THE EFFECT OF DRY MILK SOLIDS ON THE PROPERTIES OF DOUGHS

by

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INTRODUCTION

The past four decades have witnessed the rise of commercial baking from a position of comparative insignificance in trade to an industry evaluated at one and one half billion dollars annually. This growth has been accompanied by an ever increasing competition which has resulted in improvement in equipment, processes, products and merchandising methods. In order to improve the products the baker has resorted to many expedients, most of which have led to a better understanding of the use of ingredients. This in turn has widened the range of products and enhanced their value as human food. One of the most important recent developments is the use of dry milk solids in the baking formula. The addition of dry milk solids has in most instances resulted in a better product but, at the same time, it has increased the number of major problems confronting the baker. The action of dry milk solids in doughs is not well understood. It was believed that a fundamental study of this action might lead to even more valuable uses of this material. It was for this reason that the present investigation was initiated.

REVIEW OF LITERATURE

The high nutritive value of milk has long been recognized. It has been used as an added ingredient in cookery for the flavor which it contributes as well as for its value as a human food. It is uncertain when milk was first used as an ingredient in bread doughs but it is probable that it has been used by housewives for many decades.

The first scientific studies of milk in bread were made from the viewpoint of added nutritive value. Sherman *et al* (1921) indicated that bread made with milk has a greater nutritive value than bread made with water. Morison and Amidon (1923) cite Food Inspection Decision 188, issued by the United States Department of Agriculture, 1923 which defines milk bread as follows:

> Milk bread is bread obtained by baking a wheat bread dough in which not less than one third (1/3) of the water ingredient has been replaced by milk or the constituents of milk solids in proportions normal for whole milk. It conforms to the moisture limitations for wheat bread.

Morison and Amidon (1923) fed to albino rats bread made according to the above definition of milk bread, and also bread made with all of the water replaced by whole milk. They concluded that the increased rate of growth of the rats fed on bread made entirely with milk, over that made with one third of the water replaced by milk, indicates strikingly the value of a liberal portion of milk in bread formulas.

It is interesting to note in this connection that, according to Wilfahrt (1931), the United States Government changed the definition of milk bread in 1931 to read as follows:

> Milk bread is the product, in the form of loaves or smaller units, obtained by baking a leavened and kneaded mixture of flour, salt, yeast and milk or its equivalent (milk solids and water in proportions normal to milk); with or without edible fat or oil, sugar and/or other fermentable carbohydrate substance. It may also contain diastatic and/or proteolytic ferments, and such minute amounts of unobjectionable salts which serve solely as yeast nutrients. (The propriety of the use of minute quantities of oxidizing agents as enzyme activators is reserved for future consideration and without prejudice). The flour ingredient may include not more than 3 per cent of other edible farinaceous substance. Milk bread contains, one hour or more after baking, not more than 38 per cent of moisture.

Fairbanks (1938) studied the improvements in nutritive value of bread by the addition of dry milk solids. In these experiments white rats were fed three diets by the ad libitum method of feeding. The diets were: (1) milk-free bread, (2) 6 per cent dry milk solids bread, and (3) 12 per cent dry milk solids bread. All of these diets were fed with sufficient water. Fairbanks concluded that the addition of dry milk solids to a water bread increased the nutritive value and that bread made with 12 per cent added dry milk solids is of greater nutritive value than bread made with 6 per cent added dry milk solids. The importance of these conclusions may seriously be questioned because of the use of bread and water as a base diet. This is known to be a deficient diet.

Fairbanks and Mitchell (1935) investigated the effects of the heat treatment used in the manufacture of dry milk solids on the nutritive value of milk proteins. They concluded that milk powders subjected to a temperature sufficiently high to produce a barely perceptible scorching are still as valuable as liquid skim milk for energy sources in the animal body. Biological values of the proteins were established and it was found that the biological value of the liquid skim milk was depressed as much as 10 per cent in the "choice" roller and spray process milks and as much as 20 per cent in scorched milks. It was shown by feeding tests that preheated milks are deficient in cysteine, and that addition of lysine to the diet markedly improved the growth-promoting effect. This deficiency in lysine, in scorched milks, destroys their value as a lysine-furnishing supplement in cereal foods.

