EFFECTIVENESS OF DRY MILK SOLIDS IN PREVENTING OVER-BROMATION OF SOME BLEACHED FLOURS

by

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INTRODUCTION

Milk, one of our oldest foods and often called the most nearly perfect food, has been responsible during the past decade for many developments in the baking industry. Today, most commercially produced milk-containing bread is made with dry milk solids, and its presence enhances their value as a human food. In addition to improving the product nutritionally, the addition of dry milk solids in most instances results in a better appearing loaf of bread.

The action of dry milk solids in dough is not definitely understood and continually introduces new problems to the commercial and experimental baker. The use of potassium bromate in the bread formula usually increases the loaf volume, and definitely improves the internal characteristics. Similar effects are noted from bleaching treatments, but to a much less degree. Recent investigations have shown the "buffering effect" of dry milk solids toward over-bromation, but little work has been done which concerns the combined effect of bleaching agents and potassium bromate. It was to study some of these problems, involving the use of dry milk solids, that the present investigations were undertaken.

REVIEW OF LITERATURE

Dry Milk Solids in Bread Making

The preference for milk-containing bread has become so prevalent in recent years that today the American bakers spend approximately 30 million dollars annually for milk products. The practice of supplementing the baking formula with milk is relatively new to the commercial baker, although an ancient practice of the housewife. Liquid milks were never very desirable to the baker, and it was the development of high quality dry milk solids that was responsible for much of the increase in the production of milk bread.

Since Sherman et al (1921) investigated milk in bread from a nutritive viewpoint there has been considerable attention given to the study of milk in bread, particularly dry milk solids.

Greenbank et al (1927) found that the condition to which milk was subjected prior to and in the manufacturing process affected the quality of its powder for baking purposes. They found that the milk receiving higher preheat treatments seemed to impart to the dough a greater water holding capacity and gave loaves of greater volume. Milk given low preheating treatments (65°C. and below) resulted in a binding effect upon the dough in baking. This effect was attributed to the fact that the temperatures were too low to coagulate the albumins. The authors believed that the idiosyncrasies resulting from various heat treatments were the result of a change in the degree of hydration and in the degree of dispersion of the proteins in the products.

St. John and Bailey (1929b) found that it was necessary to add about one unit of water by weight for each unit of dry milk solids to maintain the same degree of plasticity in the dough as measured with the wattmeter and motor driven mixer. The time required for mixing milk doughs to proper consistency was considerably longer than for milk-free doughs. This in part was attributed to the fact that the addition of dry milk solids effected a decrease in the mobility of the dough, moreover, a reduced rate of change in mobility with an elapse of time was evident when the milk was present. They ascribed this effect to the dry milk constituents holding the imbibed water for a longer time or to a tendency to imbibe the water so slowly that the imbibitional period was increased.

Skovholt and Bailey (1932b) found that the inclusion of dry milk solids in dough increased the mixing time necessary to reach the maximum plasticity. Common salt was found to more than double the amount of additional water which could be added to reach a definite maximum plasticity when using dry milk solids. When salt and milk were used, the mixing time requirement to obtain essentially the maximum plasticity was from 2 to 4 times as long as in milk-free doughs. Absorption increases caused by milk were found to be nearly the same regardless of milk quality if the highest plasticity level attained was used as a measure.

Confirming results were published by Bohn and Bailey (1937). They found that dry skim milk solids markedly decreased stress readings after mixing, and increased the time of mixing required to reach optimum development as shown by the farinograph. Good quality milk powders appeared to make a greater contribution to strength and gave higher stress readings than poor quality milk powders, as well as showing greater tolerance to mixing.

Skovholt and Bailey (1935) found that properly prepared dry milk solids imparted excellent qualities of firmness and stability to bread doughs. Dried milk solids prepared with insufficient heat treatment appeared to accelerate the physical breakdown of any dough in which they had been incorporated, when subjected to extremes of mixing or fermentation.

Studying the action of phosphatides in dough, Working (1928a) found that if 4 to 6 percent of dry milk solids were added to the bread formula that an improvement could be obtained by the addition of both a phosphatide and an oxidizing agent.

Grewe (1928) stated that the properties of strong flours for which bakers were willing to pay an extra price could be imparted to dough by the addition of dry milk solids. The reason given for this statement was that the range of fermentation time over which good bread could be produced was greatly prolonged by the use of dry milk solids. She observed that milk bread when over-proofed continued to increase in volume to a greater extent than bread made without milk. This increase in volume was accompanied by an increased coarseness of grain.

St. John and Bailey (1929a) demonstrated that the buffer action of dry milk solids was appreciable, as shown both by the initial hydrogen-ion concentration of the freshly mixed doughs and by the relative rate of change in pH of control and milk-containing doughs. They observed that the increased rate of fermentation with milk doughs was influenced by factors other than the quantity of phosphates carried by the milk as was earlier supposed. They concluded that the greater stability of milk doughs might be the consequence of the slower change in hydrogen-ion concentration.

Skovholt and Bailey (1937) observed that in all doughs containing liberal amounts of added sugar, the usual accelerating effect of dry milk solids upon the rate of gas production was in evidence. The amount of gas produced from sugar deficient doughs was markedly decreased by the addition of dry milk solids to the dough. This decreased gas production was attributed to an inhibition of sugar production by amylolysis, resulting from a reduction in acidity by the dry milk solids. Yeast, treated to inhibit growth, was used in doughs and the results seemed to indicate that dry milk solids increased the activity of the zymase complex. This activation of zymase by milk solids appeared to be partially due to an effected reduction in the hydrogen-ion concentration.

Skovholt and Bailey (1932a) using new crop flours compared the effects of additions of malt and dry milk solids and also the effects of additions of Arkady and dry milk solids. They observed greater improvements by adding malt to doughs containing dry milk solids than to milk-free doughs. This complementary effect of malt and dry milk solids was especially noticeable when winter wheat flours were used. Increased scores resulted from the use of Arkady in every case when used in doughs containing dry milk solids. The improvement obtained by the use of Arkady under these conditions was much greater with the winter wheat flours than with the spring wheat flours. The improvement from dry milk solids was smallest with winter wheat flours when using the basic formula, however, this was corrected by using Arkady and malt.

Larmour et al (1939) using hard red winter wheat flours observed that the addition of 6 percent dry milk solids to the bread formula made it possible to include sufficient potassium bromate to condition the flours of the highest bromate requirements without over-oxidizing those of very much lower requirement.

Ofelt and Larmour (1940) observed that the inclusion of 6 percent dry milk solids conferred a high degree of tolerance toward the action of potassium bromate on flours. Dry milk solids, together with the appropriate amounts of bromate, produced increases in loaf volume, and improvements in texture beyond what could have been obtained with optimum amounts of potassium bromate alone. The authors pointed out the commercial significance of the buffering effect of milk solids toward bromate as being a safeguard against the possibility of damaging flours that had already been brought close to their optimum "oxidation" condition by bleaching or by addition of other oxidizing agents. This work was confirmed by Eisenberg (1940) and Harris and Bayfield (1941) who presented corroborative evidence.

Flour Bleaching

Several factors are involved in the visual appearance of flour but the most important is the color exhibited by the flour pigments. The flour pigments are responsible for the yellow color of unbleached flour, and they are not influenced by any mechanical processes encountered in milling. The quantity of pigment contained in flour comes from the wheat and is influenced by both heredity and environmental growing conditions. Bleaching of flour to remove the yellow pigment was its original purpose, but it also renders a valuable service by conferring upon the flour an improvement comparable to natural aging.

