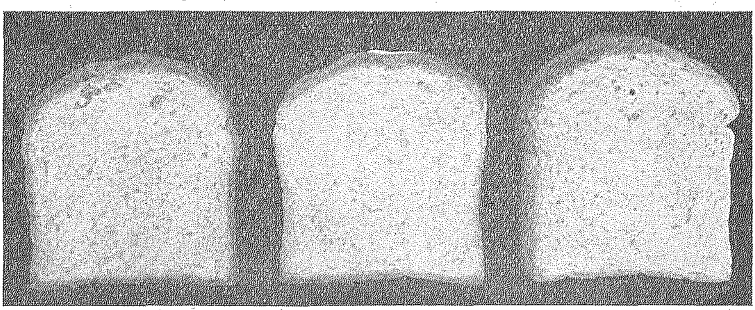
9 Third Middlings — 10 Fourth Middlings — 11 Fifth Middlings — 12 Sixth Middlings



13 Seventh Middlings — 14 Second Germ — 15 Shorts Duster

Figs. 123 and 124. Bread from Middlings Flours and Low Grade.

Color. Comparisons as to color are made on the basis of the middlings flours which were light cream in color. The numbers assigned in the column headed "Color value" are simply relative and designate the order in which the various flours ranked when compared with the fifth middlings flour which is marked 1. The third middlings marked 2 ranks next in color value. The break flours were compared one with another, the Roman numerals being assigned to designate their grade as to color. Color is a physical property which is of material value in determining quality, and is used as an index by the miller to establish comparative grades. It indicates in a unique way the



9 First Tailings — 10 Second Tailings — 11 Second Cut

Fig. 125. Bread from "Tailings" Flours.

character of a flour, as differences in chemical composition and bread making value of the different streams are attended with differences in color. The color of a flour, of the gluten and of the bread indicate in a characteristic way the comparative bread making values of the flour samples. When exposed to the sunlight, flours bleach, but imperfections, as dust particles and debris, are then often more discernible because many of these bodies darken upon oxidation. The miller when he takes the color of his flour as a guide in milling operations employs the most suitable simple test applicable to the purpose, as the colors of the different streams vary with their purity and quality.

Expansion. The expansion of the gluten is expressed in millimeters and represents the height reached by the gluten mass obtained from 20 grams of flour, when baked in a Foster gluten tester, which is provided with a cylinder 1 3-16 inches in diameter. A piston carrying a 4 ounce weight is placed above the gluten. The figures given represent the expansion of the glutens from similar weights of flour and not the comparative expansion of similar weights of gluten. A high expansion may represent either a large amount of gluten or a smaller amount of more elastic, tenacious gluten. A high gluten expansion usually indicates capacity for producing a large sized loaf, although the size of the loaf is not always proportional to the expansion of the gluten. A high expansion of gluten, however,

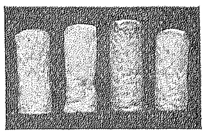


Fig. 126. Glutens baked in a Foster Gluten Tester.

is desirable in a flour, as it is generally an indication of good bread making properties.

The color values and comparative physical properties of the bread made from the different streams of flour apply only to this system of milling. In longer systems, the second and third middlings flours usually make a better showing as to color and quality than the fourth and fifth middlings. There is usually but little difference in the quality of the bread made from the second, third and fourth middlings. That the fifth middlings produced the best and whitest loaf in this investigation is doubtless due to this particular system of milling and the wheat used.

Quality of Bread. Bread was made from the different flour samples, and the size, and quality of the loaves, as to texture and color, were determined. The same amounts of flour, yeast, shortening and salt were used in each baking test. Some of the flours absorbed and required more water for making the dough than did others. All of the samples were treated alike with the object of securing comparative results. The size of the loaves in inches is given in table VI, and also notes in regard to texture and quality. The fifth middlings flour produced the best quality of bread both in texture and color. The second break flour produced the best bread of

TABLE VI. Results of Technical and Baking Tests of Flour Samples.

Name of Sample.	Dry Gluten. Per Ct.	Expansion. mm	Color value	Size of Loaf Inches.	Remarks.
Patent, 90%	13.25	64	9	15⅜x17⅛	Good quality of bread. In texture not quite as good as bread from middlings flour.
Clear grade	14.20	49	11	13½x15⅛	Good quality and color for clear grade.
First break	14.48	61	III.	15¼x16⅜	Somewhat dark in color, very porous and of comparatively poorer quality than from other streams.
Second break	17.20	70	I.	15½x16⅝	Good color and texture.
Third break	18.42	73	II.	15 x17	Fair color and texture, somewhat porous.
Fourth break	20.35	76	IV.	14⅝x16¼	Poorest of break flour.
First germ	12.60	51	6	14⅜x16⅛	Good texture and quality.
Second germ	13.20	51	10	14 x15¾	Fair texture and quality.
First middlings	13.92	38	5	14½x16¼	Good quality, see color value.
Second middlings	14.80	77	4	15 x16½	All of the middlings flours produced a good quality of loaf, the main difference being in size and color.
Third middlings	13.75	48	3	14¼x16⅛	
Fourth middlings	13.30	66	2	14⅝x16⅝	
Fifth middlings	14.09	64	1	15⅛x16½	
Sixth middlings	13.30	75	7	14⅞x16¾	
Seventh middlings	13.96	60	8	15 x16½	
First tailings	14.29	45	13	13¼x14⅝	Dark and only fair in color and quality.
Second tailings	13.70	42	12	13⅜x14¾	
Second cut	16.43	54	14	14 x15	Dark and of poor quality.
Shorts duster	17.33	......	15	12⅜x14	

the break flours. Flours from the shorts duster and tailings produced poorer breads than did the middlings or break flours. Some of the differences in the breads can be observed in the illustrations.

It will be seen in tables 5 and 6 that the best quality of bread was produced from the middlings flour and that the largest sized loaves were not made from the flours containing the largest amounts of gluten or protein. The quality of the gluten and the absence of impurities in the flour, as dust and debris particles, influenced the character and size of the loaf more than other factors.