One of the difficulties encountered in the early use of dry milk solids as an added dough constituent was the varying effects obtained with different samples of milk. This effect was first investigated by Greenbank <u>et al</u> (1927). These researchers found that milk which had received a higher heat treatment in the drying process gave loaves of greater volume and that this higher heat treatment gave doughs with greater imbibitional properties. Forty per cent suspensions of dry milk solids were made up and checked for viscosity. Those milks which had received a heat treatment above 85°C. gave distinctly higher viscosities and were much superior in baking quality. The milk treated at 65°C. and below seemed to have a binding effect upon the doughs. These temperatures are not sufficiently high to coagulate the albumins and the authors attribute the binding effect to this cause.

Grewe and Holm (1928) studied the effects of several samples of dry skim milk, which had been subjected to varying degrees of preheating, on the baking quality of three flours obtained from the three major classes of bread wheats. A marked improvement in baking quality was obtained when preheating temperatures of 73°C., 83°C., 93°C., or 100°C. were used and only a slight difference between members of the latter series. They found that a preheating temperature of 50°C. gave the poorest results and of 63°C. the next poorest results.

Skovholt and Bailey (1931) found that preheating milks for a period of 30 minutes at temperatures of 77°C., 88°C., or 96°C. greatly improved the baking quality of the resulting powders and to about the same degree at each of these temperatures. The absorption of the dough to which milk was added and the viscosity of the milk powder in water suspensions were not increased by preheating to 77°C. for 30 minutes. Marked increases were obtained in these respects when the milks were preheated to the higher temperatures. These workers found that the use of viscosity methods in determining baking quality of dry milk solids will not give reliable results when dealing with products which have received intermediate preheating treatments. Hydrogen ion concentrations of dry milk solids in flour-water suspensions were not affected by preheating treatments. Electrical conductivity in water suspensions was only slightly different for dry milks receiving light or severe preheating treatments. The effect of depression of saccharogenic activity by added dry milk solids in a dough is not affected by the previous preheating treatment of the milk.

Johnson and Ward (1936) investigated the relationship between the viscosity of nonsweetened condensed milk and baking quality. Their results indicate that the viscosity of superheated condensed milk is not necessarily an indication of baking quality. Heat treatment seems to determine how condensed milk will react in bread making. Adequate heat treatment of the milk is necessary in order that the milk allow the proper absorption in the dough and that the bread shall show satisfactory texture, loaf volume, and oven spring. This heat treatment may or may not be accorded the milk in a manner such as to increase the viscosity of the heated product. Increase in acidity of the milk either naturally or by the direct addition of lactic acid allowed the development of considerable viscosity with a minimum of heat treatment, yet the baking results with viscous, acidified, heat treated milk were unsatisfactory. Freezing of plain condensed milk and holding the frozen milk in storage yielded milks of high viscosity but baking results of such milks were unsatisfactory.

Coombs (1938) discussed factors which, in the production of high quality dry milk solids, must be taken into consideration before the raw milk arrives at the manufacturing plant. This author indicated that increase in acidity is usually due to the action of organisms belonging to the streptococcus lactis group and is usually accompanied by an increased bacterial count. It is an indication of the manner in which the raw milk has been handled previous to delivery to the manufacturing plant. The acidity may be neutralized without injury to the dry milk solids produced but this is considered poor trade practice.