Javillier (1926) wrote, "Agents used for decolorizing flours have been found to induce the maturing of the flour which is an advantage, a convenience, and a material gain. An antiseptic effect is also exerted by the bleaching agents." He suggested that bleaching reagents might react with the proteins of lecithin and phytosterol, but no evidence was offered that such reactions occurred. He wrote that the most pronounced changes brought about by bleaching were in the constituents of the ether extract.

Working (1928b) observed that bleaching of flour had the same or similar effect in developing the dough made from that flour as the addition of oxidizing agents to the dough.

James and Huber (1927) studied the physical properties of washed gluten from bleached flours. They found that the amount of gluten recovered decreased as the degree of chlorination increased, but in no case did they have difficulty in obtaining a good yield of gluten. More force was required to extend the gluten with increasing chlorination, but the distance extended before breaking was shortened. Similar effects were received with nitrogen trichloride (Agene) bleached flours. More equivalents of chlorine than nitrogen trichloride were required to change the gluten an equivalent amount. They suggested that chlorine probably attacked the starch to a considerable extent.

Bailey (1925) observed that carotene crystals were bleached by oxidation, one-third their weight of oxygen being required to completely decolorize them. He also suggested that because of the finely divided condition of flour, and also because of such a large proportion of air, that conditions were favorable for the spontaneous oxidation of carotene in the flour. Carotene is fat soluble, but Bailey observed no quantitative correlation between these two factors. He observed a greater change in pH in patent flour for each unit of chlorine than he did in clear flours, indicating a higher buffer index for clear flours.

Ferrari and Bailey (1929) made a study of the effects of storage and bleaching agents on the carotene content of flour.

They found that low temperatures were more efficient in inhibiting natural bleaching than an atmosphere of carbon dioxide. They observed that the bleaching action of chlorine was not an entirely instantaneous process as was also true for nitrogen trichloride. They found Novadelox bleached at a slower rate than the gaseous bleaches used.

Larmour and Machon (1931) found little or no maturing effect from Novadelox except in high protein flours when heavier dosages were used. They observed that aging had a continued improvement on chlorine bleached flours, from the standpoint of both color and baking quality.

Hanson (1932) found that double the amount of nitrogen trichloride required to effect a full bleach did not in any way impair the baking quality of the flour. His investigations showed that optimum baking results were obtainable immediately after bleaching with nitrogen trichloride. He observed that the addition of potassium bromate to the fully bleached and double bleached flours did not show any beneficial results.

Smith (1937) found that bread baked from unbleached flours from the head of the mill had better shape, texture, and volume than bread baked from the tail of the mill. It was upon the latter that Agene had such remarkable effects, giving bulky and lively doughs, and loaves of better texture, color, and much increased loaf volume. Novadelox had no discernible improving properties upon doughs although baked loaves in many instances appeared to be improved in texture.

Rich (1934) investigated the chemical and physico-chemical changes induced in wheat flour by artificial maturing agents. He observed that flours of low protein content could not tolerate as much bleach as high protein flours without showing signs of over-aging. The action of potassium bromate on the dough appeared to be the same as that of nitrogen trichloride, however, bromate had a greater effect on loaf volume. He suggested that the maturing effect of bromate and nitrogen trichloride seemed to be dependent on the protein content of the flour. Artificial maturation had no influence on gas production, but increased the gas retention of the dough until an excess was used. He indicated that the maturing action of nitrogen trichloride depended primarily on some reaction with the germ content of the flour. The similar effect of bromate suggested the reaction to be oxidation.

Kozmin (1935) wrote, "The process of flour aging proceeds without participation of oxygen, as fat hydrolysis does not require the presence of the same. Oxidation of flour pigments taking place during aging has no connection with the change of gluten quality. The chemical effect of artificial aging by means of bleaching is different from the natural aging and is probably connected with the action of the strong oxidising agents upon the protein of the gluten." She found that the addition of free unsaturated fatty acids influenced the colloidal behavior of gluten similar to that of natural aging.

She concluded that temperature was the most important factor influencing the aging of flour.

Balls and Hale (1936) explained the action of bleaching agents and natural aging from a proteolytic viewpoint. They wrote that the alteration of flour was due to a dimunition of the proteolytic activity, brought about by the oxidation of the activator of the flour proteases.

The results of an investigation by Halton and Fisher (1937) indicated that when flour was stored in air considerable absorption of oxygen occurred. They attributed this absorption to three factors; mites and similar small animals; bacteria and fungi; and true chemical oxidation. The latter, they observed, progressed more rapidly as the moisture content of the flour was reduced. They suggested that moisture acted as an inhibitor of oxygen absorption to fatty substances, possibly through the formation of protective water films over the reactive material.

In a storage investigation conducted by Kent-Jones (1939) samples of flour exposed to air acquired the usual bleach, flour stored in an atmosphere of hydrogen was bleached only slightly, and flour stored in a vacuum showed no sign of any bleaching action.

Harris and Bayfield (1941) found that bread was improved by the addition of increasing amounts of Agene and Novadelox, but that it was impossible to equal the improvements produced by the addition of bromate.

Mohs (1940) wrote that the bleaching of flour could be accomplished with compounds which split off oxygen and thus acted as oxidizing agents, or with compounds which utilized oxygen on their intermediary phase of oxidation. These oxidation reactions have been accused of preventing the formation of vitamin A by destroying the carotene, however, Mohs seemed certain that no vitamin destruction occurred during bleaching.

It has been suggested by Binnington (1941) that in referring to flour pigments the designation "flour pigments calculated as carotene" be employed rather than "carotene". This suggestion was offered due to the fact that carotene is responsible for only a small part of the yellow color exhibited by unbleached flour. It has been suggested that only 15 percent of the color is due to carotene; whereas xanthophyll and other carotenoid pigments are responsible for the remaining 85 percent.

Gortner (1938) described the carotenoids as follows:

> The carotenoids are those light-yellow to deep-red nitrogen-free pigments of the plant and animal kingdoms which can be extracted from the tissues in which they occur by means of fat solvents. Most are derivatives of a highly unsaturated hydrocarbon having the general formula $C_{40}H_{56}$. Nearly all members of the group possess a carbocyclic ring or a semicarbocyclic configuration attached to each end of a highly unsaturated poly-ene hydrocarbon chain-$C_{22}H_{26}$-connecting the carbocyclic groups.

Because of the minute amount of pigment in flour it is evident that a likewise small amount of bleaching reagent can oxidize these pigments to colorless derivatives. Mohs (1940) stated that the residual traces of the chemical agents remaining in flour were so difficult to detect that from a hygienic viewpoint the process of flour bleaching could cause no justifiable concern.

Potassium Bromate in Bread Making

There have been numerous publications concerning the action of bread improvers, notably potassium bromate, upon dough, but there is probably no other subject in the field of cereal chemistry which has met with so much controversy. The use of potassium bromate was brought actively to the attention of cereal chemists in America by Herman's (1927) description of a differential test (originated by Werner).

Working (1928b) attributed the beneficial effects of small amounts of oxidizing agents to their action in rendering phosphatides more soluble in water. Working (1928a) obtained results similar to those produced by adding acid and phosphatide to the dough when using acid and an oxidizing agent. Phosphatides increase the ductility of the dough and it was believed by the author that of all the constituents of the flour they were the most likely to be affected by minute quantities of oxidizing agents.