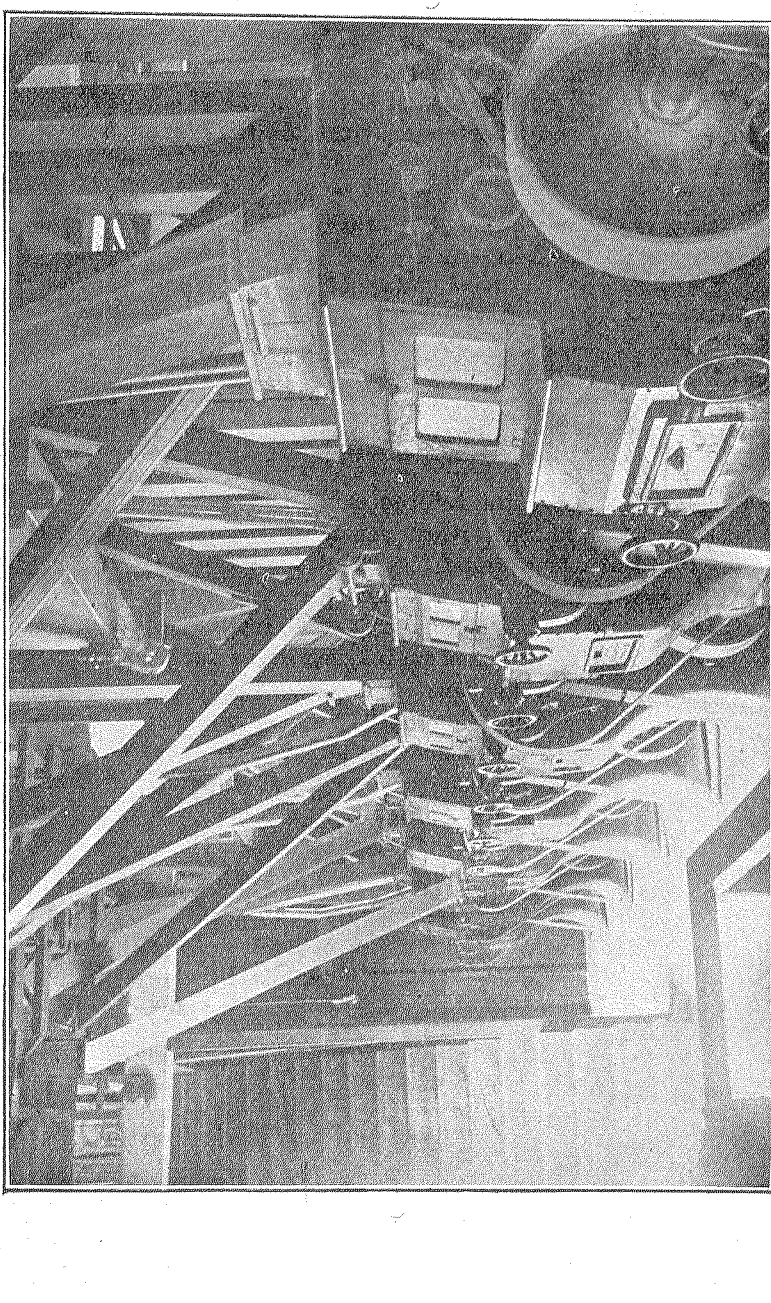


Fig. 127. Interior view of Flour Mill Showing Arrangement of Machinery for Reduction of Flour Streams.

WHEAT OFFALS.

The screenings, dust, scourings, bran, and shorts were sampled and analyzed. The shorts contained a high percentage of both fat and protein because of the presence of the germ. The composition of the wheat and of the offals is given in the following table:

TABLE VII. Composition of Wheat and Wheat Offals.

	Water. Per Cent.	Ash. Per Cent.	Crude Protein. Per Cent.	Ether Extract. Per Cent.	Crude Fibre. Per Cent.	Nitrogen free-ex't. Per Cent.
Screenings	11.62	....	13.84	....	....	....
Scourings	9.09	3.40	11.63	2.44	....	....
Dust	8.77	5.51	11.25	3.85	....	70.62
Bran	12.35	5.81	14.37	4.93	9.58	52.96
Shorts	9.79	4.05	15.94	6.23	7.19	56.80
Wheat	13.07	1.83	14.22	2.20	....	....

There was but little difference in the protein content of the wheat and bran. The lowest per cent of protein was found in the dust, which contained less than any of the flour streams.

The shorts and bran contained the largest amount of ether extract or crude fat. The range in ash percentages was quite noticeable, the wheat offals containing much larger amounts of ash than the flour streams. The dust contained a relatively large amount of ash. Ordinarily, shorts contain less protein and fat than bran, but when the larger portion of the germ is added to the shorts, as in the case of these samples, the bran contains less protein and fat than the shorts. Other characteristics in composition of the wheat offals will be observed in table 7. The wheat offals ordinarily make up about 25 per cent of the weight of the wheat, 75 per cent being recovered as flour. The influence of the removal of the offals upon the food value of the flour is discussed in another article in this bulletin.

THE RELATIVE PROTEIN CONTENT OF WHEAT AND FLOUR.

HARRY SNYDER.

This investigation was undertaken to determine what relation exists between the protein content of wheat and of the standard grades of flour; also the relation between the gliadin content of flour and the size and commercial value of the bread. It was deemed advisable to carry on the investigation for as long a period and with as large a number of samples as could consistently be done. The Northwestern Consolidated Milling Co., of Minneapolis, consented to have these experiments made in connection with three of their large mills and for a period of one month each.

Every alternate day, a composite sample of wheat and samples of three of the flour products, were taken and chemical analyses made in the Experiment Station Laboratory, the principal determinations being moisture, ash, acidity, weight of 100 kernels, and gliadin content. The baking tests and the technical tests of the flour were made in the testing rooms of the milling company under the supervision of Mr. Foster. Credit is due Mr. Ralph Hoagland for assistance rendered in carrying out details of the chemical work. This work was done during the season of 1901-02. Hard Northwestern Spring wheat of good quality and fairly uniform composition was used.

This report gives the results of a month's test in three representative mills when hard spring wheat was used, but does not cover the extreme conditions sometimes met in milling different kinds of wheat. During the period covered by this investigation over a million barrels of flour were manufactured.

In the preceding article, "The Composition and Bread Making Value of Flour, Produced by the Roller Process of Milling," explanations of the terms employed are given and general statements made in regard to the application of the various tests and the interpretation of the results.

The commercial rank of the bread as given in the table is simply the comparative value expressed numerically and assigned to the bread when made under uniform conditions, and compared with bread made from flour of known high bread making value. For example a rank of 1, means that in color, porosity and general physical characteristics, the bread is superior to all samples with which it is compared; while grades 2 and 3 indicate second and third positions as to quality. Patent and clear flours were graded separately. The numerals 1, 2 and 3, for the clear grade flours, mean that they rank in order of bread making quality as indicated, when compared with bread made from a standard sample of clear grade flour. In all of the baking tests, standard samples of flour were used for purposes of comparison and the comparisons were made by the various head millers of the company as is customary in the daily testing in order to assign rank and grade to the flours.

It is interesting to note how the chemical analyses compare with the results obtained by baking tests. The results are all given in the tables at the close of the article. The three mills are designated as Nos. 1, 2 and 3. In table No. 8 the composition of the wheat ground in mill No. 1 is given. It is to be observed that the wheat contained from 14.82 to 16.23 per cent protein, the average being 15.63 per cent. In table No. 9 is given the composition of the three grades of flour: first patent, second patent, and clear, milled from this wheat. These results show variations in protein content of from 13.13 per cent to 19.15 per cent. The first patent contained on an average 13.56 per cent protein and the second patent 14.70 per cent. It will be observed that the second patent contained only .9 per cent less protein than the original wheat. The clear grade in all cases contained more protein than the original wheat. It has frequently been asserted that the bran and other offals contain the larger proportion of the proteid matter of the wheat kernel. These analyses of the wheat and of the flour milled from the same wheat, show that this is not the case. The patent grades contain only slightly less protein than the wheat, while the lower grades contain somewhat more than the wheat itself. This suggests that if it is desired to obtain flour of highest protein content, it can be found in the lower grades as they contain more protein than the wheat itself. Such flours, however, produce a poorer quality of bread. The comparative bread making qualities of patent and clear grade flours are discussed in the preceding article, where it will be observed that the clear grades make smaller, darker loaves and a poorer quality of bread than the patent grades.