St. John and Bailey (1929b) studied the effect of dry milk solids on the absorption of doughs and the plasticity of flour suspensions. These authors demonstrated that the addition of dry milk solids increases the water-imbibing capacity of doughs as measured by the power input required in mixing. It proved necessary to add about one unit of water, by weight, for each unit of milk added to maintain the same plasticity in the dough as measured by the wattmeter and motor driven mixer. Force required to extend a dough surface, as measured by the Chopin Extensimeter, likewise tended to decrease as the proportion of water was increased. This was observed with milk-free doughs as well as those doughs which contained added dry milk solids. Extensibility, as measured with the Extensimeter, was not substantially affected by the inclusion of 10 per cent or less of dry milk solids in the dough. Plasticity of flour-water dry milk solids suspensions was measured by Bingham and Murray's (1923) method. It was found that mobility of such suspensions decreased with additions of dry milk solids and that the addition of one unit weight of water was necessary with each added unit weight of dry milk solids to retain the same relative mobility of the suspensions.

Skovholt and Bailey (1932b) found that the inclusion of dry milk solids in dough increased the mixing time necessary to reach the maximum plasticity, and also that the inclusion of sodium chloride more than doubled the amount of additional water that could be added to reach a definite maximum plasticity when using dry milk solids. They observed that the amount of decrease in dough plasticity with extended mixing in a Farinograph gave a significant correlation with baking quality in a study of a series of milks. A good agreement was found in the rating of six of these milks by their plasticity curves when using two widely differing flours in doughs containing salt. Different ratings were obtained when salt-free and salt-containing doughs were compared. Absorption increases caused by milk were nearly the same regardless of the milk quality if the highest plasticity level attained was used as the measure.

Skovholt and Bailey (1935) determined that certain milk samples produced an effect on dough properties that was similar to the action resulting from the addition of minute amounts of proteases. The most important conclusion drawn by these workers from this work was that modification of the physical properties of a dough, involving the gluten, may occur even though the conventional biochemical methods fail to disclose appreciable quantities of those protein split-products which are differentiated by these means.

Bohn and Bailey (1937) found that the addition of dry milk solids not fat markedly decreased the stress readings of a dough after mixing, and increased the time of mixing required to reach the optimum development as indicated by the Farinograph. Good quality milk powders appeared to make a greater contribution to "strength" and gave higher stress readings than did poor milk powders, as well as a greater tolerance to mixing.

The earliest publication on the effects of dry milk solids on the baking quality of flours appears to have been by Amidon (1926). This worker found that superimposing dry milk solids on the bread dough formula, in increments up to 10 per cent, gave an increase in loaf volume greater than the corresponding increase in dough weight. These results were obtained with a gradual increase in fermentation time up to 12 per cent. The color and character of crust increased progressively with additional increments of dry milk solids. The addition of milk seemed to repress a tendency of the break to "run wild". No effect on grain was noticed until 8 per cent was added. At this figure and at higher levels of added milk solids the milk appeared to detract from the quality of grain making it more open and coarser. The color of crumb was "creamier" at this milk level but it was also "brighter" and more lustrous. The flavor and taste of bread showed a gradual increase until a level of 7 per cent of added dry milk solids was reached. Above this level the flavor decreased and the taste was less desirable. The texture was softer and more velvety with increasing quantities of added dry milk solids. The total score, which was the aggregate of all observed properties, increased progressively, on all flours used, with up to 7 or 8 per cent of added dry milk solids above which it tended to drop.

Working (1928) in studying the actions of phosphatides in bread doughs observed that if 4 to 6 per cent of dry milk solids were added to dough an improvement could be obtained by the addition of both a phosphatide and an oxidizing agent.

Grewe (1928) observed that the range of fermentation time over which good bread could be produced was increased by the addition of dry milk solids, also that the break and shred are improved. She observed also that overproofing was more detrimental in doughs containing added dry milk solids than in milk-free doughs. There was a greater increase in volume as a result of overproofing a milk-containing dough than in a milk-free dough and with this increase in volume an increase in coarseness in grain resulted. In a subsequent paper Grewe and Holm (1928) reaffirmed the statement of the senior author that the range of fermentation time over which a flour will give good bread was increased by the addition of dry milk solids.