Geddes (1930) suggested that the improving effect of heat might possibly be ascribed to a similar action as that of chemical improvers. It was observed that flours giving little or no improvement on heat treatment also showed no essential response on addition of potassium bromate. The experiment indicated that the response to bromate and improvement by heat treatment were associated with the presence of germ in the flour. He concluded that the response of a flour to bromate depended on the state of oxidation of the germ constituents.

Geddes and Larmour (1933) studied some aspects of the bromate baking test. They found that natural aging resulted in a decrease in bromate response. They observed that volumes obtained by the bromate formula on unbleached flours were indicative of the results to be expected from the same flours fully matured by artificial means and baked by the basic formula. Potassium bromate did not influence the rate nor the amount of gas production in bread doughs, but modified their gas retaining capacity, indicating a direct or indirect action on the gluten proteins. Heat treatment, natural aging, increased fermentation time, and the addition of potassium bromate all resulted in a decrease in lipoid phosphorous, indicating that their effect in modifying baking behavior might be linked with the destruction of phosphatides. They found that as the quantity of bleach was increased there was a definite trend towards decreased bromate response. They also observed that the tolerance of flours to bromate increased with protein content.

Rich (1934) suggested that the action of flour improvers must be colloidal, as the small amounts used could not effect gross chemical changes. His investigation indicated that bromate acted on the germ and protein constituents, and not the phosphatides.

Flohil (1936) studied the effect of chemical flour improvers on proteolytic action in relation to the gas retaining capacity of fermenting doughs. This author classified flour improvers as proteolytic inhibitors and concluded that if through overbleaching or overtreatment with chemical improvers, too much of the proteolytic enzymes had been destroyed, tough and unyielding doughs would be obtained, resulting in unsatisfactory bread.

Jørgensen (1936) discredited the phosphatide and "electrolyte" theories and offered his theory that bromate paralyzes the proteinases of the wheat flour. He suggested that when these proteinases were inhibited, the break-down of the protein of the dough diminished, as a result, the gas retaining capacity of the dough membranes increased.

Sullivan, Near, and Foley (1936a) found that a decrease in loaf volume was directly proportional to the amount of unsaturated acids added to the dough. It was suggested that the damaging action observed in oxidation was due to the direct addition of oxygen to the double bonds of free fatty acids. They found that fresh germ fat had no harmful effect on loaf volume, indicating that the injurious character of germ was not in the fat fraction but in the water soluble fraction as was shown in a second paper (1936b).

It was suggested by Sullivan, Howe, and Schmalz (1936) that the water soluble substance responsible for the deleterious effects of germ was glutathione. They suggested that oxidizing agents changed some of the S-H glutathione to the S-S form which was unable to activate the proteases.

Ziegler (1940a) suggested that bromate worked gradually as a flour improver and that this action could be explained by its slow rate of oxidation of glutathione. Zeigler (1940b) suggested that further improvement in the baking quality of a flour could be attributed to the presence of oxidized glutathione in the dough.

Read and Haas (1937) found that bromate did not affect the proteolytic power of malt, pepsin, trypsin, or Taka-diastase when these products were allowed to act on gelatin, but it did depress the activity of bromelin and papain.

Balls and Hale (1938) wrote, "Since it may be fairly concluded that the proteinase of wheat is an enzyme similar to papain, its inactivation by oxidizing agents such as the usual bread improvers still seems to explain adequately the effect of the latter in the dough."

Freilich and Frey (1939) studied the effects of proteases and reducing substances on dough when mixed with oxygen. They found that the effects of germ, cysteine, and glutathione were greatly retarded by mixing in oxygen. Low grade flours responded more than patent flours by mixing in an atmosphere of oxygen.

Kent-Jones (1939) suggested that the action of bromate was apparently a colloidal one and that its main effect was the coagulation effect on the proteins or the suppressing of excessive proteolysis.

Mohs (1940) attributed the effect of flour improvers (potassium bromate) to their influence on the physical phase of the flour constituents. He suggested that their main influence was concerned with changes of surface tensions and consequently the regulation of swelling processes or enzyme activity. He stated that it was quite conceivable that the oxidation action might bring about a change in the arrangement or a shortening of the protein chains, with subsequent favorable effects on the processes occurring during baking. Mohs concluded his article on a study of flour treatment with the following statement.

> Viewing the flour improving methods from the economic standpoint, their application can only be desirable since they offer the possibility of alleviating the shortcomings of certain flours to a degree where they satisfy the normal demands for baking quality.

MATERIALS AND METHODS

Four hard red winter wheat varieties were used in this investigation. The four varieties; Tenmarq, Turkey, Chiefkan, and Nebred were selected, as they furnished a cross section of hard winter wheat varieties. Flours produced from Tenmarq wheats normally have a low pigment content, relatively low potassium bromate requirement, and are of good baking quality. Turkey flours have a medium amount of pigment, high bromate requirement and are of good baking quality. Chiefkan flours are low in pigment content, high in their bromate requirement, and are of poor baking quality. Flours produced from Nebred wheats have a high pigment content, very low potassium bromate requirement, and are of good baking quality.

The first three varieties were single samples grown on adjoining plots at Quivira Acres[1], Manhattan, Kansas; whereas Nebred was a composite of a sample grown at Manhattan and at Lincoln, Nebraska. The Nebred sample therefore is not strictly comparable to the other three varieties included. Unfortunately, due to growing conditions, the samples were high in protein content. This made test baking difficult, especially when using the milk formula which produced large volumes.

1/ Testing grounds for Kansas Wheat Improvement Association under the direction of Dr. John H. Parker.

Table 1. Analytical data of wheats used in this investigation.

Variety	Test wt. lb.	Moisture %	Ash[1] %	Protein[1] %
Tenmarq	57.8	15.6	1.557	16.3
Turkey	59.2	15.1	1.621	15.4
Chiefkan	60.6	15.0	1.430	16.5
Nebred	60.7	--	1.585	15.4

[1] 15 percent moisture basis.

With the exception of Chiefkan these wheats were pure varieties. Chiefkan, however, was known to contain approximately 15 percent of other winter wheats of good baking quality, and was materially benefited by this admixture as is shown by the baking tests in Table 2. As the wheat was cut in the field, samples of the mixture, the pure Chiefkan, and the bearded wheat impurity were collected and threshed. These samples were milled on an experimental mill and then baked by a rich, bromated baking formula.

Table 2. Baking data to show the effect of the bearded wheat in the Chiefkan sample.

Sample	Protein[1] %	Loaf Volume cc.
Pure Chiefkan	15.6	830
Bearded wheat	16.7	1250
Mixture	15.9	950

[1] 15 percent moisture basis.

Throughout the remainder of this thesis the use of the variety name "Chiefkan" will have reference to the mixture and not to the pure variety.

Ten-bushel samples of Tenmarq, Turkey, and Chiefkan were milled on the Kansas State College 65-barrel mill. Only a limited supply of Nebred was available, therefore it was milled on a Buhler experimental mill. Mill stream samples were collected for those varieties milled on the 65-barrel mill. An extensive study[2] was performed on the baking quality of the various mill streams using milk and milk-free formulas. The methods, analytical data, and results of this experiment have been reported elsewhere.

The experimental flours were placed in a refrigerated room (40 - 45°F.) immediately after milling to reduce natural aging and bleaching to a minimum. The flours used in the bleaching and baking study were thoroughly mixed before making any chemical analyses.

Analyses for all of the wheat and flour samples were determined in the laboratories of the Kansas State College Milling Department using approved procedures normally employed for all routine work.

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[2] Quality of mill streams. Paper presented at Tri-Section meeting of Cereal Chemists, Manhattan, Kansas, April 5, 1941. To be published in American Miller.