The wheat used in Mill No. 3 showed an average composition of 15.22 per cent protein. The first patent flour contained 12.90 per cent, the second patent 14.17 per cent, and the clear grade 17.01 per cent. These figures show about the same range and comparative difference observed in the flours produced by Mill No. 1. It is noticeable that the patent grades of flour contain a high percentage of protein.

The gliadin content of the various wheat samples was not determined, as the laboratory was then without suitable apparatus for grinding the samples sufficiently fine for this determination. An examination of the gliadin number of the different flour samples showed that in general, the first patent has a higher gliadin number than the second patent, while the clear grade has the lowest gliadin number. In a few cases the second patent contained as much gliadin as the first patent, and second patent contained as much gliadin as the first patent, and in some the clear grade yielded as high a gliadin number as the first and second patents. The average gliadin number of the first patent flour from Mill No. 1 was 59.07, of the second patent 56.25, and of the clear grade 54.21. In Mill No. 2, where only one grade of patent was made, the gliadin number was 58.33, while that of the clear grade was 54.88. In Mill No. 3, the same average difference in the gliadin content of the three grades of flour was observed.

The gliadin number is to some extent an index to the grade of the flour; the lower grades show a general tendency to contain less gliadin than the higher grades, although exceptions to this are noticeable. In regard to the gliadin number and the rank of the loaf, there is no general relationship except as to size of the loaf. This is as might be expected, inasmuch as quality or commercial value is based upon a number of factors of which size of loaf is only one. The gliadin number and the size of the loaf appear to be more closely related than the gliadin number and the rank or commercial value of the flour. Only in a few cases are the large sized loaves produced from flours of low gliadin content. The size of the loaf is dependent upon a number of factors, as nature and extent of the fermentation and character and quality of the various constituents of which the flour is composed. Since gliadin is only one of the constituents of gluten and flour, it is quite evident that there are other factors capable of exerting themselves in the expansion of the loaf. From the results given in the tables it is quite evident that these factors have manifested themselves and have influenced the size of the loaf.

While the gliadin number of the flour and the size of the loaf are not in all cases strictly in accord, there is a general relationship between the two; if a flour is abnormally low in gliadin it does not generally produce a large sized loaf. The gliadin content of wheat and flour appears to be of more value in comparing the composition and characteristics of different types and varieties of wheat than in determining the quality or value for bread making purposes of flour made from wheat of uniform character, such as was used in these investigations.

Since gliadin is an acid proteid, its characteristics and properties are capable of being modified to an appreciable extent by the ferment action during bread making. In former investigations it was shown that during the process of bread making, organic acids are developed which unite with the wheat proteids producing a larger amount of alcohol soluble bodies similar to gliadin. Some of the organic acids of the flour are in combination with the gliadin. That gliadin is susceptible to the action of oxidizing agents is shown in the article on the bleaching of flours, and it also appears to undergo various hydration changes. Because of these various reactions to which gliadin is susceptible, the amount of active gliadin in a flour is capable of being influenced to an appreciable extent. This may affect the bread making qualities either favorably or unfavorably.

In this study of the protein content of wheat and of the various grades of flour it is manifest that the most nitrogenous flours are not always produced from wheats of the highest protein content; for example, in Mill No. 1, wheat containing 16.23 per cent of protein produced patent flour with a protein content of 13.91 per cent, while wheat with 15.79 per cent protein produced flour with 14.14 per cent; in Mill No. 3, wheat with 15.50 per cent protein produced flour with 12.84 per cent, and wheat with 14.33, per cent protein produced flour with 12.86 per cent.

The nitrogen may be variously distributed in different samples of wheat; for example, in some wheats, more nitrogen is in the endosperm or floury portion and less in the germ and bran, while in others more of the nitrogen is in the offal parts and less in the endosperm or floury portion. This is a matter of considerable importance in the selection of wheat for seed and milling and in the testing of varieties, because not all of the wheat kernel being used for human food purposes, it is far more desirable to secure wheat with a large protein content in the endosperm than wheat with a large protein content in germ and bran. In the case of corn the entire kernel is used for the feeding of farm animals, and any increase in the nitrogen content proportionally increases that which the animal secures. In the case of wheat, an increase in the nitrogen content may mean more nitrogen in the germ or bran rather than in the floury portion. This fact appears most prominent in this investigation: one wheat may contain a lower total protein than another and still produce the more nitrogenous flour.

The way in which the nitrogen is distributed in the wheat kernel is equally as important for bread making and human food purposes as is the total amount. It should be the aim to obtain wheat of high protein content in the endosperm rather than in the bran or germ, that is an increase of protein in the floury portion of the kernel rather than in the offals; furthermore this protein should be of the best quality for bread making purposes as well as large in amount.

TABLE VIII. Composition of Wheat Used in Mill.

No.	Date. 1901		Dry Matter. Per Cent.	Ash. Per Cent.	Protein. (Nx6.25) Per Cent.	Acidity. Pr Ct.	Wgt. of 100kernl's Grams
73	12-9	Wheat.........	88.74	1.96	16.23	.22	2.042
77	12-11	Wheat..........	89.17	1.64	14.82	.20	2.212
81	12-13	Wheat..........	89.32	1.87	15.79	.20	2.135
85	12-16	Wheat..........	88.86	1.95	15.88	.18	2.028
89	12-18	Wheat..........	89.70	1.89	15.05	.16	2.226
93	12-20	Wheat..........	90.47	....	15.61	.17	2.238
97	12-23	Wheat..........	88.95	1.94	15.81	.24	2.314
101	12-30	Wheat..........	89.45	1.99	15.91	.19	2.104
....	1902						
105	1-1	Wheat..........	88.72	1.88	15.50	.19	2.210
109	1-3	Wheat..........	89.37	2.06	15.84	.25	2.290
113	1-6	Wheat..........	88.71	1.96	15.56	.21	2.411
		Average.	89.20	1.91	15.63	.20	2.201

TABLE IX. Composition of Flours Produced at Mill.