St. John and Bailey (1929a) found that production of total carbon dioxide in yeast leavened doughs was increased when dry milk solids were superimposed on the control formula. The effects were greater than those obtained by the use of fluid skim milk. Rate of increase of volume and total displacement of doughs were practically the same with and without added dry milk solids. This is an indication that loss of carbon dioxide from doughs was increased when dry milk solids were added. They demonstrated that the buffer action of dry milk solids was appreciable, as shown by the initial hydrogen ion concentration of the freshly mixed doughs and by the relative rate of change in pH of the control and the milk-containing doughs.

Skovholt and Bailey (1932a) compared the effects of additions of malt and dry milk solids and also the effects of additions of Arkady and dry milk solids. The investigators used flours from both hard winter wheats and hard spring wheats. These authors reported that malt and milk had a complementary effect on doughs. Malt added to doughs containing dry milk solids resulted in greater improvement than malt added to milk-free doughs. Likewise, milk added to doughs containing malt gave a more marked improvement than milk added to malt-free doughs. The effects of Arkady were much greater in the presence of milk than in doughs that were milk-free. The improvement obtained by the use of Arkady under these conditions was much greater with the winter wheats than with the spring wheat flours. The improvement obtained by the use of added dry milk solids was much greater in doughs containing Arkady than in the control doughs. Again a much greater percentage increase in improvement was obtained with the winter wheat flours than with the spring wheat flours. These results were obtained using both two and three hour fermentation periods.

Skovholt and Bailey (1933) found, while studying the susceptibility of milk bread to molds, that added dry milk solids increased the hygroscopicity of both the bread crumb and the crust.

Skovholt and Bailey (1937) studied the effects of added dry milk solids on fermentation reactions. They found that proteolytic activity in doughs, as judged by available methods which may quite possibly be inadequate. is not affected. They found that diastatic activity is retarded by the introduction of dry milk solids which reduces the hydrogen ion concentration. There was no effect in buffered doughs. Gas production was accelerated in fermenting doughs if sufficient sugar was available. The milk-free doughs produced gas more rapidly during the earlier stages of fermentation but the doughs containing added dry milk solids produced gas more rapidly during the latter stages of fermentation in a three or four hour schedule. This was desirable in order to obtain the proper proof of the loaves. Yeast treated to inhibit growth was used in doughs and the results indicate that milk solids increased the activity of the zymase complex. This increase in activity seemed to result partially from an affected reduction in hydrogen ion concentration.

Bohn and Bailey (1937) stated that a good grade of milk powder will improve the volume, texture, eating, and keeping qualities of bread. Poor milk powders, at a 6 per cent level, may impair the physical and eating qualities of bread; the volume usually was decreased and the grain, though uniform, tended to be open and the cell walls thick.

MATERIALS AND METHODS

Table 1 lists the flours used in this investigation. These flours were chosen as representative of the various types used in commercial bread production in different parts of the country, as well as flours which are used for the production of cake, pastries, and alimentary pastes. They consisted of commercially milled and experimentally milled

Table 1. Flours used, their protein content, bleaching treatment, and the method in which they were milled.

Wheat variety or class from which flour was milled.	Per cent protein on a 13.5 per cent moisture basis.	Bleaching treatment	Method of milling
Durum (North Dakota)	11.1	Unbleached	Experimental
Hard red spring (Minnesota)	14.7	Unbleached	Commercial
Hard red spring (Canadian)	13.3	Unbleached	Commercial
Hard red winter (Kansas)	11.5	Bleached	Commercial
Soft red winter (Missouri)	10.3	Unbleached	Commercial
Soft red winter (Missouri)	9.3	Bleached	Commercial
Pacific short patent (Oregon)	6.8	Bleached	Commercial
Tenmarq (Kansas)	9.8	Unbleached	Commercial scale experimental mill
Chiefkan (Kansas)	11.5	Unbleached	Commercial scale experimental mill
Low-protein composite from Turkey, Tenmarq, and Blackhull	9.9	Unbleached	Experimental
High-protein composite from Turkey, Tenmarq and Blackhull	14.4	Unbleached	Experimental

flours, both bleached and unbleached. Two of the flours, an unbleached Tenmarq and an unbleached Chiefkan, were extracted with ethyl ether for further investigation. This extraction was performed in an enlarged extractor of the Soxhlet type for a period of at least 24 hours. After extraction with ether the flours were exposed to the atmosphere for a time sufficient to remove all traces of ether as detectable by organoleptic methods. The absorption was determined in the usual manner and baking tests conducted using the extracted flours.