Table 3. Analytical data of flours used in this investigation.

Variety	Extraction[1] %	Moisture %	Ash[2] %	Protein[2] %	Maltose mg.	Absorption[2,3] %
Tenmarq	71.6	11.5	.372	15.7	100	65.4
Turkey	70.1	11.4	.384	14.5	115	61.5
Chiefkan	71.7	11.4	.379	15.8	126	56.7
Nebred	72.7	13.7	.397	14.8	--	61.1

[1] Total weight of flour on basis of dry cleaned wheat.

[2] 15 percent moisture basis.

[3] Values for milk-free formula without bromate.

The baking formula used in this investigation was identical to that used by Harris and Bayfield (1941). The formula involved the use of the ingredients listed below and the quantities indicated. Percentage ingredients are based on 100 grams of flour as 100 percent.

Ingredient	Percent
Flour	100.00
Sugar	6.00
Salt	1.50
Yeast	2.00
Shortening	3.00
Malt syrup (120°L.)	0.25
Water (distilled)	As required
Dry milk solids	(0 or 6%) As indicated
Potassium bromate	(0 to 7 mg.) As indicated

Baking absorption was determined by mixing together in a micro mixer small quantities of flour, water, sugar, and salt. On the basis of 20 g. of flour, 5 percent of sugar, and 1 percent of salt were added with 50 percent water. Additional water to produce a dough of proper consistency was added during mixing with a small syringe. Changes in the predetermined absorption values necessary to obtain the proper absorption at the panning stage were made after the first baking trial. The addition of 6 percent dry milk solids resulted in an increase of 4 percent in the absorption value. The absorption figure for each variety was held constant regardless of the bleaching treatment; although the absorption was increased with increasing increments of potassium bromate.

The doughs were mixed at 100 r.p.m. in a Swanson-Working mixer using a bowl containing two opposite pins. The doughs were all given an optimum mixing time, however, the only cause for a significant change in mixing time within a variety was the addition of dry milk solids to the formula. An increase in mixing time from the use of dry milk solids confirms the work of St. John and Bailey (1929b); Skovholt and Bailey (1932b); and Bohn and Bailey (1937). The doughs were fermented and proofed at 86°F. (30°C.) and 80 percent relative humidity. The fermentation bowls were covered during fermentation to prevent drying or excessive wetting of the doughs. The total fermentation time was three hours, during which time the doughs were punched twice, at intervals of 105 minutes (first punch), and

50 minutes (second punch). A pair of National pup sheeting rolls were used to punch the doughs. Twenty-five minutes after the second punch the doughs were molded in a Thompson laboratory molder. The doughs were then panned in tall form A.A.C.C. baking pans and proofed for 55 minutes. The loaves were baked at 420°F. for 25 minutes in a specially designed Despatch oven equipped with a rotating hearth. Loaf volumes were taken immediately upon removal of the loaves from the oven. All bakes were replicated for loaf volume (agreement within 25 cc.) to insure more accurate results. The loaves were cut and graded for internal characteristics approximately 16 hours later. The laboratory in which all baking was done was conditioned, the temperature being held between 76 and 78°F.

Solutions of potassium bromate were made to various concentrations so that 10 cc. of solution would deliver the increment desired for a dough containing 100 grams of flour. Increments of potassium bromate ranging from zero to 7 mg. or zero percentage to 0.007 per cent were used.

Dry milk solids is the product resulting from removal of the water from liquid skim milk and contains less than 5 percent of moisture and less than 1½ percent of fat. The dry milk solids used in this investigation was from a 50 pound drum of "Breadlac" manufactured by the spray process by The Borden Company. The fat and moisture content of the sample was 0.94 percent and 3.00 percent respectively. The drum of dry milk solids was kept in the refrigerated room throughout the entire investigation. A sample of this milk was compared with samples of known baking quality and gave comparable results in the baking test. The dry milk solids was not reconstituted before adding to the flour and other ingredients but was thoroughly mixed with the flour before any liquids were added.

Two methods of bleaching were used in this investigation; one employing a gaseous reagent and the other making use of a solid. The gaseous bleach employed was nitrogen trichloride, which is better known by its commercial trade name, Agene. Nitrogen trichloride is an oily liquid, very highly explosive, and for this reason it is generated in the mill instead of being shipped in drums. The reagent is produced by passing chlorine gas through a solution of ammonium salt. The reaction proceeds in two stages; hypochlorous acid being formed in the first stage, which reacts with the ammonium salt (chloride or sulphate) to form nitrogen trichloride as follows.

1. $6Cl_2 + 6H_2O \rightleftharpoons 6HCl + 6HOCl$

2. $6HOCl + (NH_4)_2SO_4 \rightleftharpoons 2NCl_3 + H_2SO_4 + 6H_2O$

When nitrogen trichloride is applied to the flour along with an abundance of moist air, the above reaction reverses and hypochlorous acid and ammonia gas are liberated.

$$NCl_3 + 3H_2O \rightleftharpoons NH_3 + 3HOCl$$

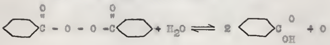
The general consensus of opinion is that the hypochlorous acid, being relatively unstable, releases its oxygen which reacts with the flour pigments to form colorless derivatives. The exact nature of this reaction and the end products formed, however, is not exactly known.

Nitrogen trichloride was added to the flour in quantities equivalent to 3 grams and 9 grams per barrel, which is referred to as normal bleach and 3-normal bleach, respectively. The calculations, procedure, and equipment used in applying nitrogen trichloride to the small flour samples were fully explained by Harris (1940).

Benzoyl peroxide was the solid reagent used for bleaching and it is used in the milling industry under the trade name Novadelox. This compound is a mixture of benzoyl peroxide (16 parts), dicalcium sulphate (80 parts), and magnesium carbonate (4 parts). The two inorganic salts are mixed with the organic peroxide to reduce its inflammability and liability of spontaneous combustion.

The reaction of benzoyl peroxide on the flour pigments is not as rapid as gaseous bleaching agents, and therefore is not immediately apparent. Usually from 24 to 48 hours is sufficient for maximum bleaching. The reaction of benzoyl peroxide on flour is shown below:

$$(C_6H_5CO)_2O_2 + H_2O \rightleftharpoons 2C_6H_5COOH + O$$



When benzoyl peroxide comes in contact with the moist flour it is thought to release oxygen which reacts with the flour pigments to form colorless derivatives. A trace of benzoic acid is supposedly left in the flour as an end product of the bleaching reaction.

Novadelox was added to the flour in quantities equivalent to 0.4 oz. and 1.2 oz. per barrel, which is referred to as normal and 3-normal bleach.

All bleached samples were stored in sealed cans under laboratory conditions (70°F.) for two weeks before baking. At the end of this period they were returned to the refrigerated room until the end of the investigation.

To determine the effectiveness of the bleaching agents and the extent to which the flours were bleached, flour pigment determinations were run on all of the flour samples. A Wilkens-Anderson K.W.S.Z. photometer was used in connection with the method described by Binnington and Geddes (1939). The apparatus was calibrated against B-carotene, but values were recorded as flour pigments (p.p.m.), calculated as carotene.

EXPERIMENTAL RESULTS

Ofelt and Larmour (1940) pointed out the commercial significance of the buffering affect of dry milk solids toward bromate as being a safeguard against the possibility of damaging bread made from flours that had already been brought close to their optimum "oxidation" conditions by bleaching or by other oxidizing agents.