No.	Date. 1901		Dry Matter. Per Cent.	Ash. Per Cent.	Protein. Per Cent.	Gliadin. No.	Acidity. Per Cent.	Ether Ex. and Carbo-hydrates. Per Cent.	Size of Loaf. Inches.	Rank.
74	12-9	1st Patent.........	88.79	.39	13.91	58.20	.07	74.42	27.9x24.75	2
75	12-9	2nd Patent.........	89.13	.48	....	56.12	.08	....	27.6x24.25	11
76	12-9	Bakers' or Clear.	88.78	.87	17.25	50.22	.11	70.55	24.75x20.75	3
78	12-11	1st Patent.........	88.22	.38	13.13	58.41	.08	74.62	28.25x25	2
79	12-11	2nd Patent.........	89.18	.47	14.83	54.32	.10	73.70	28.6x25.9	11
80	12-11	Bakers'..............	88.68	.83	16.94	49.59	.12	70.79	24.x20.45	3.
82	12-13	1st Patent.....	87.79	.40	14.14	57 83	.08	73.17	29.5x26.6	1
83	12-13	2nd Patent.........	87.90	.46	15.40	56.26	.09	71.91	29.45x26.75	12
84	12-13	Bakers'......	88.21	.81	18.70	50.73	.13	68.57	24.51x21.	1
86	12-16	1st Patent.........	87.68	.40	13.34	60.88	.07	72.87	28.25x25.50	2
87	12-16	2nd Patent.........	87.79	.45	14.17	59.24	.07	73.00	28.75x26.25	11
88	12-16	Bakers'..............	87.46	.77	16.30	57.47	.11	70.28	25.45x22.10	1
90	12-18	1st Patent.........	87.98	.42	13.05	60.78	.07	74.44	29.x25.50	3
91	12-18	2nd Patent.........	87.75	.46	14.55	58.00	.08	72.59	28.5x25.5	9
92	12-18	Bakers'..............	88.23	.74	16.02	56.56	.10	71.37	25.x22	1
94	12-20	1st Patent.........	89.29	.38	13.19	60.77	.07	75.65	29.x26.25	1
95	12-20	2nd Patent.........	88.15	.48	14.04	60.37	.08	73.55	28.5x25.75	6
96	12-20	Bakers'..............	88.94	.82	16.56	54.74	.12	71.44	23.5x20	6
98	12-23	1st Patent	88.17	.38	13.31	57.94	.07	74.41	29.5x26	1
99	12-23	2nd Patent.........	87.89	.46	14.50	52.87	.10	72.79	28.5x25.5	7
100	12-23	Bakers'	88.96	.92	16.33	57.47	.12	71.69	24.x20.45	1
102	12-30	1st Patent.........	87.25	.37	13.93	58.32	.06	72.89	28.x23.75	2
103	12-30	2nd Patent.........	87.99	.49	14.60	58.58	.07	72.83	29.x25.75	6
104	12-30	Bakers'..............	87.20	.94	18.00	56.50	.12	68.14	24.x20.10	5
	1902									
106	1-1	1st Patent.........	88.34	.38	14.47	57.14	.06	73.43	28.6x24.75	2
107	1-1	2nd Patent.........	88.98	.49	15.09	56.11	.09	73.31	29.x25.75	9
108	1-1	Bakers'..............	88.65	.88	19.50	50.00	.11	68.16	23.5x19.6	6
110	1-3	1st Patent.........	87.30	.37	13.17	60.24	.08	73.68	28.6x25.25	1
111	1-3	2nd Patent.........	88.17	.47	15.32	55.37	.07	72.31	28.x25	9
112	1-3	Bakers'..............	88.09	.89	18.04	48.49	.16	69.00	23.9x20.6	5
114	1-6	1st Patent.........	88.59	.40	13.57	59.30	.08	74.54	28.25x25.25	2
115	1-6	2nd Patent.........	88.69	.49	14.49	57.38	.08	73.63	29.5x26.6	6
116	1-6	Clear (Bakers') ..	89.00	.90	17.36	56.19	.15	70.59	24.6x21.45	4
Average		1st Patent.........	88.12	.39	13.56	59.07	.07	74.10	28.62x25.32	
Average		2nd Patent..... ...	88.33	.47	14.70	56.25	.08	72.96	28.67x25.72	
Average		Clear (Bakers')...	88.38	.84	17.27	54.21	.12	70.05	24.29x21.09	

TABLE X. Composition of Flour Produced in Mill 2.

No.	Date. 1901		Dry Matter. Per cent.	Ash. Per cent.	Protein (Nx6.25) Per cent.	Gliadin No.	Acidity. Per cent.	Size of Loaf. Inches.	Rank.	Ether Ex. and Carbo-hydrates. Per cent.
57	10-2	Patent..........	90.06	.43	14.77	55.63	.10	29x25.5	14	74.76
58	10-2	Bakers'..........	90.17	.79	17.11	53.83	.18	24x20.25	9	72.09
59	10-7	Patent..........	89.79	.41	15.26	57.79	.11	30.1x26.5	10	74.01
60	10-7	Bakers'..........	89.62	.78	18.58	52.76	.13	25.25x22	11	70.13
61	10-9	Patent..........	89.19	.47	15.04	59.44	.09	29x26.1	5	73.59
62	10-9	Bakers'..........	89.11	.80	18.01	56.77	.14	24.5x21.2	2	70.16
63	10-10	Patent..........	89.32	.46	14.71	61.09	.08	30x26.75	7	74.07
64	10-10	Bakers'..........	89.96	.73	17.67	57.84	.13	24.25x20.75	7	71.43
65	10-11	Patent..........	89.73	.46	14.66	58.61	.10	29.25x26	7	74.51
66	10-11	Bakers'..........	89.93	.84	17.77	51.90	.15	24.5x20.9	13	71.17
67	10-16	Patent..........	90.00	....	15.18	57.35	.09	29.25x26.5	10	....
68	10-16	Bakers'..........	90.25	.89	17.87	54.13	.12	23.9x20.25	6	71.37
69	10-21	Patent..........	89.79	.45	15.41	58.27	.09	29.6x26.6	6	73.84
70	10-21	Bakers'..........	90.34	.85	18.71	55.66	.14	23.9x20.75	8	70.64
71	10-23	Patent	90.28	.43	15.30	58.42	.09	29.6x27.45	14	74.46
72	10-23	Bakers'..........	90.43	.86	18.34	56.15	.12	24x20.6	8	71.11
Average		Patent..........	89.77	.44	15.05	58.33	.09	29.47x26.42		74.18
Average		Clear (Bakers').	89.98	.82	18.01	54.88	.14	24.29x20.83		71.01

TABLE XI. Composition of Wheat used in Mill 3.

No.	Date 1901		Dry Matter Per cent	Ash Per cent	Protein (Nx6.25) Per cent	Acidity Per cent	Wgt. of 100 Kernels Grams
1	9-18	Wheat......................	91.96	1.83	15.50	.20	2.204
5	9-21	Wheat......................	91.06	1.80	15.38	.19	2.274
9	9-24	Wheat......................	90.85	1.74	14.33	.19	2.234
13	9-26	Wheat......................	89.45	1.76	15.51	.20	2.420
17	9-28	Wheat......................	89 25	1.89	15.37	.20	2.278
21	10-1	Wheat......................	88.75	1.81	15.00	.23	2.223
25	10-2	Wheat......................	87.19	1.84	15.15	.18	2.293
29	10-4	Wheat......................	88.42	1.84	15.33	.16	2.169
33	10-7	Wheat......................	86.15	1.69	15.00	.15	2.315
37	10-9	Wheat......................	87.56	1.89	15.19	.13	2.449
41	10-11	Wheat......................	87.38	1.82	14.87	.15	2.364
45	10-14	Wheat......................	88.18	1.94	15.19	.14	2.249
49	10-16	Wheat......................	89.89	1.88	15.44	.15	2.221
53	10-18	Wheat......................	88.87	1.84	15.75	.16	2.189
	Average	....	89.26	1.83	15.22	.17	2.277

TABLE XII. Composition of Flours Produced in Mill 3.