The bromate used in this investigation was a chemically pure potassium bromate of reagent quality. It was used in water solution of such concentration that 1 cc. contained 1 mg. of the chemical. One cc. of water was subtracted from the normal baking absorption for each cc. of bromate solution used.

The cysteine-monohydrochloride used in one portion of this investigation was a commercially prepared product and was used in water solution. This solution was prepared in such a manner that 1 cc. of the solution should contain 1 mg. of the chemical. One cc. was subtracted from the usual amount of water used for each cc. of cysteine solution used.

Dry milk solids is the product resulting from removal or the water from liquid skim milk and contains less than 5 per cent of moisture and less than 1½ per cent of fat.

The dry milk solids used in this investigation was manufactured by the spray process. A sample of this milk was compared with a sample of known baking quality and gave comparable results in the baking test. The dry milk solids was incorporated into the doughs by mixing the dry ingredients thoroughly with the flour before the addition of any of the other baking ingredients.

The baking procedure used in this investigation was a modification of the standard method approved by the American Association of Cereal Chemists. The formula involved the use of the ingredients listed below and the quantities indicated. Percentage ingredients are based on flour as 100 per cent. Formula: Flour 100 per cent; water as required; yeast 2 per cent; sugar 6 per cent; salt 1.75 per cent; shortening 3 per cent; bromate and dry milk solids in variable quantities. Baking absorption was determined by a method developed by Finney[1]. The figure for absorption was increased 1 per cent for each per cent of dry milk solids except where 8 per cent of dry milk solids was used, in which case the absorption increase was the same as that for 6 per cent dry milk solids doughs. This procedure was followed because previous experience indicated that the doughs became too sticky to handle properly

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[1] Unpublished data.

if this increase were exceeded. Doughs were mixed until they attained an optimum consistency as determined by visual observation. Finney and Barmore[2] have shown that this procedure is preferable to mixing for a definite period of time for all samples. The doughs were mixed from 200 g. of flour, divided into equal portions, fermented, and proofed at 86°F. They were baked according to the time schedule from the standard method of the American Association of Cereal Chemists. Punching was done with a National Pup Sheeting roll, and molding of the loaves by a Thompson laboratory scale molder. The loaves were baked in tall narrow pans at 450°C. in a Despatch oven with a rotating hearth. Loaf volume was measured immediately upon removal of the loaves from the oven. A National Pup-loaf measuring device was used to determine the volume. The figures for loaf volume given in the tables are averages of two loaves as measured in this manner. The loaves were cut the day following baking for scoring of the interior characteristics and for obtaining a photographic record of the interior grain structure.

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[2] Unpublished data.

EXPERIMENTAL DATA

Each of the flours obtained for this investigation was baked using 6 per cent dry milk solids and 1 mg. increments of bromate ranging from zero to as high as 7 mg. per 100 g. of flour in some cases. For comparative purposes a similar series was baked with the same flours using milk-free doughs. The 6 per cent level of dry milk solids was chosen because this level is commonly advocated for commercial usage and also because the work of Amidon (1926) showed that this value approached the upper safe limit for optimum results with added dry milk solids. The baking results are given in Tables 2 to 10 inclusive and in Tables 13 and 14. Results are graphically and pictorially presented in Figures 1 to 9 inclusive and Figures 12 to 13b inclusive. Two blends were made from flours in this group, a 50-50 blend of the Chiefkan and Pacific short patent flour. These also were baked in a similar manner to the above flours. Results of these bakings are given in Tables 11 and 12 and in Figures 10 to 11 inclusive. A study of these data and a comparison of the results from 6 per cent dry milk solids doughs with the milk-free doughs show that the presence of dry milk solids not only invariably increased the volume of

Table 2. Baking data on Durum flour showing the comparative effects of $KBrO_3$ on milk-free doughs and doughs containing six per cent dry milk solids (DMS).