Harris and Bayfield (1941), using milk-free and milk-containing formulas, compared the improvement obtained from bleaching agents against potassium bromate. The bleaching agents and the potassium bromate were used separately and it was concluded that the Agene and Novadelox, although responsible for some improvement in loaf volume, were not capable of producing results comparable to those obtained by using optimum amounts of bromate. Dry milk solids conferred a noticeable degree of tolerance towards potassium bromate, but was unnecessary as a buffering ingredient for heavily bleached samples.

This investigation was a continuation of the work reported by Ofelt and Larmour (1940) and by Harris and Bayfield (1941). It was essentially a study of the combined effect of bleaching agents and potassium bromate upon flour baked with and without dry milk solids.

The baking results and flour pigment determinations are shown in Tables 4 to 7. The optimum potassium bromate requirements for all flour samples, with either baking formula, are given in Table 8. Plate I shows the effect of bleaching agents upon the content of flour pigment. Plates II to V show graphically the effects of Novadelox, Agene, potassium bromate, and dry milk solids upon the loaf volumes.

Table 4. Data on Tenmarq flour given various treatments when baked with or without 6 percent dry milk solids (D.M.S.) and varying amounts of potassium bromate ($KBrO_3$).

Flour treatment	$KBrO_3$ mg.	Flour Pigment p.p.m.	Baking data--No milk Grain	Texture	Color	Volume cc.	Baking data--6% D.M.S. Grain	Texture	Color	Volume cc.
None	0	1.74	76	A	77	835	77	A	79	870
	1		83	A+	85	1060	--	-	--	--
	2		80	A+	83	1103	--	-	--	--
	3		73	A+	85	1107	80	A+	80	1188
	4		75	A+	80	1007	75	A+	80	1255
	5		--	-	--	--	77	A+	79	1241
	6		--	-	--	--	73	A+	79	1237
	7		--	-	--	--	--	-	--	--
Agene 3 g. per bbl.	0	0.61	80	A+	85	892	78	A+	87	958
	1		84	A+	90	1125	--	--	--	--
	2		78	A+	90	1145	--	--	--	--
	3		79	A+	90	1020	82	A+	90	1220
	4		--	--	--	--	78	A+	89	1233
	5		--	--	--	--	--	--	--	--
	6		--	--	--	--	75	A+	89	1217
	7		--	--	--	--	--	--	--	--
9 g. per bbl	0	0.33	77	A+	89	938	78	A+	89	1028
	1		80	A+	93	1103	--	--	--	--
	2		80	A+	93	1097	--	--	--	--
	3		81	A+	93	1012	80	A+	94	1263
	4		--	--	--	--	78	A+	93	1256
	5		--	--	--	--	--	--	--	--
	6		--	--	--	--	79	A+	93	1218
	7		--	--	--	--	--	--	--	--

Table 4. Continued.

Novadelox										
0.4 oz. per bbl.	0	0.90	77	A+	83	900	78	A+	83	978
	1		78	A+	85	1088	--	--	--	--
	2		77	A+	85	1168	--	--	--	--
	3		78	A+	85	1058	81	A+	85	1190
	4		--	--	--	--	79	A+	85	1263
	5		--	--	--	--	--	--	--	--
	6		--	--	--	--	77	A+	85	1223
	7		--	--	--	--	--	--	--	--
1.2 oz. per bbl.	0	0.26	80	A+	91	912	78	A+	92	983
	1		81	A+	93	1120	--	--	--	--
	2		75	A+	94	1163	--	--	--	--
	3		79	A+	94	1047	81	A+	95	1228
	4		--	--	--	--	78	A+	95	1280
	5		--	--	--	--	--	--	--	--
	6		--	--	--	--	75	A+	95	1253
	7		--	--	--	--	--	--	--	--

Table 5. Data on Turkey flour given various treatments when baked with or without 6 percent dry milk solids (D.M.S.) and varying amounts of potassium bromate ($KBrO_3$).

Flour treatment	$KBrO_3$ mg.	Flour Pigment P.P.M.	Baking data – No milk Grain	Texture	Color	Volume cc.	Baking data – 6% D.M.S. Grain	Texture	Color	Volume cc.
None	0	2.49	74	A-	73	665	74	B	79	760
	1		78	A	78	920	--	--	--	--
	2		75	A+	77	1053	--	--	--	--
	3		74	A+	77	1075	--	--	--	--
	4		75	A+	75	1023	77	A+	80	1075
	5		--	--	--	--	79	A+	79	1140
	6		--	--	--	--	76	A+	79	1146
	7		--	--	--	--	74	A+	78	1140
Agene										
3 g. per bbl.	0	0.80	79	A	83	755	77	A	86	855
	1		80	A+	85	985	--	--	--	--
	2		78	A+	85	996	--	--	--	--
	3		78	A+	85	958	--	--	--	--
	4		75	A+	85	873	79	A+	90	1140
	5		--	--	--	--	80	A+	89	1148
	6		--	--	--	--	--	--	--	--
	7		--	--	--	--	75	A+	87	1155
9 g. per bbl.	0	0.49	77	A	85	800	82	A	88	898
	1		78	A+	88	980	--	--	--	--
	2		79	A+	88	1008	--	--	--	--
	3		78	A+	88	993	--	--	--	--
	4		80	A+	88	880	77	A+	89	1160
	5		--	--	--	--	80	A+	89	1135
	6		--	--	--	--	--	--	--	--
	7		--	--	--	--	79	A+	89	1105

Table 5. Continued.

Novadelox										
0.4 oz. per bbl.	0	1.21	77	A	82	713	79	A	80	805
	1		78	A+	83	920	--	--	--	--
	2		73	A+	83	1043	--	--	--	--
	3		70	A+	83	1020	--	--	--	--
	4		80	A+	80	868	81	A+	83	1165
	5		--	--	--	--	76	A+	83	1180
	6		--	--	--	--	--	--	--	--
	7		--	--	--	--	75	A+	83	1120
1.2 oz. per bbl.	0	0.46	73	A	86	730	76	A	89	818
	1		83	A+	90	913	--	--	--	--
	2		75	A+	90	1065	--	--	--	--
	3		72	A+	89	1010	--	--	--	--
	4		78	A+	88	910	77	A+	90	1143
	5		--	--	--	--	76	A+	90	1192
	6		--	--	--	--	--	--	--	--
	7		--	--	--	--	75	A+	90	1165

Table 6. Data on Chiefkan flour given various treatments when baked with or without 6 percent dry milk solids (D.M.S.) and varying amounts of potassium bromate ($KBrO_3$).

Flour treatment	$KBrO_3$ mg.	Flour Pigment p.p.m.	Baking data - No milk Grain	Texture	Color	Volume cc.	Baking data -6% D.M.S. Grain	Texture	Color	Volume cc.
None	0	1.73	60	B-	73	610	58	B-	72	645
	1		80	A	79	840	--	--	---	--
	2		80	A	80	960	--	--	--	--
	3		74	A	80	1000	78	A	78	940
	4		70	A+	80	990	85	A+	77	960
	5		--	--	--	--	80	A+	77	965
	6		--	--	--	--	78	A+	79	980
	7		--	--	--	--	73	A-	80	998
Agene										
3 g. per bbl.	0	0.64	74	A-	84	698	70	A-	82	713
	1		78	A	85	873	--	--	--	--
	2		74	A	85	997	--	--	--	---
	3		75	A	85	1035	--	--	--	--
	4		76	A+	85	963	82	A	87	970
	5		--	--	--	--	83	A+	87	988
	6		--	--	--	--	--	--	--	--
	7		--	--	--	--	85	A+	87	1013
9 g. per bbl.	0	0.43	75	A-	85	725	68	A-	84	735
	1		79	A	88	905	--	--	--	--
	2		77	A	88	1000	--	--	--	--
	3		76	A	88	980	--	--	--	---
	4		75	A+	88	963	80	A	89	963
	5		--	--	--	--	82	A+	89	990
	6		--	--	--	--	--	--	--	--
	7		--	--	--	--	80	A+	89	1008

Table 6. Continued.