No.	Date. 1901		Dry Matter. Per cent.	Ash. Per cent.	Protein (Nx6.25) Per cent.	Gliadin No.	Acidity. Per cent.	Ether Ex. and Carbo-hydrates. Per cent.	Size of Loaf Inches.	Rank.
2	9-18	1st Patent.........	88.17	.34	12.84	....	.09	74.90	28.6x25	2
3	9-18	2nd Patent.........	88.45	....	13.90	....	.11	73.93	28.75x25.25	13
4	9-18	Bakers' or Clear.	88.33	1.04	....	48 71	.16	....	23.75x20.75	9
6	9-21	1st Patent.........	87.91	.33	12.54	58.34	.10	74.94	28.75x25	2
7	9-21	2nd Patent.........	87.95	.46	14.65	54.58	.12	72.72	28.x24.75	11
8	9-21	Bakers'..............	87.99	.84	17.28	49.06	.17	69.70	23.50x20	6
10	9-24	1st Patent.........	87.71	.34	12.86	55.71	.11	74.40	28.25x24.75	1
11	9-24	2nd Patent.........	88.24	.43	13.88	53.94	.10	73.83	30.x27	15
12	9-24	Bakers'..............	88.39	.87	17.63	48.23	.16	69.73	23.25x19.90	8
14	9-26	1st Patent..	87.92	.34	13.19	53.60	.08	74.31	28.25x25.45	1
15	9-26	2nd Patent.........	88.33	.47	14.44	54.11	.10	73.32	28.5x25	9
16	9-26	Bakers'.....	88.61	.90	17.19	48.62	.13	70.39	23.60x20.5	8
18	9-28	1st Patent.........	87.32	.37	13.05	53.40	.09	73.81	28.x24.75	1
19	9-28	2nd Patent.........	87.87	.45	....	....	.09	....	....	...
20	9-28	Bakers'..............	88.06	.83	18.31	48.40	.13	68.79	24x20.25	8
22	10-1	1st Patent.........	86.77	.34	12.63	55.79	.08	73.72	29.1x26	1
23	10-1	2nd Patent.........	87.65	.43	13.94	51.93	.08	73.20	29.50x26.6	7
24	10-1	Bakers'..............	88.07	.80	16.94	48.89	.15	70.18	24.45x21.25	3
26	10-2	1st Patent.........	87.25	.36	12.94	59.23	.08	73.87	28.10x24.75	2
27	10-2	2nd Patent.........	87.51	.47	14.06	58.89	.09	72.89	28.50x24.75	13
28	10-2	Bakers'..............	87.80	.78	17.15	46.50	.13	69.74	23.5x19.5	8
30	10-4	1st Patent.........	86.95	.37	12.50	62.00	.09	73.99	28.60x25.25	1
31	10-4	2nd Patent.........	87.35	.48	14.25	57.64	.08	72.54	27.75x24.75	13
32	10-4	Bakers'..............	87.55	.95	17.06	53.99	.13	69.41	24.5x21.1	9
34	10-7	1st Patent.........	88.77	....	12.56	62.19	.08	....	28.25x25.25	1
35	10-7	2nd Patent.........	87.98	.45	13.44	60.79	.08	74.01	28.50x25.45	5
36	10-7	Bakers'..............	88.14	.88	16.06	51.20	.12	71.08	24.6x20.6	9
38	10-9	1st Patent.........	87.26	.32	13.38	64.94	.08	73.48	28.6x25.9	1
39	10-9	2nd Patent.........	87.71	.44	14.19	64.93	.08	73.00	28.25x25.25	13
40	10-9	Bakers'..............	88.49	.81	17.04	54.29	.18	70.46	23.5x19.9	8
42	10-11	1st Patent..	87.80	....	12.94	64.90	.10	....	29.5x26.75	1
43	10-11	2nd Patent.........	87.30	....	14.19	57.84	.11	....	28.25x25.25	8
44	10-11	Bakers'.............	87.32	.84	16.73	55.08	.13	69.62	24x20.90	7
46	10-14	1st Patent.........	87.06	.30	12.92	56.29	.10	73.74	28.25x25.25	2
47	10-14	2nd Patent.........	87.47	.45	14.60	51.95	.09	72.33	28x25.25	14
48	10-14	Bakers'..............	87.65	.88	16.44	52.05	.12	70.21	24.75x21.45	7
50	10-16	1st Patent.........	88.05	.44	12.93	56.29	.13	74.55	29x25.45	1
51	10-16	2nd Patent.........	88.53	.47	14.13	52.66	.15	73.78	28.5x25.25	14
52	10-16	Bakers'..............	88.53	.80	16.50	49.24	.22	71.01	23.50x19.45	8
54	10-18	1st Patent.........	87.83	.29	13.25	54.91	.09	74.20	28.9x25.9	2
55	10-18	2nd Patent.........	88.09	.46	14.60	55.14	.10	72.93	28.10x24.75	12
56	10-18	Bakers'..............	88.44	.87	17.44	46.17	.23	69.90	23.9x20.45	11
Average...		1st Patent.........	87.63	.35	12.90	58.28	.09	74.16	28.51x25.39	....
Average...		2nd Patent.........	87.89	.46	14.17	56.20	.10	73.21	28.62x25.31	....
Average...		Clear (Bakers') ..	88.12	.86	17.01	50.03	.15	70.02	23.91x20.43	....

COMPOSITION OF AN ANCIENT EGYPTIAN WHEAT.

HARRY SNYDER.

A sample of ancient Egyptian wheat was presented to the Chemical Laboratory in 1901 by Mr. James S. Bell, President of the Washburn-Crosby Milling Co. The sample was taken from an ancient Egyptian tomb during archaeological researches. Mr. Bell was in Luxor soon after the tomb was opened and obtained the sample from El Hadji Mohammed Mohassed, a collector of prominence, recognized by the Egyptian Research Society. According to archeologists, the tomb from which this wheat was taken is 3,700 years old. The wheat was in a good

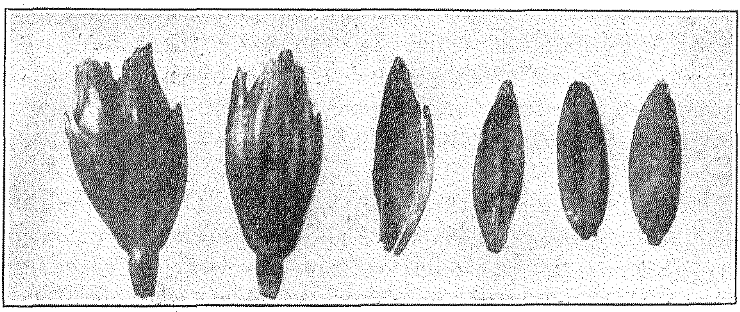


Fig. 128. Ancient Egyptian Wheat. (Emmer.)

state of preservation, although dark in color. It is a variety of spelt or Emmer and resembles modern samples very closely, as will be observed in the photograph. The removal of the chaff showed well formed wheat kernels, but somewhat dried and shriveled.

