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THE EFFECT OF BLEACHING WITH OXIDES OF NITROGEN UPON THE BAKING QUALITY AND COMMERCIAL VALUE OF WHEAT FLOUR.

A THESIS

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I. Introduction.*

Early in 1917, the writer became connected with an investigation into the effect of bleaching upon flour, conducted by the Bleached Flour Laboratory of the Bureau of Chemistry, of the United States Department of Agriculture; his work being to assist in determining whether or not flour is injured in quality or strength by the application to it of the oxides of nitrogen generated in the Alsop process of flour bleaching. The chemical work and the greater part of the laboratory baking work were done in the Bleached Flour Laboratory of the Bureau of Chemistry, under the supervision of Dr. Phelps and Mr. Jacobs of that laboratory. Part of the laboratory baking work was done in baking laboratories in other cities, the milling and commercial baking work was done in flour mills and commercial bakeries in various localities, and the investigation into the commercial aspects of the question was made by conferences with leading flour men in every important flour-producing section of the United States; in all this work the writer reporting directly to Dr. Alsberg, the Chief of the Bureau.

There are a few technical expressions, well-understood in the flour trade, which may require explanation here. The terms "patent", "straight", "clear", and "low-grade", are generally recognized among flour men as indicating certain grades of flour; but the lines of demarcation between them are very indefinite.

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Patent flour is generally considered to be the flour which is milled g from the endosperm of the wheat berry, and contains the smallest possible amounts of bran and dirt. Older millers say that patent should be milled largely or entirely from purified middlings and should comprise sixty to seventy per cent of the flour content of the wheat. Many flour men, however, say that the term is practically meaningless, and that any flour which contains less than one hundred per cent of the flour content of the wheat may properly be called a patent. A "high patent", or "short patent" is a flour which contains a relatively low percentage,--- i.e., from fifty to seventy per cent,---of the flour content; and as the percentage of patent is increased, or, as it is generally called, "lengthened", the flour becomes a "long patent", and approaches a"straight" "Low-grade" is the poorest and dirtiest grade of flour milled. It is always slight in amount compared with the other grades. "Clear" flour is the medium-grade flour; that portion which is left after the patent and low-grade have been removed. "Straight" flour is the entire flour content of the wheat, with only the low-grade taken off. In a"100 % straight", the low-grade is not separated.

The use of oxides of nitrogen for the treatment of cereals was probably first proposed by Sydney Pitt, in British Patent 11,097 of 1894. His process consisted in treating cereals "by gaseous fumigation with chlorine, sulphur dioxide, nitrous vapors, and the like" in a closed chamber. This process was intended primarily as a general sterilization process, and included cereals only incidentally.

The first successful process for the bleaching of cereal products by this agent was probably that of Frichot (Brit. Pat. 21,971 of 1898); though he ascribed the bleaching effect to ozone, and the patent claims the use of ozone as a bleaching agent. The "ozone" used in

Frichot's process was produced by the use of glass tubes containing metal filings, connected to a high-tension coil, which was in turn connected to a dynamo. It appears from the work of Avery[5] and also from that of Fleurent[10] that the active agent in this and other "ozone" processes is not ozone, but nitrogen peroxide. It was found that all electrically-prepared ozone contains nitrogen peroxide; and that when the ozone thus prepared is carefully purified, its ability to bleach flour disappears.

The first patents covering the use of this gas as such were issued to John and Sydney Andrews (Brit. 1661 of 1901; U. S. 693,207, dated Feb. 11, 1902; and U. S. 698,240, dated Apr. 22, 1902). This was the first really important commercial flour-bleaching process. In it the oxides of nitrogen are generated by mixing solutions of nitric acid and ferrous sulphate; the resulting gas being mixed with a large proportion of air and brought into intimate contact with the flour in a suitable agitator.

The Alsop process, covered by patents ~~Brit. 14,006 of 1903; German 232,534, dated July 17, 1905; and U. S. 759,651, dated May 10, 1904;~~ produces the bleaching agent by means of a flaming arc in a current of air. The older type of machine produced the arc by means of pairs of electrodes, one stationary and one having a reciprocating motion. In the later type, a set of rotating electrodes is used as the moving member. The strength of the gas is regulated by the density of the current used, and the bleaching gas is applied to the flour in an agitator, as in the other methods.

The Werner process, covered by patents Brit. 23,391 of 1905; Fr. 359,711, dated Nov. 4,1905; and U.S. 812,777, dated Feb. 13, 1906; which generates the oxides of nitrogen by decomposing ammonia in the presence of an oxidizing agent, was invented by E. E. Werner and put on

the market by the Nordyke and Marmon Company. In this process air is blown through strong aqua ammonia, then through a catalyst such as heated platinum sponge or copper oxide, and the resultant mixture of air and oxides of nitrogen is led into the flour agitator.

The Williams process was originated by John M. Williams, of Oklahoma. In his process, the bleaching agent is formed by the electrolysis of a solution of nitric acid, the resultant gases being mixed with a current of air and the flour treated with the mixture in the same way as in the other processes. Williams has taken out several patents covering his process;-- U.S. 769,522, dated Sept. 6, 1904; Brit. 6,636 of 1907; U.S. 963,970, dated July 12, 1910; and U. S. 1,132,058, dated Mar. 16, 1915. His apparatus was put on the market by the Electric Catalytic Air Company, of Oklahoma.

It was soon recognized that the bleaching agent employed in these and other less important processes was practically identical and a great deal of patent litigation ensued; the Alsop Process Company, owners of the Alsop patents, and the Flour Oxidizing Company Ltd., owners of the Andrews patents, being the principal litigants. The matter was carried to the highest courts of England and France; in both countries the Andrews patents were adjudged valid and the Alsop patents declared infringements; and to protect their American interests, the Alsop Process Company purchased the American rights to the Andrews patents. In these trials[40] it was fully established that nitrogen peroxide is the active principle in all flour-bleaching processes using oxides of nitrogen, however those oxides may be prepared; therefore all such processes may be considered identical so far as their effect upon the flour is concerned.

With the purchase of the Andrews patents, the Alsop Process Company gained such an advantage over all competitors that practically

all the flour now bleached in this country by means of nitrogen peroxide is treated by the Alsop process.

Nitrogen peroxide has been described too often to warrant any extended description. It is a corrosive, reddish-brown gas, with a peculiar and highly characteristic odor. Its composition is $N_n O_{2n}$; being NO_2 at low temperatures and pressures (-12° C and 115 m m), N_2O_4 at 150° C under atmospheric pressure, and a mixture of the two at temperatures and pressures between these limits. Avery[5] found that it is the most efficient known agent in the bleaching of flour, bleaching a far greater quantity in proportion to the amount used than any other bleaching agent. He found that three cubic centimeters of the gas in three liters of air effectively bleached one kilogram of flour, that the maximum bleaching effect was secured by the use of forty cubic centimeters of the gas. and that more than this amount injured the flour.

II. Summary of Previous Work.

A great deal of work has been done upon the effect of nitrogen peroxide upon flour. In order to secure a clear view of the most important work done, it is convenient to discuss it in several divisions, corresponding to the particular phase of the subject under investigation.

Effect of Nitrogen Peroxide upon the Coloring Matter of Flour.

There are three principal sources of the coloring matter of flour; (1) Crease-dirt and other outside dirt; (2) finely-divided bran, and (3) the coloring matter of the endosperm, or inside portion of the wheat berry itself. The first two classes, in general, cannot be effectively bleached, but must be removed by more careful cleaning of the

wheat and by improvements in milling. The coloring matter of the endosperm is that which is bleached. This coloring matter is intimately connected with the fat of the flour, so that it is always extracted with the fat. It was at first supposed that this coloring matter was a nitrogenous compound. Avery[5] supposed that it was characterized by an amino group because it reacted so readily with nitrous acid. Snyder[29] also held that view. Ladd[16] and his collaborators, Bassett[17] and Stallings,[18] however, showed that the oil from unbleached flour contained no nitrogen, and this view was sustained by Monier-Williams,[21] who made an exhaustive study of this coloring matter and showed it to be carrotene, a highly unsaturated hydrocarbon corresponding to the formula $C_{40}H_{56}$. This formula was later confirmed by other investigators, who found that it belongs to the terpene class of compounds.