Novadelox										
0.4 oz. per bbl.	0	0.75	63	B+	82	658	63	B	83	683
	1		80	A	88	880	--	--	--	--
	2		74	A	87	1000	--	--	--	--
	3		73	A	87	1020	--	--	--	--
	4		73	A+	88	965	80	A	89	978
	5		--	--	--	--	77	A	89	1033
	6		--	--	--	---	--	--	--	--
	7		--	--	--	---	76	A+	89	1015
1.2 oz. per bbl.	0	0.36	67	B	86	670	63	B	86	693
	1		83	A	90	880	--	--	--	--
	2		73	A	89	1013	--	--	--	--
	3		73	A	89	1015	--	--	--	--
	4		75	A+	89	977	80	A	90	968
	5		--	--	--	--	80	A	90	1010
	6		--	--	--	--	--	--	--	--
	7		--	--	--	--	84	A+	90	985

Table 7. Data on Nebred flours given various treatments when baked with or without 6 percent dry milk solids (D.M.S.) and varying amounts of potassium bromate ($KBrO_3$).

Flour treatment	$KBrO_3$ mg.	Flour Pigment p.p.m.	Baking data - No milk: Grain	Texture	Color	Volume cc.	Baking data -6% D.M.S.: Grain	Texture	Color	Volume cc.
None	0	2.95	76	A-	69	720	81	A	70	920
	1		84	A	72	910	--	--	--	--
	2		82	A+	72	960	--	--	--	--
	3		80	A+	72	910	80	A+	72	1135
	4		--	--	--	--	79	A+	72	1178
	5		--	--	--	--	77	A+	72	1170
	6		--	--	--	--	77	A+	72	1153
	7		--	--	--	--	--	--	--	--
Agene										
3 g. per bbl.	0	0.86	82	A	84	827	79	A	83	998
	1		80	A	85	905	--	--	---	--
	2		81	A+	85	885	--	--	--	--
	3		82	A+	85	820	77	A+	85	1090
	4		--	--	--	--	77	A+	85	1075
	5		--	--	--	--	--	--	--	--
	6		--	--	--	--	81	A+	85	1018
	7		--	--	--	--	--	--	--	--
9 g. per bbl.	0	0.41	75	A-	86	843	86	A	89	1018
	1		79	A	88	920	--	--	--	--
	2		77	A+	88	863	--	--	--	--
	3		76	A+	98	790	87	A+	90	1060
	4		--	--	--	--	80	A+	90	1025
	5		--	--	--	--	--	--	--	--
	6		--	--	--	--	80	A+	90	968
	7		--	--	--	--	--	--	--	--

Table 7. Continued.

Novadelox										
0.4 oz. per bbl.	0	1.56	82	A	83	763	84	A	83	935
	1		82	A	83	923	--	--	--	--
	2		84	A+	83	937	--	--	--	--
	3		83	A+	83	885	84	A+	83	1065
	4		--	--	--	--	85	A+	83	1110
	5		--	--	--	--	--	--	--	--
	6		--	--	--	--	84	A+	83	1016
	7		--	--	--	--	--	--	--	--
1.2 oz. per bbl.	0	0.54	83	A	90	817	83	A	90	973
	1		85	A	90	947	--	--	--	--
	2		83	A+	90	955	--	--	--	--
	3		84	A+	90	885	83	A+	90	1125
	4		--	--	--	--	80	A+	90	1138
	5		--	--	--	--	--	--	--	--
	6		--	--	--	--	82	A+	90	1055
	7		--	--	--	--	--	--	--	--

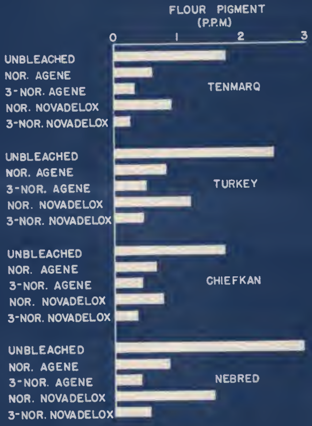
Table 8. The optimum $KBrO_3$ requirements of bleached and unbleached flour samples when baked with and without 6 percent dry milk solids. (D.M.S.)

Sample	Optimum $KBrO_3$ level (expressed as mg.) No milk	6% D.M.S.
Tenmarq:		
Unbleached	2	4
Normal Agene	2	4
3-Normal Agene	1	3
Normal Novadelox	2	4
3-Normal Novadelox	2	4
Turkey:		
Unbleached	3	5
Normal Agene	2	5
3-Normal Agene	2	4
Normal Novadelox	2	5
3-Normal Novadelox	2	5
Chiefkan:		
Unbleached	3	7
Normal Agene	3	7
3-Normal Agene	2	7
Normal Novadelox	3	5
3-Normal Novadelox	3	5
Nebred:		
Unbleached	2	4
Normal Agene	1	3 (2)
3-Normal Agene	1	3 (2)
Normal Novadelox	2	4
3-Normal Novadelox	2	4

EXPLANATION OF PLATE I

The effect of normal and 3-normal treatments of Novadelox and Agene upon the content of flour pigment in flours of four winter wheat varieties.

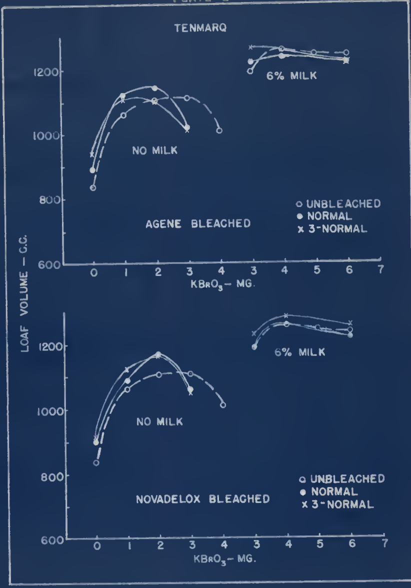
PLATE I


FLOUR PIGMENT
(P.P.M.)
0
1
2
3
UNBLEACHED
NOR. AGENE
3-NOR. AGENE
NOR. NOVADELOX
3-NOR. NOVADELOX
TENMARQ
UNBLEACHED
NOR. AGENE
3-NOR. AGENE
NOR. NOVADELOX
3-NOR. NOVADELOX
TURKEY
UNBLEACHED
NOR. AGENE
3-NOR. AGENE
NOR. NOVADELOX
3-NOR. NOVADELOX
CHIEFKAN
UNBLEACHED
NOR. AGENE
3-NOR. AGENE
NOR. NOVADELOX
3-NOR. NOVADELOX
NEBRED

EXPLANATION OF PLATE II

Loaf volumes of bleached and unbleached Tenmarq flour when baked with various amounts of potassium bromate and with and without 6 percent dry milk solids.