At first it seemed that a chemical analysis would be of little value, because of the partial oxidation of the material. An analysis of the ash, however, was undertaken in the belief that such a determination would be of value in indicating the extent to which this ancient wheat varied from the modern varieties in the amount of ash or mineral constituents. The chaff was found to contain 11.79 per cent of ash and the kernels 3.94 per cent. This suggested that but little oxidation had taken place, as the percentages of ash were no greater than are found in some samples of spelt wheat at the present time, when calculated on a dry basis. So far as the total ash elements are concerned, this sample of ancient Egyptian wheat contains practically the same amount as our present modern varieties of spelt. An examination of the phosphoric acid content showed the presence of 41.1 per cent of total phosphoric acid. On the basis of the total mineral matter in modern wheat, from 40 to 50 per cent of the ash is phosphoric acid. The fact that the ash or mineral content showed that but little oxidation had taken place, suggested further tests particularly as to the nitrogen content. A determination of the total nitrogen showed the presence of 3.5 per cent, equivalent to 21.87 per cent of proteid matter. This is somewhat higher than is found in average wheat, but is no greater in amount than is present in many varieties when considered on the basis of dry matter. Some of the wheat was burned in the calorimeter and it was found that one gram yielded 4.086 calories, which is practically the same caloric value as of modern wheat. A microscopic examination of the wheat kernels showed the presence of starch grains identical in form and structure with the starch in modern varieties of spelt.

The germinating powers were tested by the Horticultural Division, but none of the kernels showed any indication of activity of the germ. A chemical analysis did not reveal the presence of any mineral matter or other material used as a preservative agent. The kernels appear as if they had been slightly parched by the action of heat; this, however, may be due to slow oxidation. Some of the kernels are more perfectly preserved than others and show highly polished surfaces when taken from the chaff. From the chemical examination of this sample, it does not appear to be materially different from modern wheat of the spelts variety. From all indications the sample is one of great antiquity. And if it is 3,700 years old, as there seems no reason to question, it would appear that during the past thirty seven centuries wheat has changed but little in chemical composition. There is no greater difference in composition between this ancient Egyptian wheat and modern wheat of the same variety than is frequently found between two samples of modern wheat.

INFLUENCE OF STORAGE AND BLEACHING UPON FLOURS.

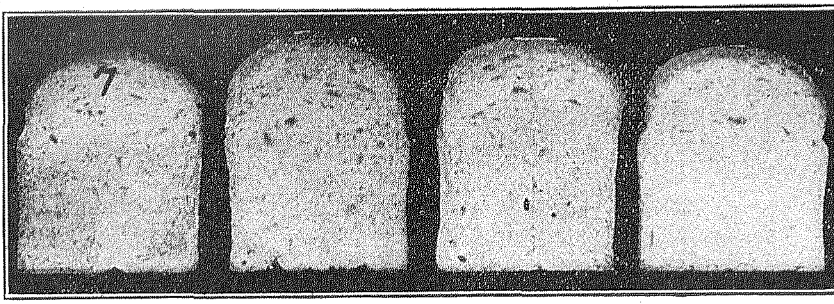
HARRY SNYDER.

Flour is often stored in warehouses for several months before it reaches the consumer. In order to determine the influence of storage upon the bread making qualities, samples of flours which had been stored for four, eight and twelve months in a dry, well ventilated warehouse were tested and compared with fresh flour milled from similar wheat. Both spring and winter wheat patents were included in the tests.

The flours were analyzed and subjected to the technical and baking tests described in the preceding article. The moisture, ash, protein, gliadin, dry gluten, expansion of gluten, absorption, color value, size of loaf, and character of the bread produced from the fresh and stored flours were determined. All of the flours were milled from sound wheat, and were from sufficiently large lots to be fairly representative. The results of the analyses and technical tests are given in the following tables:

TABLE XIII. Influence of Storage upon Spring Wheat Patent Flours.

	Freshly milled.	4 months old.	8 months old.	12 months old.
Sample No.	1	2	3	4
Moisture, per cent	12.84	10.98	10.87	10.63
Ash, per cent	.45	.45	.46	.43
Protein, per cent	13.06	12.63	12.50	12.53
Gliadin number	52.7	53.1	53.3	53.2
Gluten, dry, per cent	13.00	12.33	12.90	12.50
Acidity	.10	.10	.10	.10
Expansion of gluten, mm	70	75	78	67
Relative color value	4	3	2	1
Absorption in cc	77	75	73.5	70
Size of loaf in inches	14½x15¾	14½x16¼	14½x16¼	14½x15⅞



16 Fresh. 17 4 mos. old. 18 8 mos. old. 19 12 mos. old.

Fig. 129. Bread made from Hard Spring Wheat Patent Flour.

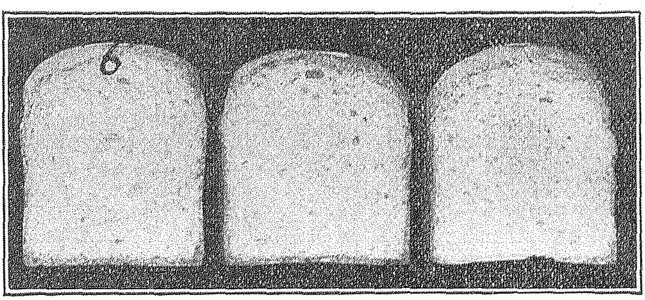
The flours which had been stored in the warehouse lost from 1.86 to 2.21 per cent moisture. The differences between the ash, protein, gluten and acid content of the stored samples, and the fresh flour are not large, and are undoubtedly due to differences in the wheat. The per cent of acid, .10, shows that no material fermentation change in which acid products are formed had taken place. A slight bleaching had resulted from storage. The freshly milled sample was not as light in color as the stored samples; this was offset, however, by a slight loss of absorption power in the stored samples. The flours which had been stored four and eight months respectively produced a somewhat larger loaf than the freshly milled sample. From these results it would appear that when flour is milled from sound wheat there is no deterioration in bread making value from storage, when the flour is stored in a well ventilated warehouse, a slight improvement in color and size of loaf being observed in the stored samples which, in part, was offset by the slight loss of absorption power. No effect upon the general composition of the flours sufficient to influence the food value was noted. When flours are milled from unsound wheats, or contain debris particles of a fermentable nature, they possess poor keeping qualities and such flours deteriorate in storage. In these tests a slight improvement resulted from storage of the sound flours; this is undoubtedly due to the action of the soluble ferments or enzymes which are known to be present in the wheat kernel.

The winter wheat flours showed somewhat less loss of moisture during storage, but otherwise the changes were similar to those noted in the case of the spring wheat flours.

TABLE XIV. Influence of Storage upon Winter Wheat Patent Flours.

	Freshly Milled.	4 months old.	8 months old.
Sample No	5	6	7
Moisture per cent	9.77	9.69	10.01
Ash per cent	.48	.45	.43
Protein per cent	10.38	10.29	10.43
Gliadin No	66.3	66.6	58.7
Gluten, dry, per cent	9.50	9.66	9.50
Acidity per cent	.10	.11	.12
Expansion of Gluten, mm	55	52	53
Relative color value	3	2	1
Absorption in cc	71	71	70
Size of loaf in inches	14½x15	13½x15⅝	13¾x15¼

In the storage of flour for family use, there is no danger of deterioration either in bread making properties or food value provided sound flour is stored in a dry, well ventilated room. Flour, however, readily absorbs undesirable odors as from fresh pine wood, decaying vegetables, kerosene and smoked meats.



20 Fresh. 21 4 mos. old. 22 8 mos. old.

Fig. 130. Bread made from Soft Spring Wheat Patent Flours.