There are two principal theories concerning the effect of nitrogen peroxide upon the coloring matter of flour. The first is that the process is essentially an addition of a nitrogen-bearing group to the unsaturated molecule; the second is that it is an oxidation process, in which nitrogen peroxide acts merely as a carrier of oxygen. In favor of the first theory are Fleurent,[10] Avery,[5] Monier-Williams,[21] Rousset,[24] and Moore and Wilson.[22] In favor of the second theory are Steensma,[31] who states that the coloring matter "is obviously oxidized during bleaching", but does not offer any proof of the statement, and Snyder,[29] who reasons from theoretical possibilities. Jago[15] concluded that the effect might be a combination of both nitration and oxidation.

Effect of Nitrogen Peroxide upon the Fat.

Snyder[29] states that there is no perceptible difference in the fat extracted from unbleached and from bleached flour. Ladd,[16] Bassett,[17]

and Stallings;[18] Monier-Williams,[21] Moore and Wilson[22], and Winton[39] all conclude that the fat is markedly altered when flour is bleached; especially in its nitrogen content, iodin number, and saponification value.

Antiseptic Action upon Flour.

Fleurent,[10] Ladd[16] Halliburton[13] and Scheringa[26] agree that nitrogen peroxide when applied to flour acts as a preservative; and that enough of the bleaching agent is retained through the process of baking to discourage the growth of micro-organisms upon the bread.

Bleaching and Natural Aging.

It is a matter of common knowledge that flour improves with age, for several months after milling. The chemistry of the change is unknown, though several theories have been proposed. Most investigators think that the change is due to oxidation; though some ascribe it to enzymic action, and others to the absorption of nitrous vapors from the air. Snyder[29] holds the last-named view; and McGill[20] and Shutt[28] showed that flour exposed to the air would absorb slight amounts of nitrite-reacting material. Ladd[16] Bassett[17] and Stallings[18], Rousset,[24] Saunders[25] Monier-Williams[21], Moore and Wilson[22], Thomson[32], Scheringa[26] and Winton[39] found that natural aging was an oxidation, was not a nitrous addition, or that the effects of bleaching were not at all similar to those of natural aging.

Digestibility of Bleached Flour, and Animal Experiments.

Snyder[29], Wesener[34], Wesener and Teller[35], Willard and Utt[38], and Rockwood[23] found that bleaching had no appreciable effect upon the digestibility of flour. Ladd[16], Ladd and Bassett[17], Ladd and Stallings[18] Halell, Halliburton[13] and Shepard[27] found that bleaching with various amounts of nitrogen peroxide exerted a marked inhibitory effect upon the

digestion of flour.

Ladd[16] extracted unbleached, bleached and overbleached flour with alcohol, finding that the evaporated extract from unbleached flour was harmless to rabbits when administered per stomach; but that the extracts from both bleached flours were fatal to rabbits. Hale[11] failed to corroborate these results, but found that such extracts from bleached flours were toxic to white mice and rats when administered subcutaneously while similar extracts from unbleached flours were not toxic. Wesener and Teller[35], Snyder and Haines[30], Wilcox[36], and Luff[19] all found that alcoholic extracts of bleached flour were not toxic to experimental animals when administered per stomach.

Bleached Flour and Health.

Snyder[29], Alway[1] and his collaborators Gortner[2] and Pinckney[3] Rousset[24], Haley[12] and Scheringa[26] agree that commercially-bleached flour cannot be regarded as injurious to health. Steensma[31] concluded that the nitrite-reacting material in flour was not in itself harmful in any way, but that the bleaching agent might attack the "vitamines" in flour, and thus lower its quality. On the other hand, Ladd[16] and his collaborators Bassett[17] and Stallings[18], Hale[11], Hammill[14], Moore and Wilson[22] Halliburton[13], and Winton[39] conclude that the use of bleached flour is probably injurious to health.

Nitrite Reacting Material in Flour and Bread.

Avery[4], Ladd and Stallings[18], Alway[1], Alway and Gortner[2] McGill[20] and Scheringa[26] found that such material is not a normal constituent of wheat flour, unless it has been exposed to contamination; while Snyder[29] found that unbleached flours contain traces of nitrites.

The champions of bleaching maintain that nitrite reacting material is not combined with the flour, but is merely absorbed in it;

and is driven off by baking, or even by gentle heating. These views are forcefully presented by Snyder[29] and Wesener and Teller[35]. Other investigators, however, found that bread baked from bleached flour retained a nitrite-reacting material. Ladd and Stallings[18] and Winton[39] found that such bread contained from one-third to one-half of the nitrites originally present in the flour from which the bread was made.

Effect of Nitrogen Peroxide upon Gluten.

Since the work reported in this paper deals largely with the effect of bleaching upon the baking quality and upon the commercial value of flour, previous work upon gluten and commercial value should be reported more fully than the other phases of the work.

Snyder[29] holds the opinion that flour is improved by bleaching just as it is improved by natural aging, and states that there is a slight tendency toward improvement of the bread-making quality, and that there is no injurious effect. This opinion is in direct conflict with his earlier views, as expressed in Bulletin 85 (page 217) of the Minnesota Agricultural Experiment Station, which were

a) That there is no necessity for the use of bleaching agents to improve the keeping quality of the flour or to whiten it.

b) That bleaching tends to destroy the characteristic and natural color which is desirable as indicating character.

c) That the gluten is affected by bleaching, so that the gluten of bleached flour has lessened powers of expansion and absorption, and yield loaves of bread which, although whiter in color than those made from unbleached flour, are smaller in size and less in weight.

Shutt[28] thinks it possible that bleaching may result in an improvement of the bread-making quality of the gluten, due to a higher absorption of moisture.

Many investigators have found that bleaching has little or no effect upon the bread-making quality of the flour. Avery[5] found that unbleached and bleached flours produce loaves of practically the same size, weight, and texture. Rousset[24] concluded that flour is unchanged by bleaching except in the lightening of the color and the addition of a minute quantity of nitrite-reacting material. Alway[1] found that bleaching does not change the absorptive capacity nor the expansion of the gluten, and that bread made from bleached flour does not differ from that made from unbleached flour in weight, lightness, volume, texture, odor, or taste. Alway and Gortner[2] corroborated these results, as did Alway and Pinckney[3]. Buchwald and Neumann[8] reported that bleaching makes very little change in the chemical properties of flour, and does not affect its baking quality. Saunders[25] found that the difference in strength between various flours before and after bleaching is extremely slight and within the limits of experimental error, and that there is no perceptible difference in the flavor of the bread. He stated, however, that bleached flour does not improve in strength upon aging, as does unbleached flour.

Many other investigators have held that bleaching injures the bread-making quality of the flour. Snyder, as has been mentioned, was formerly of this opinion. Balland[6] concluded that while the elasticity of the gluten was affected very littly by bleaching, gluten from bleached flour has a less delicate color than that from unbleached flour, and that the resulting bread is less savory. Brahm[7] found that both the odor and the baking quality of flour are unfavorably affected by the bleaching process. He also held that the color was not improved, in that the white color of the bleached product was not as attractive

as the natural color of the flour. Ladd and Stallings[18] found that flour is injured in its absorptive and expansive properties by bleaching, and that bleached flour yields a smaller and poorer loaf than does unbleached. Ladd and Bassett[17] concluded that bleaching injuriously affects the gluten of flour. Monier-Williams[21] found that bleaching changes the protein of flour, increasing its water-soluble fraction by hydrolyzing the gluten and thus lowering its baking quality. He admitted, however, that unless the flour is heavily bleached it produces loaves of excellent quality and of normal taste and smell. Moore and Wilson[22] found that bleaching "nitrates" the gluten to a certain extent, thus lowering its quality. Winton[39] found that bleached flour is markedly lower in bread-making quality than is unbleached flour; and that the gluten is altered in physical character and diminished in quantity by bleaching.

Concealment of Inferiority by Bleaching.

Men in favor of the bleaching process contend that it is impossible to conceal inferiority in flour by bleaching it, as only high-grade flour is susceptible to improvement in that way. Opponents of bleaching hold that various inferiorities may be and are concealed by the bleaching process; as follows; (a) the inferiority of color of new flour, (b) the inferiority of dark-colored wheat, such as Durum wheat, which has a lower market value, and (c) the inferiority of lower-grade flours, so that by bleaching a miller is enabled to lengthen his patent by adding certain portions of the clear flour to the patent stream.