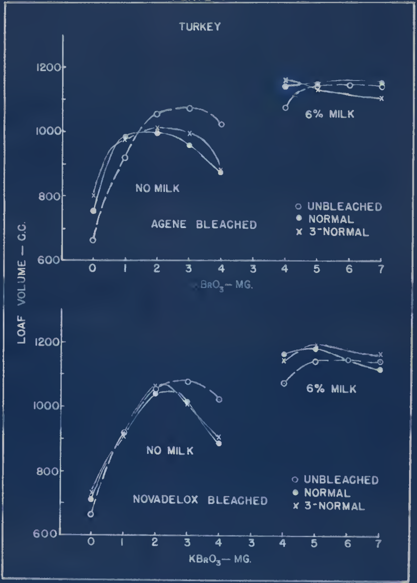
PLATE 2


TENMARQ
6% MILK
NO MILK
AGENE BLEACHED
o UNBLEACHED
● NORMAL
x 3-NORMAL
LOAF VOLUME — C.C.
KBrO3 – MG.
6% MILK
NO MILK
NOVADELOX BLEACHED
o UNBLEACHED
● NORMAL
x 3-NORMAL
KBrO3 – MG.

EXPLANATION OF PLATE III

Loaf volumes of bleached and unbleached Turkey flour when baked with various amounts of potassium bromate and with and without 6 percent dry milk solids.

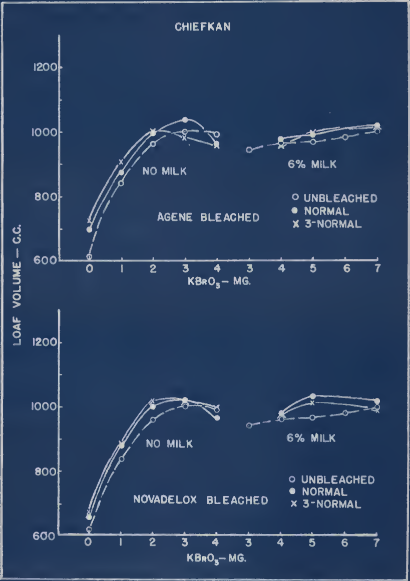
PLATE 3


TURKEY
LOAF VOLUME — C.C.
1200
1000
800
600
6% MILK
NO MILK
AGENE BLEACHED
o UNBLEACHED
• NORMAL
x 3-NORMAL
0 1 2 3 4 3 4 5 6 7
BrO3 — MG.
1200
1000
800
600
6% MILK
NO MILK
NOVADELOX BLEACHED
o UNBLEACHED
• NORMAL
x 3-NORMAL
0 1 2 3 4 3 4 5 6 7
KBrO3 — MG.

EXPLANATION OF PLATE IV

Loaf volumes of bleached and unbleached Chiefkan flour when baked with various amounts of potassium bromate and with and without 6 percent dry milk solids.

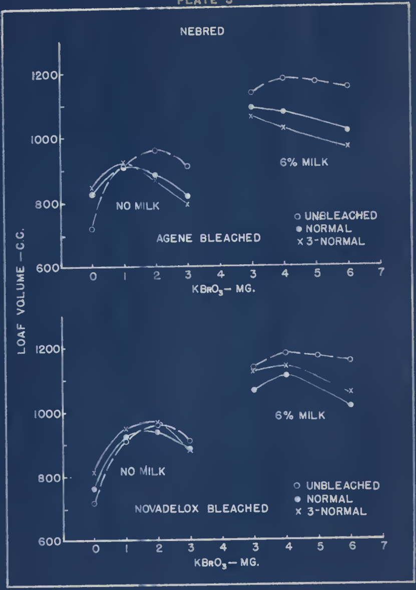
PLATE 4


CHIEFKAN
LOAF VOLUME – C.C.
1200
1000
800
600
NO MILK
6% MILK
AGENE BLEACHED
O UNBLEACHED
● NORMAL
X 3-NORMAL
0 1 2 3 4 3 4 5 6 7
KBrO3 – MG.
NO MILK
6% MILK
NOVADELOX BLEACHED
O UNBLEACHED
● NORMAL
X 3-NORMAL
KBrO3 – MG.

EXPLANATION OF PLATE V

Loaf volumes of bleached and unbleached Nebred flour when baked with various amounts of potassium bromate and with and without 6 percent dry milk solids.

PLATE 5


NEBRED
LOAF VOLUME — C.C.
1200
1000
800
600
6% MILK
NO MILK
AGENE BLEACHED
○ UNBLEACHED
● NORMAL
× 3-NORMAL
0 1 2 3 4 3 4 5 6 7
KBrO$_3$ — MG.
1200
1000
800
600
6% MILK
NO MILK
NOVADELOX BLEACHED
○ UNBLEACHED
● NORMAL
× 3-NORMAL
0 1 2 3 4 3 4 5 6 7
KBrO$_3$ — MG.

Without potassium bromate the addition of 6 percent dry milk solids resulted in a definite volume increase for all flours, bleached or unbleached. This response was greatest for the Nebred samples and least for the Chiefkan flours.

Excepting bleached Nebred a high degree of tolerance towards bromate was conferred upon the doughs through the use of dry milk solids, as shown by Plates II to V. The buffering action of dry milk solids towards potassium bromate found in this investigation corroborated the results of Ofelt and Larmour (1940), and Harris and Bayfield (1941). Dry milk solids increased the bromate requirement needed for optimum loaf volume in all of the samples as given in Table 8. In addition to loaf volume, the crust color, grain, and texture were improved through the use of dry milk solids.

The application of Agene and Novadelox gave definite loaf volume improvements for each of the four varieties when using either baking formula. This loaf volume response resulting from the use of the bleaching agents increased with the amount of bleach applied. The improvements in loaf volume resulting from Novadelox treatments were not as great as those resulting from the respective Agene treatments. These results are similar to those reported by Harris and Bayfield (1941).

In commercial practice Novadelox is not considered to be a very effective flour improver, but is usually added in conjunction with one of the gaseous bleaches for the purpose of improving the color. The results of this investigation, however, seemed to indicate that in addition to improving the color of flour, Novadelox also has a maturing effect on the flour. The possibility that this improvement was a result of the dicalcium sulphate or magnesium carbonate fillers was not investigated, but may offer the solution to the improving properties of Novadelox.

Optimum loaf volumes of flours treated with Novadelox and baked without dry milk solids were nearly always as large or larger than the loaf volumes of the unbleached flours. The optimum loaf volumes of the normal and 3-normal Novadelox bleached samples were nearly identical. The bromate requirement needed for optimum loaf volumes was altered only slightly by treatment with Novadelox. The use of potassium bromate in quantities larger than optimum resulted in a more rapid volume decrease in the bleached samples. Using the formula containing 6 percent dry milk solids, optimum loaf volumes of Novadelox treated flours, with the exception of Nebred, were as large or larger than the untreated samples.

The action of Agene was much more severe than Novadelox as is shown by Plates II to V. Agene bleached samples of Turkey and Nebred flours without milk failed to equal the loaf volumes of their respective unbleached samples. The bromate requirement for the bleached samples was reduced in several cases, particularly those samples receiving the 3-normal bleach.

Using the milk-formula, optimum loaf volumes of Agene bleached flours, with the exception of Tebred, were approximately the same as the unbleached flours.

From the results obtained in this investigation, it appeared that the improving effects of Agene and Novadelox were very similar to the effects of potassium bromate but to a much less degree. That the potassium bromate had a greater effect on dough structure than bleaching agents was also shown by the absorption changes. Doughs containing bromate became "bucky" during fermentation unless additional water was added, although it was not found necessary to increase the absorption of the bleached flours. Due mostly to a greater volume increase, potassium bromate affected the grain and texture of the resulting loaves to a greater degree than the bleaching agents.