Bleaching of Flours. Color is an important characteristic in determining the commercial value of flour and because of this, processes have been devised for bleaching and improving the color of inferior flours. Chemical bleaching, as far as known to the author, is not practiced in the manufacture of flour in this country. It is, however, to some extent in European countries and has been advocated in this country. In order to determine the influence of the bleaching process upon the bread making qualities, experiments were undertaken in which standard grades of both hard and soft wheat flours were subjected to the process of bleaching and technical and bread making tests were made of the bleached and unbleached flours.

The principle involved in the operation of bleaching is to subject the flour to the action of some oxidizing gas. Oxygen gas generated from potassium chlorate was used as the bleaching agent in this experiment; it was generated in a flask and conducted into a large glass Woulff bottle containing the flour, which readily bleached. The bleaching process did not materially affect the percentage amounts of the various compounds present in the flour. It oxidized the coloring matter and had some influence upon the physical properties of the gluten. The composition of the flours used and the results of the technical and baking tests are given in the following tables:

TABLE XV. Composition of Untreated Flours.

	No. 1 Per cent.	No. 2 Per cent.
Water	10.78	10.94
Ash	.45	.42
Crude protein	12.60	11.80
Dry gluten	12.90	12.02
Gliadin number	64	70
Expansion of gluten	74	70
Absorption	74	68
Color	Creamy.	White.

The flours were of good quality, No. 1 was a hard spring wheat patent and No. 2 a soft winter wheat patent. The bleached flours were whiter in color but the glutens were of poorer quality, being less elastic and lacking in expansive power. The influence of bleaching upon the expansion of the gluten and capacity of flour for the absorption of water was quite noticeable. The bleached flours showed a loss both as to expansion of gluten and absorption of water.

TABLE XVI. Bleached and and Unbleached Flours.

	Flour No. 1		Flour No. 2	
	Unbleached.	Bleached.	Unbleached.	Bleached.
Absorption cc.	74	70	68	63
Expansion in mm.	74	69	70	65
Size of loaf, ins.	15x17	14¾x16½	14¾x16⅝	14½x16

Bleaching did not improve the bread making qualities of the flours, the loaves from the bleached flours being smaller and lighter in weight. Wheat gluten appears to be too sensitive a chemical compound to allow any appreciable oxidation to take place without suffering a change in properties and a loss in bread making value.

It is claimed that the bleaching process improves the keeping qualities of a flour, but no tests have been made that establish this claim. When flour is made from sound, well cleaned wheat and the dirt and impurities are removed, there is no necessity for the use of bleaching agents to improve the keeping qualities or to whiten the flour. The bleaching of flours only tends to destroy the characteristic and natural color which is desirable as indicating character. In the bleached flours, dust particles and debris are more readily discernible as they blacken by oxidation instead of bleaching.

From these experiments, there appears to be no gain in bleaching purified flours made from a good quality of wheat, as the glutens were slightly oxidized, had lessened power of expansion and absorption and the loaves from the bleached flours, although whiter in color, were smaller in size and less in weight.

THE RELATIVE FOOD VALUE OF GRAHAM, ENTIRE WHEAT, AND STRAIGHT GRADE FLOURS.

HARRY SNYDER.

Graham flour is the product obtained by grinding the entire wheat kernel. In entire wheat flour about one-half of the coarse bran is removed before grinding. This flour is finer than graham, but not as fine as the patent grades of flour. In milling the patent grades of flour all of the bran is removed. Several grades of patent flour are produced, but the one most commonly found on the market, known as "standard patent," "straight patent," or "straight grade," consists of the first and second patents and first clear grade combined. By ordinary processes of milling a little over 72 per cent of the total wheat is recovered as straight or standard patent flour and about 2.5 per cent as low grade and "red dog" flours, the remaining 25 per cent being returned in the form of bran, shorts and other offal.

During late years the relative food value and merits of these different kinds of flour have been the subject of extensive discussion, but an examination of the literature on bread and flour shows that but few digestion experiments which are really directly comparable have been made with the different kinds of flour. Wheat ranges in protein content from about 11 to 17 per cent; therefore, in order that the results of experiments may be comparable, the three kinds of flour should be milled from the same lot of wheat. In a former report it was shown that when the three kinds of flour were ground from the same lot of hard spring wheat the graham and entire wheat flours contained a little more protein and gave a slightly higher fuel value than the straight grade flour; but the coarser graham and entire wheat flours had a lower coefficient of digestibility than the finer straight grade flour. Hence the straight patent

Note.—This article gives simply a summary of results; the details of the experiments with tables of analyses and methods employed are published in Bulletin No. 126, U. S. Department of Agriculture, Office of Experiment Stations, Washington, D. C. In this investigation credit is due Mr. J. A. Hummel, assistant chemist, for help rendered in carrying on the details of the work.

flour furnished the body with more nutritive material per gram or per pound than either the graham or the entire wheat flour. Because of the importance of the subject and the extensive use of wheat as human food it was deemed advisable to repeat the work, and in so doing to extend the periods of the digestion experiments over a longer time than in the case of the experiments previously reported, in which they were only two days each. The experiments of 1900-1901 were practically a repetition of those of 1899-1900, except that the digestion period was twice as long, i. e., four days.

TABLE XVII. Summary of Digestion Experiments with Hard Spring Wheat; Digestibility of Nutrients and Availability of Energy of Bread Alone.

Experiment No.	Subject. No.	Kind of Food.	Protein. Per Cent.	Carbohydrates. Per Cent.	Energy. Per Cent.
242	1	Entire wheat bread	83.4	96.2	89.1
243	2	Entire wheat bread	86.5	96.5	90.0
244	3	Entire wheat bread	88.8	95.9	90.2
		Average of 3	86.2	96.2	89.8
		Average of 3 (1899-1900)	80.4	94.1	85.5
		Average of 6	83.3	95.1	87.6
245	1	Graham bread	81.1	90.9	83.9
246	2	Graham bread	81.5	91.4	85.1
247	3	Graham bread	85.9	92.2	86.2
		Average of 3	82.8	91.5	85.1
		Average of 3 (1899-1900)	77.6	88.4	80.7
		Average of 6	80.2	90.0	82.9
248	1	White bread (stan'd patent)	85.5	97.9	90.9
249	2	White bread (stan'd patent)	88.4	98.1	91.4
250	3	White bread (stan'd patent)	91.1	97.0	90.3
		Average of 3	88.3	97.7	90.9
		Average of 3 (1899-1900)	85.3	97.5	90.1
		Average of 6	86.8	97.6	90.5

It will be observed that the average coefficients of digestibility of the protein and carbohydrates and the available energy of the bread made from straight grade flour ground from hard spring wheat were larger than in the case of entire wheat bread or graham bread from the same lot of wheat. In the experiments here reported it appears that in the graham bread the average digestibility of the protein is 82.8 per cent; of the carbohydrates 91.5 per cent, and the available energy is 85.1 per cent. The digestion coefficients for the graham bread are lower than for either the entire wheat bread or the bread from straight grade flour. In the case of the bread from the entire wheat flour 86.2 per cent of the protein was digested, and in the straight flour bread 88.3 per cent, while 96.2 per cent of the carbohydrates in the entire wheat flour bread and 97.7 per cent of those in the bread from the straight flour were digestible.