In support of the contention of those in favor of bleaching, Fleurent[10] reported that low-grade flours are not improved by bleaching,

because the cellulose impurities have a greater affinity for the bleaching gas than the particles of flour have. Alway[1] found that bleached low-grade flours produce loaves of uninviting color. Alway and Pinckney[3] stated that bleached low-grade flours do not resemble patent flours in appearance. Snyder[29] found that it is impossible for any fraud to be practised by means of bleaching low-grade flours, as bleaching only intensifies the difference in color between the particles of flour and the impurities. Wesener and Teller[35] contend that "straight and clear flours are superior to patent flours from a food and economic standpoint, because they contain more protein and fat. Their commercial inferiority lies in their darker color, caused by the greater proportion of fragments of the grain situated near the bran coat, which are richer in natural color than the fragments from the interior, but are also more nutritious. Therefore, in the opinion of the authors, by removing the color, inferiority is removed, and not concealed, as some contend" (Chem. Abst. 4, p 226).

On the other side of the question, Snyder was formerly of the opinion that "Bleaching tends to destroy the characteristic and natural color which is desirable as indicating character", as has been mentioned (see page 9). Ladd[16] blended bleached flour made from Durum wheat -- a strongly colored variety which sells at a marked discount -- with flour milled from the best white hard wheat, in proportions as high as 30% of the bleached Durum flour, and the fact that the lower-grade flour had been blended in could not be detected by testing the flour with a slick. Jago[15] concluded that bleached flour should always be declared as such, since bleaching does not change the low-grade flour in any way except by lightening its color. Moore and Wilson[22], after a comprehensive study

of the whole question, concluded that bleaching made the cheaper grades of flour appear the same as those of higher quality. The Wisconsin Food Commission[41] decided that the practise of bleaching flour affords opportunity for fraud. Most of the foregoing investigators, all scientific men, worked on the subject of bleaching the low-grade flour alone, whereas the problem of most interest to millers is whether or not the patent may be lengthened by adding to it a portion of the better streams of clear, by the use of the bleaching process. Many men who use the process assert that they do not lengthen their patents; but the selling arguments of the manufacturers of bleaching machinery and the statements of many millers who have successfully lengthened their patents by bleaching, leave very little doubt that such a practise is possible. Thus, A. R. Waldron, in a letter to the "Operative Miller" of January, 1906 (p 28) says in part:-

"No miller would go to the expense of installing a bleacher if there was not a good profit promised, --- since millers can only get the top of the market for their flour, they must increase their percentage of patents. In my own work---previous to installing the bleacher we made two grades, 70% patent and 30% extra fancy. After installing the bleacher we ran 85% and 15%, getting the same price as before for each grade."

Again, on page 35 of the same journal is found the following:

"The answer to the question why a miller keeps it dark that he has installed a bleaching outfit in his plant is simple enough, for he does not want to give away a good thing as long as he can help it and wants to reap the advantages of being able to produce a higher per

cent of patent or high grade goods which can certainly compete with unbleached flour, other conditions being equal".

These two letters were chosen at random from a great number of communications on the same subject to the milling journals. Lack of space prevents the quotation of any more.

Another fact which is emphasized by the opponents of flour bleaching is that the millers who use the bleaching process, though maintaining that flour is greatly benefitted by bleaching, do not advertise the fact that it is bleached; in fact, they object to labelling their product "bleached". On the other hand, many millers who do not bleach, call attention to that fact in their advertisements. These facts tend to show that millers themselves believe that unbleached flour is of superior quality.

III. Preliminary Work.

A. The Samples.

For the purpose of a short, preliminary investigation, W. R. M. Wharton, a Food and Drug Inspector of the Bureau of Chemistry, visited a mill in Nebraska on March 6,1917, and collected samples of bleached and unbleached flour of various grades; the bleached and unbleached flour of each grade being identical except that one portion of the flour was subjected to the regular Alsop bleaching process as used in the mill. The samples collected were as follows:-

Straight Flour, Unbleached.
Straight Flour, Bleached.
Patent Flour, Unbleached.
Patent Flour, Bleached.
Clear Flour, Unbleached.
Clear Flour, Bleached.

These samples were all shipped to the Bureau of Chemistry, Washington, D. C., and portions of each of them were forwarded by the Bureau to the writer at the Fleischmann Laboratory in Peekskill, N. Y., where he was temporarily stationed at that time.

B. Chemical Analysis.

Upon chemical analysis using the official methods of the A. O. A. C., these flours showed the following composition:

TABLE I. Chemical Analysis.

Substance	Unb. Straight	Bleached Straight	Unb. Patent	Bleached Patent	Unb. Clear	Bleached Clear
Ash, %.	0.536	0.546	0.458	0.414	0.594	0.594
	0.538	0.542	0.458	0.414	0.598	0.598
			0.458	0.400		
			0.460			
Moisture, %.	12.81	12.46	12.94	12.91	13.07	12.87
	12.87	12.51	12.92	12.94	13.11	12.87
Acidity, %.	0.13	0.14	0.10	0.10	0.18	0.17
Cold Water Extract, %.	4.46	4.44	4.54	4.54	4.76	4.86
Total Nitrogen, %	1.52	1.46	1.38	1.40	1.60	1.57
	1.52	1.52	1.40	1.43	1.57	1.63
Water-Soluble Nitrogen, %.	0.32	0.28	0.30	0.32	0.30	0.32
	0.32	0.29	0.32	0.34	0.32	0.31
Alcohol-Soluble Nitrogen, %.	0.90	0.84	0.80	0.81	0.88	0.90
	0.87	0.84	0.83	0.80	0.88	lost
Nitrite-Reacting Nitrogen, p p m:	none	1.92	none	1.41	none	1.00
	none	1.94	none	1.38	none	0.96
Gasoline No. (EBS)	2.77	0.60	2.76	0.75	2.88	0.86
do (BRJ)	2.57	0.56	----	----	----	----

As is well known, the determination of ash in flour is one of the most accurate and reliable indices of quality and uniformity we have. The ash figures given for the unbleached and bleached patent flours in the above table show such a marked discrepancy that grave doubts must be entertained as to the identity of the two samples. They were collected and reported as identical except for the bleaching of one portion, but a difference of 0.049 %, verified by repeated analyses on different portions of each sample, is far too great to be caused by the bleaching process, by the ordinary variations naturally occurring in very large samples, or by any possible error in analysis. There must have been some real difference in the two samples; a difference which might or might not affect the baking qualities of the two flours. In the case of the straight flours, unbleached and bleached, there was found a difference of 0.007 %. This difference, while a little greater than the limit of experimental error (0.005%) observed by the writer, is readily accounted for by the natural variations in large samples, previously referred to. The clear grade flour, being much smaller in amount than either the straight or patent grades, was probably more uniformly mixed, and a very satisfactory sample was secured.

Taking all variations into consideration, it is seen from the above table of results that bleaching causes no perceptible change in the analytical results as shown by the routine methods of flour analysis employed in flour testing laboratories. It is only revealed by tests specifically applied for its detection. The most widely used test for the detection of bleaching by nitrogen peroxide is by the use of the Griess-Ilosvay reagent, which gives a pink or red coloration with

nitrite-reacting material. Another method for the detection of flour bleaching by any means, is the actual measurement of the amount of coloring matter dissolved out of the flour by gasoline. This test is reliable when the same flour is measured before and after bleaching, but will not show with certainty whether or not any one flour of unknown history has been bleached, unless the degree of bleaching is relatively heavy.

Some investigators have reported that flours definitely known to be unbleached gave positive tests with Griess-Ilosvay reagent. Our work has shown that flour ground in a mill in which an Alsop machine is running, even though the flour does not pass through the bleaching agitator, will absorb measurable quantities of nitrogen peroxide from the air of the mill. "Unbleached" flour, to be above suspicion, must be ground in a mill in which no bleaching machinery has been in operation for several hours. The results given in Table I show that our unbleached samples, which were very carefully protected against contamination in the mill, were all free from nitrite-reacting material. While this fact does not prove that unbleached flours are all free from nitrite, it is an indication that such may be the case. It is to be seen that the straight flour was bleached more heavily than the patent, and the patent more heavily than the clear. Many millers state that the lower a grade of flour is, the less effectively can it be bleached. If this statement is true, it would account for the lighter bleach of the clear, but no explanation can be offered as to why the straight should have been bleached more heavily than the patent, unless the opponents of flour bleaching are right in their contentions that millers do bleach straights heavily in order to make them simulate patents, while such deception is

not ordinarily practiced in the case of clears, which are sold as such, and only bleached to improve their color and make them appear of a somewhat better grade than they really are.

The "gasoline number" is secured by comparison of a definite gasoline extract of the flour, which contains the fat and coloring matter of the flour, with a 0.005% solution of potassium chromate as a standard. As the flours lost more than three-fourths of their color by bleaching, it is plain that the bleaching power of nitrogen peroxide, even in minute quantities, is enormous.