It is evident that potassium bromate and bleaching agents increase the gas retention of doughs, however, there is little agreement regarding the mode of action of such flour improvers. That the resulting action involves the oxidation of some flour constituents is logical since benzoyl peroxide, nitrogen trichloride, and potassium bromate are powerful oxidizing agents. It has been suggested by Larmour (1940) that the improvements resulting from bleaching agents might not be the result of the same action responsible for improvement from the use of potassium bromate. He recommended the use of specific terms such as "bromate effect" and "bleaching effect" instead of the single term "oxidizing effect".

These flours provided a basis for variety comparisons. Flours from the four winter wheats were compared both from the standpoint of baking characteristics, and to the effectiveness of color removal by bleaching with Agene and Novadelox.

Flours from Tenmarq and Chiefkan wheats were approximately one percent higher in protein than the Turkey and Nebred flours. Bread made from Tenmarq or Turkey flours without the benefit of dry milk solids was superior to Chiefkan with or without dry milk solids. This statement also held true when the optimum amounts of potassium bromate were used.

Nebred containing one percent less protein than Chiefkan when baked without dry milk solids was inferior to the latter variety. The unbleached sample of Nebred baked with 6 percent dry milk solids was decidedly superior to Chiefkan. This showed the benefit conferred on Nebred by the inclusion of dry milk solids and suggested the importance of using dry milk solids for the proper evaluation of varieties.

The addition of dry milk solids to the Chiefkan sample had no appreciable effect in increasing the loaf volume. These Chiefkan data were very disconcerting and no explanation of its poor response to dry milk solids will be attempted. The optimum bromate requirement for Chiefkan, with and without dry milk solids, was higher than for any of the other three varieties investigated. Tenmarq and Nebred flours were practically identical in their optimum bromate requirements and the Turkey flours were higher as shown in Table 8.

The results obtained from the Nebred bleached samples when using 6 percent dry milk solids were much different from those received from the other varieties. The unbleached sample of Nebred gave loaf volumes approximately the same as Turkey and exhibited a high degree of tolerance toward potassium bromate. Bleached samples of Nebred, however, were definitely over-bromated at the higher levels (above 4 mg.) of potassium bromate. It is very possible that the optimum bromate level for Agene bleached samples of Nebred when using 6 percent dry milk solids was only 2 mg. That dry milk solids was effective as a buffering agent is evident as shown in Plate V, although its effectiveness did not extend to the higher levels of potassium bromate.

Turkey and Nebred flours before bleaching were much higher in their content of flour pigment than either Tenmarq or Chiefkan flours. Treatment with Agene and Novadelox, especially the 3-normal treatments, resulted in approximately the same flour pigment content for each of the four varieties. Bleaching Turkey and Nebred flours with Agene resulted in a reduction of their loaf volumes; whereas Agene bleached Tenmarq and Chiefkan flours were not so effected.

A normal treatment with Agene (3 g./bbl.) was more effective in removing the yellow pigment of flour than the normal treatment of Novadelox (0.4 oz./bbl.). Increased bleaching up to three times the normal treatment further reduced the amount of color left in the flour. Using such large treatments, Novadelox proved to be as effective as Agene in the decolorization of flour pigments. Dough curves for all of the bleached and unbleached samples were made on a Swanson-Working dough recording machine. Within a variety no appreciable difference could be noted in the curves as a result of the various bleaching treatments.

In a trial bake, bread was made from the unbleached Turkey flour and the following factors were varied: mixing time, fermentation time, and quantities of potassium bromate. The resulting loaves of bread were dried and ground. The ground crumbs were used to run pigment tests in the same manner as employed for flours. The purpose of this study was to ascertain whether or not the so-called "oxidation" operations in baking were responsible for the removal of any flour color. The data are given in Table 9. It was found that over-mixing was the only one of the three factors that was responsible for any appreciable color removal. The crumbs of some representative loaves baked during the course of these investigations were also analyzed for pigment content and the results indicated very little if any loss in pigment from the action of potassium bromate.

Table 9. The amount of flour pigment in dried bread crumbs of Turkey flour baked several ways.

Treatment	Flour pigment p.p.m.
Unbleached flour	2.49
Normal bake[1] - No $KBrO_3$	1.26
1 mg. $KBrO_3$	1.40
3 mg. $KBrO_3$	1.39
5 mg. $KBrO_3$	1.48
10 mg. $KBrO_3$	1.41
1 hour fermentation-no bromate	1.13
5 hour fermentation-no bromate	1.10
1 minute mixing time-no bromate	1.40
5 minute mixing time-no bromate	.88

[1] 3-minute mixing time and 3-hour fermentation time used in normal bake.

It was not attempted in this investigation to obtain results which would explain the action of dry milk solids in bread dough. The purpose of this study, however, was to investigate the effectiveness of dry milk solids in preventing over-bromation of bleached flours.

Bread doughs are highly complex colloidal systems and the inclusion of dry milk solids further increases the complexity of the dough system. That the addition of dry milk solids considerably affects the dough system and materially benefits the finished loaf of bread has been known for many years. Knowledge of its buffering effect towards potassium bromate, however, is relatively new, and at the present time there is no satisfactory explanation of its so-called buffering effect. It was suggested by Ofelt (1939) that dry milk solids might have a stabilizing effect on the oxidation-reduction potential of the dough system. He also suggested that dry milk solids might act as protective colloids.

Whatever course of explanation is followed as to the effect of dry milk solids in the bread dough, the point remains that it is of great practical importance to the baker. When dry milk solids are used, the danger of overtreating flours with bread improvers, containing potassium bromate is minimized. Heavy applications of bleaching agents apparently may be given to flours without greatly altering the optimum bromate level. These benefits of dry milk solids are most welcome by the baker for they are added assurance that he will still be able to obtain satisfactory bread from sound flours, regardless of their previous bleaching treatments.

SUMMARY AND CONCLUSIONS

1. A study was made with four winter wheat flours to ascertain the effectiveness of dry milk solids in preventing damage from over-bromation of flours previously bleached with Agene or Novadelox. In addition, the combined effect of bleaching agents and potassium bromate was studied as well as the individual effects of these two factors.

2. All samples, bleached or unbleached, were baked with or without 6 percent dry milk solids. The flours were baked with amounts of potassium bromate ranging from zero to 7 mg., per 100 g. of flour. Both Agene and Novadelox bleaching agents were used in normal and 3-normal quantities.

3. The results obtained showed defintely that the presence of 6 percent dry milk solids in dough reduced the possibility of damage from over-bromating unbleached or bleached samples of flour. The inclusion of dry milk solids increased the loaf volume, improved the crust color, grain, and texture.

4. Bread was appreciably improved by bleaching the flour. Greater improvement resulted from the use of potassium bromate in the dough than from bleaching the flour.

5. The use of potassium bromate increased flour absorption more than bleaching.

6. Chiefkan showed little improvement from the addition of dry milk solids, and proved inferior to the other three varieties in baking quality. Nebred flour after bleaching proved to be very sensitive to added potassium bromate. Nebred benefited more than the other varieties from the addition of dry milk solids, although showed little tolerance to bromation due to added milk when the sample was bleached.

7. Unbleached samples of Turkey and Nebred contained more flour pigment than samples of Tenmarq and Chiefkan. Normal treatment of Agene was more effective in the removal

of color than the respective treatment of Novadelox. The 3-normal treatment with either bleach reduced all varieties to approximately the same pigment content.

8. Increased mixing time improved slightly the color of the bread crumb. No improvement in color, however, was observed with increased fermentation time or large amounts of potassium bromate.

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