An examination of the table shows in each of the series a range of from 4 to nearly 6 per cent in the digestion coefficients of each of the nutrients. This is probably due to differences in the digestive powers of the three subjects. Thus, for example, subject No. 3 digested all of the breads, straight patent, entire wheat, and graham, more completely than either subject No. 1 or No. 2. While individual differences are observed in the three series of experiments, in every case it appears that each subject digested the nutrients in the straight flour bread more completely than the nutrients in either the entire wheat bread or the graham bread. Hence the results for average digestibility in the different series of experiments are strictly comparable.

The table also compares the results of the experiments given in this bulletin and those formerly reported. It will be observed that although the digestion coefficients are somewhat larger in the more recent experiments than in those of 1899-1900, there is a general similarity of results. In both series the nutrients of the bread from standard patent flour are the most, and those from graham the least digestible, the entire wheat bread being between the two. These experiments are regarded as strictly comparable. In the two years' investigations, six subjects were employed and eighteen separate digestion experiments were made.

Table 17 gives the average digestibility of the nutrients and the availability of the energy of the three kinds of bread. It is believed that these figures show, with a fair degree of accuracy, the comparative digestibility of the protein and carbohydrates and the availability of the energy of bread made from the three kinds of flour milled from the same lot of hard spring wheat and consumed under similar conditions. The results, considered as a whole, show that the protein in the straight flour bread is 6.6 per cent more digestible than that of the graham bread, while the carbohydrates are 5.6 per cent more digestible. The amount of available energy in the straight flour bread is also greater by 7.5 per cent than in the graham bread.

In table 18 the total and digestible protein, carbohydrates, and total and available energy in the three different kinds of flour as milled are given. These values for digestible nutrients and available energy were obtained by multiplying the percentage of total nutrients and energy by the coefficients given in table 17.

TABLE XVIII. Percentage of Digestible Protein and Carbohydrates, and Available Energy in Entire Wheat, Graham and Straight Patent Flours as Milled.

Grade of Flour from Hard Spring Wheat.	Protein (Nx5.7)		Carbohydrates.		Energy per Gram.	
	Total Per cent.	Available Per cent.	Total Per cent.	Available Per cent.	Total Calories	Available Per Gram
Straight Grade...	13.60	12.01	72.04	70.31	3.861	3.510
Entire Wheat.....	13.72	11.83	70.09	67.43	3.877	3.481
Graham	14.21	11.77	68.55	62.62	3.971	3.379

There was a somewhat larger amount of digestible protein in the straight flour than in either the graham or the entire wheat. In the straight flour there was 70.31 per cent of digestible carbohydrates, in the entire wheat flour 67.43 per cent, and in the graham flour 62.62 per cent; that is, the carbohydrates of the straight flour were much more digestible than those of either the entire wheat flour or the graham flour. The amount of available energy of the straight flour is also larger than that of either the graham or the entire wheat flour.

That the lower degree of digestibility of the entire wheat and graham flours was due at least in part to a coarser granulation of the particles, which consequently exposed a relatively smaller amount of surface to the action of the digestive fluids, was shown by a microscopical examination of the feces. The feces from both the entire wheat and graham flours under the microscope showed a larger number of starch particles that had not been acted upon in the digestive tract than the feces from the standard patent flour. These results are in accord with numerous microscopical studies of the feces from different sorts of wheat products, and in this connection it is interesting to refer to some of these and closely related investigations.

Among others may be mentioned the work of Rubner, Pappenheim, Constantinidi and Raudnitz.

In general it may be said that these investigators found that starch was thoroughly digested, but that the cells making up the outer portion of the wheat berry were little attacked by the digestive juices, and hence the contents of such cells were not assimilated. Rubner pointed out that the amount of undigested nitrogen increased with an increase in the amount of the outer portion of the grain retained in flour in milling. Rathay reports experimental studies, of which he himself was the subject, in which the diet for a week consisted of graham bread and tea. The bread was made without leaven. The feces from the fifth and seventh day were examined microscopically. He found that the grain portions which had been little masticated were softened, but almost entirely undigested. From only a few of the outer cells of the endosperm had the starch grains and the proteid materials disappeared, while the greater part of these nutrients was execreted unchanged. The general conclusion from his investigations was that the greater portion of the feces consisted of the undigested residue of wheat bran in the form of large flakes composed of the seed coats and the aleurone layer. The latter left the intestines unchanged, probably because the thick walls of the aleurone cells prevented the action of the digestive juices upon the cell contents.

Perhaps the most extended study of vegetable residues occurring in feces was made by Moeller. In some of the experiments the diet consisted of the following rations: coarse bread with butter and cheese; white bread, rice and butter; bread, milk, and porridge made of wheat grits; bread and porridge made of milk and flour; oat preparations, namely, oat grits, oat flake soup, and cocoa; rye bread, and various mixed diets, in which potatoes or legumes predominated. Portions of feces were washed repeatedly with water and examined under the microscope. The conclusion reached was that healthy individuals digest the starch of cereals and potatoes almost completely, even when the starchy foods are not in the most favorable mechanical condition, as is the case in the bran from cereals; and further, that the soft cell walls of the starch cells are also digested. The aleurone layer of cereals, in which the cell membranes consist of pure cellulose, was not digested, nor were the protein and fat which form the contents of the cells, digested unless the cell walls had been mechanically ruptured. The cells making up the germ were not digested nor were they ruptured by the action of the digestive juices. The author believes that these experiments warrant the conclusion that fine flour is preferable to coarse flour. Comparative experiments with coarse and fine flour and the feces from these flours, lead the author to the conclusion that the cell walls almost absolutely shield the cell contents of the aleurone layer from the action of the digestive juices, and he concludes that cereal brans should be regarded as indigestible. The outer layer of the cereal grains, including the episperm cells with their starch content, was also found undigested.

Laboratory experiments indicate that cellulose is little attacked by digestive juices, the amount digested being proportional to the thickness of the cell membrane. On the other hand, the middle lamellae were readily disintegrated by digestive juices. Tests with laboratory reagents showed also that the inner side of the gluten cells was most resistant.

As noted above, in connection with the experiments reported in this bulletin, a microscopical examination of the feces showed that in those from the graham and entire wheat breads made from flour ground from the same lot of wheat, a much larger number of unaltered starch granules were present than in the feces from the straight flour, and the particles had not been so completely acted upon by the digestive fluids.

The results of these experiments confirm those of earlier work, and show that when breads made from straight grade flour, entire wheat flour and graham flour, milled from the same lot of hard spring wheat, were fed under uniform experimental conditions to men, there was a larger amount of digestible protein, carbohydrates and available energy in the patent flour than in either the entire wheat or graham flour, although judged by composition the graham flour contains the most and the patent flour the least total protein. The greater digestibility of the protein and carbohydrates of the patent flour is regarded as due in part at least to the fineness of division of the flour particles, a considerable portion of the nutrients in the graham and entire wheat flours being present in comparatively large particles, which resist the action of the digestive fluids and so escape digestion. It has also been suggested that the cell walls in the layer of the grain directly under the bran are more resistant to digestive juices than the walls of cells in the interior of the kernel. Thus while there is actually somewhat more protein, pound for pound, in graham and entire wheat than in patent flour, the body obtains less protein and energy from the coarser than it does from the finer flour, and whatever is gained in composition by adding the bran or germ is offset by the loss in digestibility.