C. Baking Tests.

Method of Baking.- The method of baking employed in the testing of these flours was that in use in the Fleischmann Baking laboratory at that time. Since in this method high, short, narrow baking pans are used, and maximum expansion is the main object, the texture of the bread is never as fine as that of bread baked in the shop. Texture is a very important factor in this method.however, since small differences in the expansive power of the glutens are plainly shown, a weak gluten breaking down under the strain of the great expansion.

The baking method employed is as follows:-

(a) Formula.

Flour-	400 grams.
Sugar-	14 "
Salt -	6 "
Yeast-	12 "
Water-	To make standard dough.

(b) Measurement and Weighing. The water is measured in a 500 cc graduate, and poured into a 500 cc wide-mouthed bottle. The yeast is weighed out as rapidly as possible on a laboratory balance, dropped into the water in the bottle, and thoroughly stirred with a bone

spatula. The salt and sugar are also weighed on the laboratory balance. (as none of the weighings require such accuracy as to necessitate the use of an analytical balance) mixed together and ketp in small aluminium dishes until used. The flour is weighed on a large equal arm balance, and placed in scoops until used. To save time, the salt and sugar were always weighed out the evening before being used.

(c) Mixing. The mixing is done in Bachman mixers. The salt and sugar are poured into the mixing bowl, and the thoroughly stirred suspension of yeast in water is added. The motor is then started at half speed, and the flour poured in from the scoop. The last drops of yeast and water are drained into the bowl, the motor advanced to full speed, and the timer is set to 2 minutes. At the expiration of this time, the mixing is automatically stopped.

(d) Fermentation Test. The dough is removed from the mixer, folded twice to form a rough ball, tossed aside on the floured top of the work table, and the mixer started on the second set of doughs, as above. Then 34½ grams of each dough are weighed off on a small, equal-arm balance, dropped into an oiled 100 cc graduate, and gently tamped into the bottom with a section of broom handle. These "tube-tests" are kept in the fermentation cabinet with the doughs, at a temperature of 90°-91° F. Readings are taken one hour after beginning mixing, and every 30 minutes thereafter until the doughs are panned (2½ hrs. from the time of mixing).

(e) Fermentation of Dough. The dough, which has had a few minutes of rest on the work table, is folded four or five times to form a football-shaped mass and placed on a greased dough-board, 12" square, which is then placed in the fermentation cabinet at a temperature of 90° - 91° F. This cabinet contains several flat, shallow pans full of water, at cabinet temperature. A period of 30 minutes is allowed from

the time of beginning the mixing of the first batch until the fermentation period is considered to have begun. (If many batches are mixed, this cannot be done, but when only two batches are mixed, no appreciable error is introduced.) The doughs and tubes should be in the cabinet in 15 or 16 minutes, the remaining 15 or 14 minutes being allowed to rest the doughs and to bring the cabinet to the correct temperature.

The first punch is made at 1¾ hours after the time of mixing. The dough is folded four or five times, with a pushing slap between each fold. The second punch is made at 2 hours, and the third at 2¼ hours in the same manner. At 2½ hours the dough is moulded and panned.

(f) Moulding and Panning. The dough is taken from the cabinet at 2½ hours from the time of beginning mixing, and 555 grams weighed off on the large balance. This dough is then flattened on the work table and folded in three, again flattened and folded in three in the opposite direction, and again flattened and moulded into a cylindrical mass by folding in three in the direction of the first folding. The dough is then placed in the pan, seam down, and the pan is placed in the proof-box at a temperature of 100° - 102° F, where it remains in proof for 65 minutes,

(g) Baking. The baking was done in a large Despatch electric baking oven. At the expiration of the proving period, the oven should be at a temperature of 560° F. This figure will vary with each oven, depending upon the heat-retaining quality of its insulation. The heat is then turned off and the pans are placed in the oven, the doors being left open until the temperature falls to 360° F. The doors are then closed, and the temperature rises to 410° - 420° F, the correct baking

temperature for that oven. Baking is complete in from 25 to 30 minutes.

(h) Measurement. About 20 minutes after removal from the oven, each loaf is measured around its greatest longitudinal circumference with a tape measure. Next morning, the loaves are cut, and sometimes the cross sections are photographed. Baking quality is judged by the size and texture of the loaf.

Baking Results.- Seven test bakes were made upon each of the six samples, following the method given above. The measurements of each loaf in inches are given in the following table:-

Table II.

Bake No.	1	2	3	4	5	6	7	Ave
Unbl. St.	28.6	27.6	28.4	27.3	28.4	28.3	27.3	28.0
Bl. St.	27.1	26.1	26.6	26.5	26.1	26.4	26.0	26.4
Unbl.Pat.	28.6	27.6	28.6	27.5	28.0	28,1	27.1	27.9
Bl. Pat.	27.8	26.3	27.1	26.3	26.4	26.5	26.1	26.6
Unbl. Cl.	27.8	26.9	27.4	26.0	27.0	26.9	26.8	27.0
Bl. Clear	27.5	26.1	26.9	26.0	26.4	26.6	26.4	26.5

In working these flours it was very apparent that they were not nearly as good as the corresponding grades milled from good Hard Winter wheat. The absorption was very low, being only about 55%, and the doughs all had a peculiarly lifeless feeling. A marked difference in the behavior of the doughs made from unbleached and bleached flours was apparent. While there was no marked difference in the stiffness of the doughs immediately after mixing, those made from bleached flour

invariably softened down during fermentation more than those made from unbleached flour, so that it was necessary to run former with one per cent less water in order to have them finish with approximately the same stiffness as the latter.

In regard to the finished loaves of bread, it is apparent from the column of average figures that in every case, bleaching lowered the loaf volume of the flour; the straight showing a loss caused by bleaching of 1.6 inches; the patent a loss of 1.3 inches, and the clear a loss of 0.5 inches. It is interesting to note that the decrease in volume is proportional to the severity of bleaching; the straight flour, being bleached the heaviest, showed the greatest decrease, while the clesr flour, bleached the lightest, showed the least decrease.

The color of the bread from the unbleached flours ranged from creamy in the case of that baked from the patent to yellowish in that baked from the clear. The color of that from the bleached flours ranged from a dead white to a grayish white. The texture of the bread from bleached flour was practically the same as that of the bread from unbleached flour.

IV. The Investigation.

In order to give a clear idea of the scope of this work, it will first be presented in outline form, as follows:-

A. Collection of Samples.
   (I) Flour from semi-dark hard winter wheat.
   (II) Flour from dark hard winter wheat.
   (III) Flour from musty wheat.
B. Chemical Analysis.
C. Laboratory Baking Tests.
   (I) Procedure.
      (a) Formula.
      (b) Measuring and Weighing.
      (c) Mixing.
      (d) Fermentation Test.

(e) Fermentation of Dough.
(f) Moulding and Panning.
(g) Baking.
(h) Measurement of Loaves.
(i) Judging the Bread.

(II) Results.

(a) Comparison of flour milled from dark hard wheat with that that from semi-dark hard wheat as to baking quality, etc.
(b) The effect of bleaching upon baking quality, etc.
(1) Baking tests upon old flours.
(2) Baking tests upon new flours.
(3) Baking tests with corn starch as a flour substitute.
(4) The effect of bleaching upon musty flour.
(5) The effect of bleaching upon the color of bread baked therefrom.

D. Commercial Baking Tests.
(I) Middle-western bakery.
(II) Southern bakery.
(III) Eastern bakery.

E. The Effect of Bleaching Upon the Commercial Value of Flour.

A. Collection of Samples.

During the months of September, 1917, August, 1918, and January 1919, Mr. B. C. Winslow, Food and Drug Inspector of the Bureau of Chemistry and the writer collected certain samples of flour for use in the bleached flour investigation.

I. The first sample of semi-dark hard, or "yellow-berry", wheat was bought by Mr. Winslow in Nebraska. It graded #2 semi-dark hard winter, and was found to contain about 35% of yellowberry, the remainder being good, dark wheat, approximating Turkey quality. It was shipped to a mill in Kansas, where it was cleaned, scoured, tempered and ground under Winslow's personal supervision. In tempering, the cleaned wheat was wet with about 6 % of water, that is, 1 gallon to 2 bushels of wheat, and put in the tempering bin at 9:30 A. M. on Sept. 10th, and ground at 3:00 P. M. Sept. 11th, a tempering period of 29½ hrs. The mill was set to yield a 90% straight flour; containing all the streams of the mill exceptthe first and fourth break flours, the

first and second tailings flours, and the "reel flour", which was composed of the low-grade and the bran and shorts duster flours. The wheat was allowed to run through the mill for 30 minutes before sampling was begun. In collecting the sample of unbleached flour, the flour stream was shunted around the bleaching agitator, in order to avoid any possible contamination with bleaching gases (even though the Alsop machine had not been running that day) and 24 49 lb. bags were collected from the packer. These 24 bags made up the unbleached sample. Testing at frequent intervals revealed no trace of nitrite reacting material. Immediately after the unbleached flour had been packed, the Alsop bleacher (a 3-point machine operating with a current of 2 amperes) was started, the flour strean shunted back through the bleaching agitator, and 48 49 lb. bags of the bleached flour were collected, each alternate bag, 24 in all, making up the lightly bleached sample. The remaining 24 bags were then carried upstairs and the flour again run through the agitator in the same manner as for the first bleaching, taking all the gas from the bleaching machine. This flour, run through the bleacher twice, made up the heavily bleached sample. Each of the three samples was then taken and separately mixed in a large wooden tank, in order to obtain perfect uniformity of sample, re-bagged, sealed with twine and lead seals, and packed in barrels for shipment by freight to the Bureau of Chemistry. Later samples of this same grade of flour were collected in the same way by Mr. Winslow and the writer, except that only one degree of bleaching was used; the flour being so treated as to contain about 2 parts per million of nitrite-reacting nitrogen.

II. The sample of dark hard winter, or true type Turkey wheat was also handled by Mr. Winslow throughout. It was bought from the Central Granaries Co., of Beaver City, Neb. It was grown locally and

graded #2 dard hard (approximately Turkey quality), testing 59.25 pounds per bushel. A small amount of smut was found, but not enough to injure its quality. It was shipped to the same mill as was the foregoing set of samples, where it was treated and ground. In tempering, the cleaned wheat was wet with about 6% of water, as was the other sample, and put into the tempering bin at 6:00 P. M. September 8th, 1918. It was milled at 10:30 A. M., September 10th, thus being tempered for a period of 40½ hrs. This length of time was sufficient to bring out the good quality of the wheat, although 6 hrs. more time would not have injured it. Being much harder that the semi-dark wheat, it required a much longer tempering process. The flour was milled and bleached, and the samples collected and shipped in exactly the same manner, as in the case of the preceding set, except that 12 49 lb. bags of each flour sample were taken instead of 24.

In both of these sets of flours, the natural flour, the lightly bleached flour, and the heavily bleached flour were each sent to the Bureau as a separate shipment; and the natural flour was routed differently than the bleached flour, in order to avoid any possibility of nitrite contamination during shipment. As a consequence of the precautions taken, the natural flour showed no trace of nitrite-reacting material upon arrival at the Bureau.

III. The musty wheat was bought by Mr. Winslow in Kansas City, Missouri. This was a very good wheat for our test, as it graded No. 5 mixed, was very musty, contained numerous live weevils, and had arrived at the terminal so hot that it had to be dried and cleaned immediately. After drying, it tested 13% moisture. This wheat was ground in the experimental mill of the Kansas State Agricultural College, at Manhattan, Kansas, into 90% flour. Two bags of this flour were left un-

bleached, two bags were lightly, and two heavily bleached.

A summary of the samples collected is given in the following table:-

Table III.

Inv. #	Date	Kind of Wheat Used	Flour made	Nitrite Nitrogen p. p. m.	Gasoline No.
4683	Sept. 1917.	Semi-dark hard winter	90% Unbl.	None	1.68
4684	"	do	" Lt. Bl.	0.20	0.67
4685	"	do	" H. Bl	0.70	0.25
4680	"	Dark hard Winter	90% Unbl.	None	1.13
4681	"	do	" Lt. Bl.	0.15	0.63
4682	"	do	" H. Bl.	1.00	0.25
4695	"	Musty, mixed	90% Unbl.		
4696	"	do	" Lt.Bl.		
4697	"	do	" H. Bl.		
10126	Aug. 1918	Semi-dark hard Winter	90% Unbl.	0.09	
10127	"	do	" Bl.	2.09	
11584	Jan. 1919	do	" Unbl.	0.03	
11585	"	do	" Bl.	2.14	

Note:- It will be noted that unbleached flours, 10126 and 11584, both show noticeable quantities of nitrite-reacting material. Since the flour was carefully tested after milling and found to be free from nitrites, the writer was at a loss to explain their presence until it was discovered that an ozone generator is used to purify the air in the cold-storage room in which the flour is stored. As is well-known, ozone gererators all produce peroxide of nitrogen. The amount found in the unbleached flour is so small, compared with that in bleached flour, however, that

it probably has no effect upon the validity of the results secured.

B. Chemical Analysis.

Upon chemical analysis, using the official methods of the A. O. A. C., the first six samples showed the following composition:

Table IV.

CHEMICAL ANALYSIS, FLOURS Inv. Nos. 4680 to 4685, Inc.

Substance	Semi-Dark Hard (Yellowberry) #4683	#4684	#4685	Dark Hard (True Turkey) #4680	#4681	#4682
Ash, %	0.392	0.392	0.390	0.417	0.413	0.415
	0.390	0.388	0.391	0.410	0.419	0.415
Moisture, %	13.60	13.70	13.70	13.28	13.59	13.63
	13.57	13.59	13.62	13.24	13.57	13.58
Acidity as Lactic, %	0.10	0.095	0.10	0.11	0.105	0.11
	0.10	0.095	0.10	0.11	0.11	0.11
Cold-Water Extract, %	4.60	4.62	4.55	4.68	4.68	4.53
	4.46	4.51	4.57	4.58	4.61	4.50
Total Nitrogen %	1.99	1.94	1.94	2.13	2.11	2.08
	1.99	1.94	1.94	2.11	2.05	2.08
Alc-Sol. N.,%	0.996	0.982	0.982	1.04	1.08	lost
	0.982	1.05	0.982	1.07	1.05	1.05
H_2O-Sol. N.,%	0.386	0.365	0.407	0.365	0.372	0.428
	0.442	0.365	0.400	0.379	0.393	0.409
Salt-Sol. N.,%	0.267	0.274	0.281	0.281	0.288	0.288
	0.274	0.274	0.281	0.281	0.288	0.288
Nitrite N. % (Av. of 6)	none	0.20	0.70	none	0.15	1.00
Gasoline Number Av. of 6)	1.68	0.67	0.25	1.13	0.63	0.25

These results show that these samples were thoroughly mixed before bleaching; that the natural, lightly bleached, and heavily bleached flours of each set are undoubtedly the same flour. A study of the figures for the natural, lightly bleached, and heavily bleached flours of either set confirms the conclusion reached in the preliminary work, "that bleaching causes no perceptible change in the analytical results as shown by the routine methods of flour analysis employed in flour testing laboratories. It is best revealed by tests specifically applied for its detection." The figures for nitrite-reacting nitrogen show that both these flours, even those supposedly heavily bleached, were in reality only lightly bleached; as the heavily bleached Yellowberry and Turkey flours showed only 0.70 and 1.00 part per million, respectively, of nitrite-reacting nitrogen.

Significant differences between the flour made from semi-dark hard wheat and that made from dark hard wheat are shown by these analyses. The former, being a much weaker wheat gives lower figures for ash content and nitrogen. Such being the case, one would expect a lower color value; but the opposite is true; the gasoline number being nearly 50% greater in the softer flour. This fact seems to bear out the contention of most millers that yellowberry is a deteriorated and inferior hard wheat, and that it yields flour markedly inferior in color to that milled from either dark hard wheat or real soft wheat.

C. Laboratory Baking Tests.

It was found necessary to do a great deal of preliminary work on different methods of baking, in order to find the method best suited to this problem and these particular flours. The Fleischmann method of testing, used in the preliminary work, was found inadequate, in that the

long period of proof made the texture very coarse, and also in that flours were all treated alike, no allowance being made for the different periods of fermentation of different flours. The "straight bake" system was also discarded, because most flours, particularly such strong flours as those used in these experiments, do not produce good results without kneading or working during fermentation.

(I) Procedure:- The method finally adopted for use in this work was as follows:-

(a) Formula:

Flour	450 grams
Sugar	16 grams
Salt	7 grams
Yeast	13.5 grams
Water	To make standard dough

(b) Measuring and weighing. Same as described in the preliminary work.

(c) Mixing. Same as described in the preliminary work.

(d) Fermentation test. This test was carried out in much the same manner as that described in the preliminary work except that the dough was taken off at the time of panning instead of immediately after mixing and enough was taken to represent 100 grams of flour, usually about 170 grams. The test was made in a graduated glass jar having a capacity of 1000 cc. Readings were taken at the end of two hours in the jar, and every 15 minutes thereafter until the dough fell.

(e) Fermentation of Dough. Same as described in the preliminary work, except that each flour was given its best period of fermentation. This period was measured from the time of placing the dough in the fermentation cabinet, and determined for each flour separately, by a series of experiments and not arrived at by " taking the dough when it was ripe" or by any other hit-or-miss method. This period of fermentation was

divided as follows, by the advice of Wilfahrt and Bachman of the Fleischmann Co., Jacobs of the Bureau of Chemistry, and other authorities. From setting of dough to first punch, 60% of the total time of fermentation; from 1st punch to 2nd punch, 20%; from 2nd punch to 3rd punch, 10%; from 3rd punch to time of moulding, 10%. This method was found to give the best quality of bread.

(f) Moulding and panning. All the dough remaining after taking off that for the fermentation test was baked into the loaf, which therefore represented 350 grams of flour. The pans used were ordinary, commercial baking pans, 3" x 8¼" on the bottom, 4" x 9½" on the top and 3¾" high. This type of pan was adopted because it gives loaves comparable in every respect to commercial bread, and also because the laboratory was already equipped with a machine to accurately measure the volumes of loaves of that size.

The dough was moulded in the manner previously described. It was left in the proof-box until the top of the dough was exactly even with the top of the pans. This method, instead of that of an arbitrary length of time in proof, was used because it gives each dough the same development. This arbitrary height of proof was adopted as giving loaves of very large loaf-volume, and yet of excellent texture. Shorter proof was found to injure the loaf volume, and longer proof to injure the texture.

(g) The baking was done in a large Despatch electric baking oven. The loaves were baked for from 35 to 40 minutes at a constant temperature of 210° C.

(h) Measurement. About twenty minutes after removal from the oven, each loaf was measured in the measuring machine manufactured by the Industrial Appliance Company of Chicago, using rape seed as a filling material.

(i) Judging. After measurement, some of the loaves were cut and judged for color, texture, odor, and taste.

(II) Results.- The early part of the work was of such a varied character, being merely trials of various methods in order to find that best suited for this work, that it is not worth while to go into it in detail. The results given here are those obtained by the use of the method finally adopted, as described in the preceding section.

(a) Comparison of flour milled from dark hard wheat with that from semi-dark hard wheat as to baking quality, etc. Many sets of comparative bakes were run on these samples, and the best results secured for each flour are given in the following table:-

Table V.

COMPARATIVE RESULTS.

6666	Unbleached Flours: Dark Hard	Unbleached Flours: Semi-Dark Hard	Lightly Bleached Flours: Dark Hard	Lightly Bleached Flours: Semi-Dark Hard	Heavily Bleached: Dark Hard	Heavily Bleached: Semi-Dark Hard
Absorption,%	72	72	70	70	70	70
Dough Ferm. Period, min.	200	200	175	175 & 120	175	120
Time in Proof min.	50	50	45	45 & 50	45	47
Loaf Volume,cc	2575	2500	2425	2400	2500	2475
Time to Maximum in jar,min	150	165	165	180	150	195
Jar Ferm.Volume cc.	880	880	900	880	860	920
Time at max. in jar, min.	30	30	15	15	15	30

Notes:-Dough quality: In gerneral, the doughs made from semi-dark, hard flour were softer, stickier, slackened down more during fermentation, and did not work as well as those made from dark hard flour.

Appearance of Loaves: No significant difference.

Color and Texture: In general the color and texture of bread made from semi-dark hard flour were poorer than in the case of bread made from the corresponding hard dark flour.

Flavor: No significant difference.

These results indicate that flour milled from semi-dark hard wheat is not as good for breadmaking purposes, as that milled from dark hard wheat. The flour is of poorer color and poorer chemical analysis (shown in Table II); the dough is inferior in water retaining and working qualities; and the bread is inferior in color, texture, and loaf-volume.

(b) The effect of bleaching upon baking quality, etc.

(1) The first work upon this phase of the problem was done by making a long series of comparative bakes upon the unbleached and bleached flour milled from semi-dark hard wheat. The bleached flour used was that previously referred to as "Heavily Bleached". This flour, containing only 0.70 p.p.m. of nitrogen as nitrite, was in reality only lightly bleached. The results secured are given in the following table:

Table VI.

Effect of Bleaching Upon Baking Quality of Flour. From Semi-Dark Wheat

	Semi-Dark Hard, Unbleached					Semi-Dark Hard, Bleached				
1918 Date	Ferm. Period	Loaf Vol.	Ferm. Vol.	Time to Max.	Time at Max	Ferm Per	Loaf Vol.	Ferm Vol.	Time to Max	Time at Max.
2/18	200	2525	810			120	2500	880	210	15
2/20	200	2350	890			120	2400	910	195	15
2/21	200	2400	890			120	2500	850	210	45
2/23	200	2475	840	225	45	120	2575	830	195	75
2/28	200	2450	850	165	45	120	2400	860	165	15
3/1	200	2500	840	195	15	120	2525	830	165	45

Table VI. (Continued)

Effect of Bleaching Upon Baking Quality of Flour.

From Semi-Dark Hard Wheat.

	Semi-Dark Hard. Unbleached					Semi-Dark Hard. Bleached				
1918: Date:	Ferm. Period	Loaf Vol.	Ferm. Vol.	Time to Max.	Time at Max.	Ferm Per	Loaf Vol.	Ferm: Vol.	Time Max.	Time Max.
3/4	200	2450	800	180	75	120	2425	880	225	30
3/7	200	2700	860	165	60	120	2600	890	165	30
3/8	200		860	225	60	120	2600	860	195	30
3/11	180	2625	860	180	15	120	2450	830	165	60
3/13	180	2725	890	210	30	120	2600	900	195	45
3/15	180	2725	840	195	45	120	2550	870	210	30
Av.		2538	852	193	45		2502	866	191	36

Notes:-Dough quality: The doughs made from bleached flour were softer, stickier, slackened down m more during fermentation, and did not work as well as those made from the unbleached flour.

Appearance of loaves: No significant difference.

Color of Crumb: The crumb color of bread baked from the bleached flour was uniformly whiter than that of bread baked from the unbleached flour.

Texture of Crumb: No significant difference.

Flavor: The flavor of the bread made from unbleached flour was uniformly better than that of the bread made from bleached flour.

(2) In order to test the claim made by those in favor of bleaching, that the process greatly improves the quality of newly-milled flour, samples Inv. Nos. 10126 and 10127 were milled, No. 10127 being bleached,

as already described. This belief in the improvement of new flour by bleaching has been carefully fostered by the bleaching interests, and the statement has been made so many times that many flour men believe it implicitly, even though they have done no work on the subject. Previous experience having shown the impossibility of getting newly-milled flour from Kansas to Washington, D. C. in sufficiently fresh condition for this test, the work was done in the baking laboratory of the Kansas State Agricultural College at Manhattan, Kansas; Dr. L. A. Fitz having kindly given his permission. The experimental work was begun when the flour was two days old, and was completed in four days. The optimum conditions of baking were determined for each flour in the manner previously described, by actually determining what conditions produced the best results. The apparatus used was the regular equipment of the baking laboratory. It differed from that used in the baking laboratory of the Bureau in that a Koellner mixing maching was used instead of a Bachman, and in that pail-shaped baking pans were used instead of regular commercial pans.

Bleached and unbleached flours, each baked under its optimum conditions, produced results as follows:

Table VII.

Effect of Bleaching upon Baking Quality of New Flour.

	Unbleached Inv. #10126	Bleached Inv. #10127
Absorption used	66%	66%
Character of dough during working	Tough and dry	Somewhat sticky
Period of fermentation	180 min.	150 min.
Loaf volume (average)	1870 cc.	1815 cc.
Texture of crumb	good	good
Color of crumb	Creamy white	Grayish white
Flavor of crumb	Normal	Somewhat sharp

Formula:-

Flour	350 gm.
Sugar	10 "
Salt	5 "
Yeast	11 "
Water	To make standard dough

Weight of dough baked for each loaf -- 500 gm.

(3) In order to determine in another way whether or not bleaching weakens the gluten of the flour, three series of experiments were run in which the flours, both unbleached and bleached, were diluted with ten, twenty, and thirty per cent of pure corn starch. The results of these series are given in the following table:

Table VIII.
Baking Tests, with Cornstarch.

1918 Date	Semi-Dark Hard Unbleached Ferm Period	Loaf Volume	Ferm Volume	Time to Maximum	Time at Maximum	Semi-Dark Hard Bleached Ferm Per.	Loaf Vol.	Ferm Vol.	Time to Maximum	Time at Maximum
				10% Corn Starch Added.						
3-4	180	2450	780	180	90	108	2400	810	180	45
3-7	180	2475	830	150	60	108	2375	860	165	30
3-8	180	2375	840	210	75	108	2350	820	165	45
3-11	160	2425	890	195	30	108	2525	820	165	60
3-13	160	2500	890	195	30	108	2450	840	180	30
3-15	160	2525	800	180	30	108	2500	860	180	15
Average		2458	838	185	53		2433	835	173	38
				20% Corn Starch Added.						
3-4						96	2200	840	195	30
3-7						96	2350	870	165	15
3-8	160	2350	790	180	30	96	2225	820	180	45
3-11						96	2300	840	210	15
3-13	140	2400	850	165	30	96	2350	900	195	30
3-15	140	2300	830	180	15	96	2250	830	195	15
Average		2350	823	175	25		2279	850	190	25
				30% Corn Starch Added.						
3-13	120	2100	820	180	15	84	2100	860	210	30
3-15	120	2175	800	165	15	84	2175	790	165	15
4-15	90	2150	840	165	30	60	2175	760	165	15
	90	2175	780	165	45	60	2150	770	165	15
Ave.		2150	810	169	26		2150	795	176	19

Notes:- Dough Quality: The doughs made from unbleached flour were markedly superior to those made from bleached flour of the same dilution, the latter being softer and

stickier, slackening down more during fermentation and not working so well as did the former.

Appearance of Loaves: The unbleached flour uniformly yielded loaves of better appearance than did the bleached flour of the same dilution. Loaves baked from the unbleached flour were better in crust color and quality, and much better in shape, having smooth and even breaks, while those from the bleached flour had very ragged and uneven breaks.

Color of Crumb: The crumb color of the bread baked from bleached flour was uniformly whiter than that baked from unbleached flour of the same dilution.

Texture of Crumb: In some cases the textures of the two breads were practically the same; in others the bread from unbleached flour was somewhat superior but in no case was the texture of bread from the unbleached flour inferior to that of the bread made from bleached flour of the same dilution.

Flavor: In general, the flavor of bread baked from the unbleached flour was found somewhat superior to that of bread baked from bleached flour of the same dilution.

(4) The color scale of the crumb of the bread made from the first six samples in question, and three authentic samples of definitely-known grades of Minnesota hard spring flour, was determined by four sets of bakings, and is as follows: the flour giving the whitest bread being No.1 in the list, that giving the darkest bread, No. 6:-

1. Heavily Bleached Dark Hard Winter, and Heavily Bleached Semi-Dark Hard Winter, each 90%.
2. Lightly Bleached Dark Hard Winter, and Lightly Bleached Semi-Dark Hard Winter, each 90%.
3. Unbleached Minnesota Hard Spring, 70%.
4. Unbleached Minnesota Hard Spring, 90%.
5. Unbleached Dark Hard Winter, 90%.
6. Unbleached Semi-Dark Hard Winter, 90%, and Unbleached Minnesota Hard Spring, 96%.

It will be noted from this color scale that bread made from the unbleached hard dark Kansas flour was darker in color than the 90% Minnesota flour,

and that bread made from the unbleached semi-dark hard Kansas flour was about the same color as that made from the 96% Minnesota flour. A light bleaching of the Kansas flours, however, enabled them to produce bread lighter in color than the 70% Minnesota patent. This table shows plainly the effect of bleaching upon the southwestern flours, and explains why many millers desire to bleach their product.

(5) Samples of the unbleached and bleached flour from the musty wheat previously described were baked at the same time and under the optimum conditions for each flour. The bread from both flours was very rank in smell, especially while hot; the odor of must being noticeable throughout the laboratory. No difference in odor could be detected between the bread made from unbleached and that from bleached flour; they were both very bad.

D. Commercial Baking Tests.

The foregoing laboratory experiments indicated that bleaching has an injurious effect upon the quality of flour. Since these experiments were made upon such a small scale, with relatively large quantities of yeast, and with most rigid control of all conditions, it could not be assumed that the same difference between unbleached and bleached flour would appear in the bread baked from the flours under commercial conditions; and the baker's oven is the final test of flour quality. Therefore it was decided to conduct experiments upon a commercial scale, in commercial bakeries, under varying, but commercial, conditions.

For this purpose samples Inv. Nos. 11584 and 11585 were collected as previously described. Five lots of flour were prepared, each consisting of five barrels of unbleached and five barrels of bleached flour.

One lot was shipped to each of five commercial bakeries, in various parts of the country. The experiments in three of these bakeries, a middle-western, a southern, and a very large eastern bakery-- were under the direct supervision of the writer. In each case the regular methods in use in the bakery were used, no changes being made in the formula or method of working the plant; the object being to discover what difference, if any, would be found in the commercial bread produced from unbleached flour in comparison with that from the same flour after bleaching.

In each plant, a certain amount of preliminary work was done, in order to familiarize the head baker with the two flours, so that he could give each flour the treatment necessary to secure the best results. Only the final results are given in this report.

(I) Middle-Western Bakery. This bakery was selected as being a typical medium-sized plant in a city of moderate size. The process of manufacture is not characterized by rigid scientific control, but the owner has made his product well-known throughout his section because of a high standard of flavor and general quality. The following table shows the work done and the results secured;-

Table IX.

	Unbleached	Bleached
Formula of Sponge:		
Flour	196 lbs.	196 lbs.
Water	16½ Gal.	16½ gals.
Yeast	3 lbs.	3 lbs.
Temperature of Sponge	80° F	80° F
Time in Sponge	5 hrs.40 min.	5 hrs.20 min.
Added to Sponge for Dough		
Flour	196 lbs.	196 lbs.
Water	12 gal.	12 gal.
Sugar	8 lbs.	8 lbs.
Salt	9 lbs.	9 lbs.
Fat	6 lbs.	6 lbs.
Temperature of Dough	80° F	80° F
Time in Dough	2 hrs.	1 hr. 50 min.
Time in Proof	1 hr.20 min.	1 hr. 25 min.
Temperature of Proof Box	820-85° F	820-85° F
Average measurement of 10 loaves (2 circumferences)	41.54 inches	40.12 inches
Weight of loaves	24¼ to 24½ oz.	24¼ to 24½ oz.
Loaf Quality		
Loaf Volume	Very good	Good
Crust Color	Very good	Trifle dark; dull
Crumb Color	Creamy	White,grayish cast
Texture	Very good	Good.
Flavor	Normal	Trifle sharp,acid.

Throughout the experiments, it was observed that the dough made from unbleached flour was superior to that made from bleached flour, in that the former was tougher, springier, more elastic, and of better working quality than was the latter.

(II) Southern Bakery. This bakery is comparable to the previous one, except that it is located in a southern city. In this bakery, the following observations were made:-

Table X.

Work Done in Southern Bakery.

Batch Number	4	3	5	6	7	8
Sample (Inv.) Number	11584	11585	10126	10127	11584	11585
Bleached or Unbleached	Unbl.	Bl.	Unbl.	Bl.	Unbl.	Bl.
Method of Doughing	Sponge	Sponge	Straight Dough	Straight Dough	Straight Dough	Straight Dough
Formula of sponge or straight dough:						
Flour	147 lbs.	147 lbs.	171 lbs.	171 lbs.	242 lbs.	242 lbs.
Water	11 gal.	11 gal.	14 gal.	14 gal.	18½ gal.	18½ gal.
Yeast	2½ lbs.	2½ lbs.	3 lbs.	3 lbs.	3 lbs.	3 lbs.
Salt			3 "	3 "	4 "	4 "
Sugar			2½ "	2½ "	4 "	4 "
Malt			2 "	2 "	2½ "	2½ "
Oil			1 2/3 "	1 2/3"	3 "	3 "
Temp. of sponge	83° F	82° F				
Time in sponge	4 hrs. & 15 min.	4 hrs.				
Formula added to sponge:						
Flour	150 lbs.	150 lbs.				
Water	12 gal.	12 gal.				
Sugar	6 lbs.	6 lbs.				
Salt	4½ "	4½ "				
Malt	1 qt.	1 qt.				
Temp. of dough	84° F	83° F	84° F	84° F	80° F	81° F
Time in dough	2 hrs.	1½ hrs.	4½ hrs.	4½ hrs.	4hr. 40 min.	4hr. 40 min.
Time in proof (about 90° F)	50 min.	50 min.	1 hr.	50 min.	50 min.	1 hr.
Av. measurement of ten loaves	36.08"	35.91"	36.70"	36.44"	35.36"	36.13"
Comparison of pairs of batches:						
Color of crumb	Better		Better		Better	
Texture	Better			Better		Better
General Appearance	Better			Better		Better
Flavor	Better		Better		Better	
Volume	Better		Better			
Grain		Better		Better		Better

These results show that the flavor of bread made from unbleached flour, by either the sponge method or the straight dough method, is superior to that of bread made from bleached flour.

The newer flours (Invl Numbers 11584 and 11585) were baked by both methods. It was observed that when the sponge method was employed the unbleached flour yielded bread greatly superior in quality to that from the bleached flour. When the straight dough method was used, however, the differences between the bleached and unbleached bread were comparatively slight.

The older flours (Inv. Numbers 10126 and 10127) were baked by the straight dough method only. In this case, the bread from the unbleached flour was superior in volume, as well as in flavor, and but very slightly inferior in texture and general appearance, so that upon the whole, the unbleached flour was superior in baking quality.

(III) Eastern Bakery. The plant in which the work was done is a very large bakery, in a large eastern city. This work was done by automatic machinery almost exclusively; the pans travelling through the proof-box on shelves, and the bread being baked in a travelling oven. In this bakery, observations were made as follows:-

Table XI.

Work Done in Eastern Bakery.

Formula of Sponge	Unbleached	Bleached
Flour	193 lbs.	193 lbs.
Water	110 "	110 "
Yeast	4¾ "	4¾ "
Temp. of Sponge	82° F	81° F
Time in Sponge	4 hrs.	4 hrs.
Formula added to Sponge:		
Flour	199 lbs.	199 lbs.
Water	105 "	105 "
Sugar	6 "	6 "
Malt	4 "	4 "
Shortening	8 "	8 "
Condensed milk	12 "	12 "
Salt	6 "	6 "
Yeast	¾ "	¾ "
Temperature of Dough	82° F	80° F
Time in Dough	1 hr & 25 min.	1 hr. and 30 min.
Time in Proof	54 min.	53 min.
Temp. of Proof(Saturated humidity)	115° F	115° F
Number of loaves	380	379
Average volume (of ten loaves)	3035 cc	3039 cc
Average weight " " "	675.6 gm.	673.4 gm.
Specific gravity of bread	0.2223	0.2216
General appearance of loaf	Very Good	Very Good
Color of crust	Very Good	Very Good
Color of crumb	Creamy	White, grayish cast
Texture of crumb	Very Good	Very Good
Flavor of crumb	Normal	Normal

There was very little difference in the working quality of the two doughs, throughout the process of doughing and baking. The bread baked from each flour was of excellent quality, and the two breads were so similar that no significant difference could be detected, except in point of color; that from bleached flour being somewhat the lighter in color, having a grayish instead of a creamy tint.

E. Bleaching and Commercial Value.

The commercial value of any given flour cannot be determined by any analytical method, as there are too many variable factors to permit of scientific accuracy. In the course of this investigation and allied work, however, the writer had occasion to interview several hundred men interested in flour. Among them were managers of mills, operating millers, flour salesmen, flour brokers, flour buyers, and bakers; and the general trend of opinion in each one of these classes of men is of great interest in answering the question of whether or not bleaching does increase the apparent commercial grade of flour. Of course, there are numerous individual exceptions in each class, but the agreement of opinions among each group is remarkable.

In general, managers of mills are in favor of the process; or have been forced to install bleaching machinery by competition. Many mills still hold out against bleaching, but they are only a small minority The majority state that people prefer white flour, and they must sell white flour. Many managers stated that "the other mill" increased their percentage of patent by bleaching, and thus gained a great commercial advantage.

Operating millers are sharply divided into two classes. The

older millers, men who learned the trade before bleaching was introduced, are very generally against the process. They say that bleaching does no good except to lighten the color; that it is a fraud in that patents have been so lengthened by bleaching that the term is now meaningless whereas a patent flour was originally, and should be, a flour made exclusively from purified middlings; and that bleaching is a "poor miller's crutch," in that it enables an unskillful or lazy miller to produce a light-colored and uniform color by the mere regulation of the strength of the bleach applied, instead of by the exertion of good craftsmanship. On the other hand, younger millers, men who have learned the trade since the general introduction of the bleaching process, are in favor of it. Most of them have been told so often that bleaching improves flour that they believe it; although very few of them have done any work to prove the point; and nearly all agree that bleaching enables the miller to put out a lighter-colored and more uniform product. They do not admit that bleaching will permit of lengthening the patent.

Flour salesmen are in favor of bleaching, saying that the whiter flour is the easier it sells.

Flour brokers are infavor of the process. They say that patents have undoubtedly been lengthened by bleaching; but that they know enough about flour so that no mill can sell them a bleached straight for a patent and that bleached flour sells easier than unbleached.

Flour buyers are against the process, because they are accustomed to judging flour largely by color, and they agree that while a bleached clear grade or long straight flour cannot be sold as a patent to an expert buyer, it is possible to lengthen patents ten or

fifteen per cent by bleaching, without making the difference noticeable even to an expert, by means of the tests ordinarily applied by buyers.

Bakers are also against the process, because bleaching deceives them as to the grade and quality of flour they are buying. They agree that patents have been lengthened by bleaching: and that most of them are deceived by a bleached straight sold as a patent. They say that this deception is so widespread that the term "patent" is practically meaningless, so that most of them have been compelled to buy by brand instead of by grade, depending only upon the performance of the flour in the ~~the~~ shop to reveal its true quality.

From a comparison of the group-opinions outlined above, with the business-interests of each group, the conclusion seems unavoidable that bleaching lends itself to commercial deception, by raising the commercial grade and value of any given flour.

V. Conclusions.

From the foregoing work, the author has concluded:-

1. That the routine chemical analysis of any given flour is of little or no use in determining the effect of bleaching. It is of great use, however, in determining whether or not a lower grade of flour has bbeen substituted in whole, or in part, for a higher grade, by means of the bleaching process.

2. That nitrite-reacting material is not a normal constituent of flour, and that its determination is of great value in proving bleaching by nitrogen peroxide.

3. That the gasoline number shows definitely the amount of color removed by any bleaching process, when samples of the same flour, bleached and unbleached are available. It is also useful in that it provides an easy and rapid method of stating numerically the intensity of color of

any given flour. It does not prove bleaching in the case of an unknown flour, unless the flour has been comparatively heavily treated.

4. That flour milled from yellowberry or semi-dark hard wheat, is inferior to that from true Turkey or dark hard wheat in color, strength and general baking quality.

5. That bleached flour is inferior in quality and strength to the same flour in its natural condition in the following respects:-

(a) In that dough made from it is softer, stickier, slackens down more during fermentation, does not show as much life, and does not work as well.

(b) In that dough made from it has a much shorter period of fermentation.

(c) In that it apparently does not mature and improve with age as does unbleached flour. More work must be done upon this point, however, before definite conclusions can be drawn.

(d) In that bread made from it is inferior in loaf-volume, the decrease in loaf-volume being roughly proportional to the degree of bleaching.

(e) In that bread made from it is, in general, inferior in flavor.

(f) In that it is unable to carry a diluent, such as corn starch or other flour substitute, with as good results.

6. That bread made from bleached flour is markedly whiter than that made from unbleached flour.

7. That the bleaching of musty flour does not improve the appearance of the flavor of bread made therefrom.

8. That bleaching has no improving effect whatever upon even freshly-milled flour, except a lightening of the color. On the other hand it definitely injures its quality and strength.

9. That commercial baking does not reveal slight differences in the quality of flour as plainly as does laboratory baking. In commercial work, the sponge method of doughing reveals these differences more plain-

ly than does the straight dough method. Commercial baking tests show that the quality and strength of flour are injured, or at least, are in no way improved, by bleaching.

10. That in connection with these results, the group-opinions of various classes of flour-men indicate that bleaching is a deception and lends itself to fraud;

(a) In that bleaching makes it possible to lengthen the patent grade of flour by the addition to it of a portion of the clear, or "extra fancy," grade;

(b) In that it is possible to bleach a patent flour milled from a darker, commercially inferior wheat and add it to a patent flour milled from a superior wheat.

(c) In that such fraudulent practices cannot be detected except by a flour expert or a person skilled in the chemical testing of flour.

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