$KBrO_3$. mg. per 100 g. flour.	Milk-free doughs		Six per cent DMS	
	Volume in cc.	Score of crumb	Volume	Score of crumb
0	485	50	513	60
1	463	43	513	48
2	443	35	513	45
3	435	25	493	33

Table 3. Baking data on Minnesota hard red spring wheat flour showing the comparative effects of $KBrO_3$ on milk-free doughs and doughs containing six per cent dry milk solids (DMS).

$KBrO_3$ mg. per 100 g. flour.	Milk-free doughs		Six per cent DMS	
	Volume in cc.	Score of crumb	Volume in cc.	Score of crumb
0	768	85	817	93
1	888	90	960	95
2	770	70	993	80
3	695	63	978	80
4	690	60	895	75

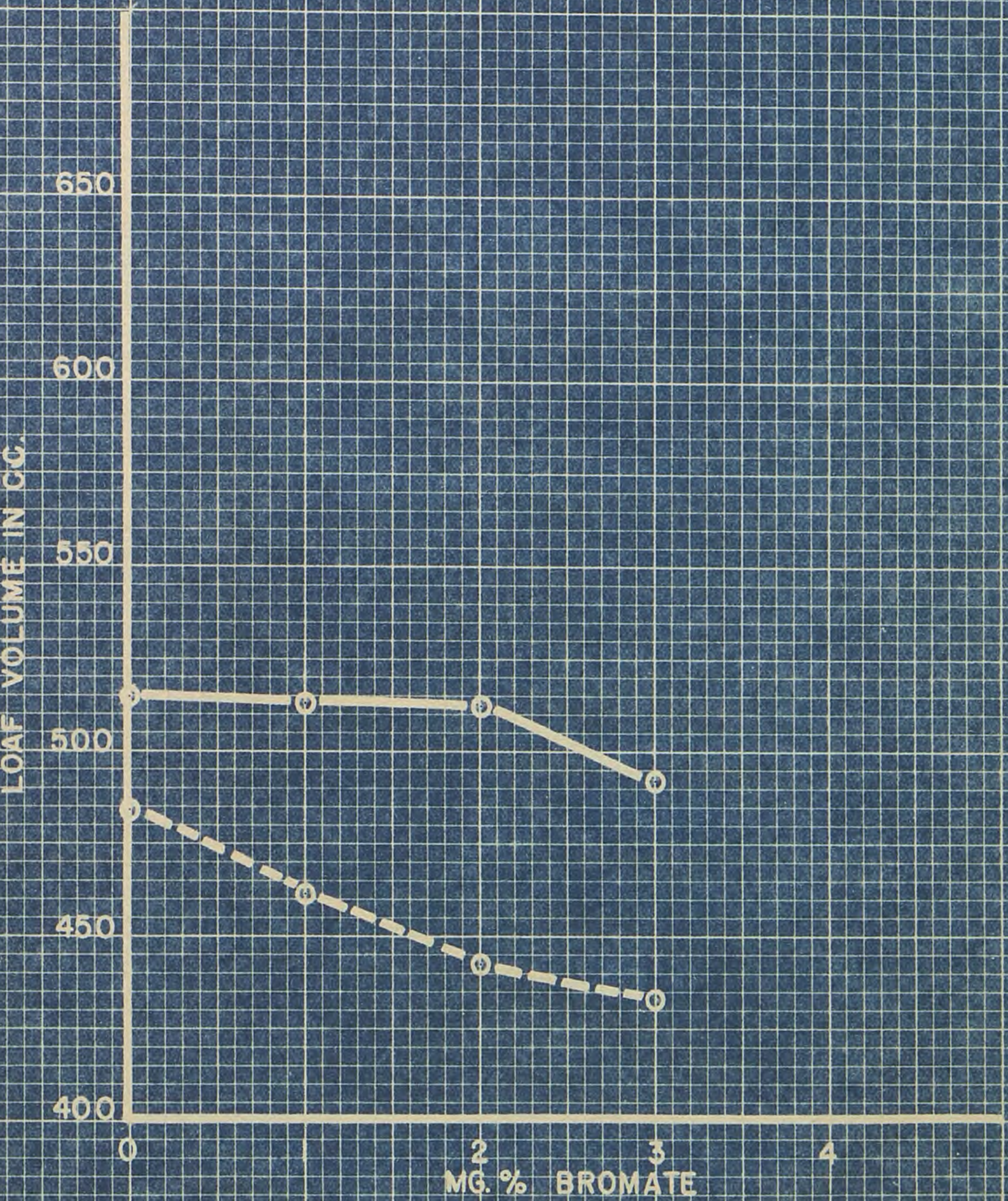

FIG. I. EFFECT OF DRY MILK SOLIDS IN RELATION TO INCREMENTS OF BROMATE ON DURUM.

——— 6% DRY MILK SOLIDS.

– – – – – MILK FREE DOUGHS.

Fig. 1a. Effects of dry milk solids in relation to increments of $KBrO_3$ on loaf exterior. Durum flour.

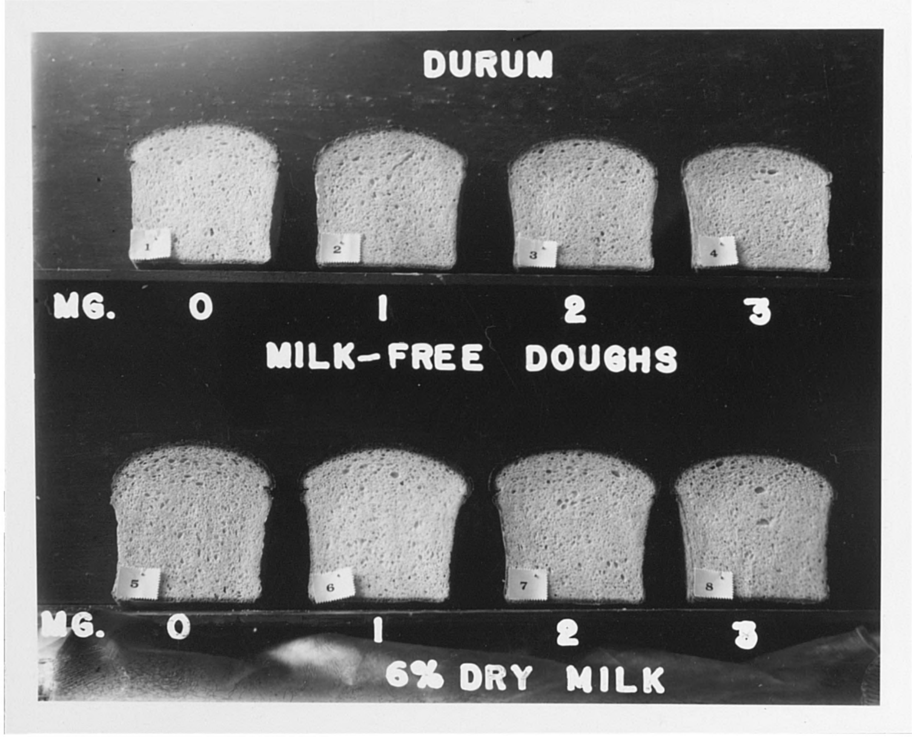

Fig. 1b. Effects of dry milk solids in relation to increments of $KBrO_3$ on loaf interior. Durum flour.

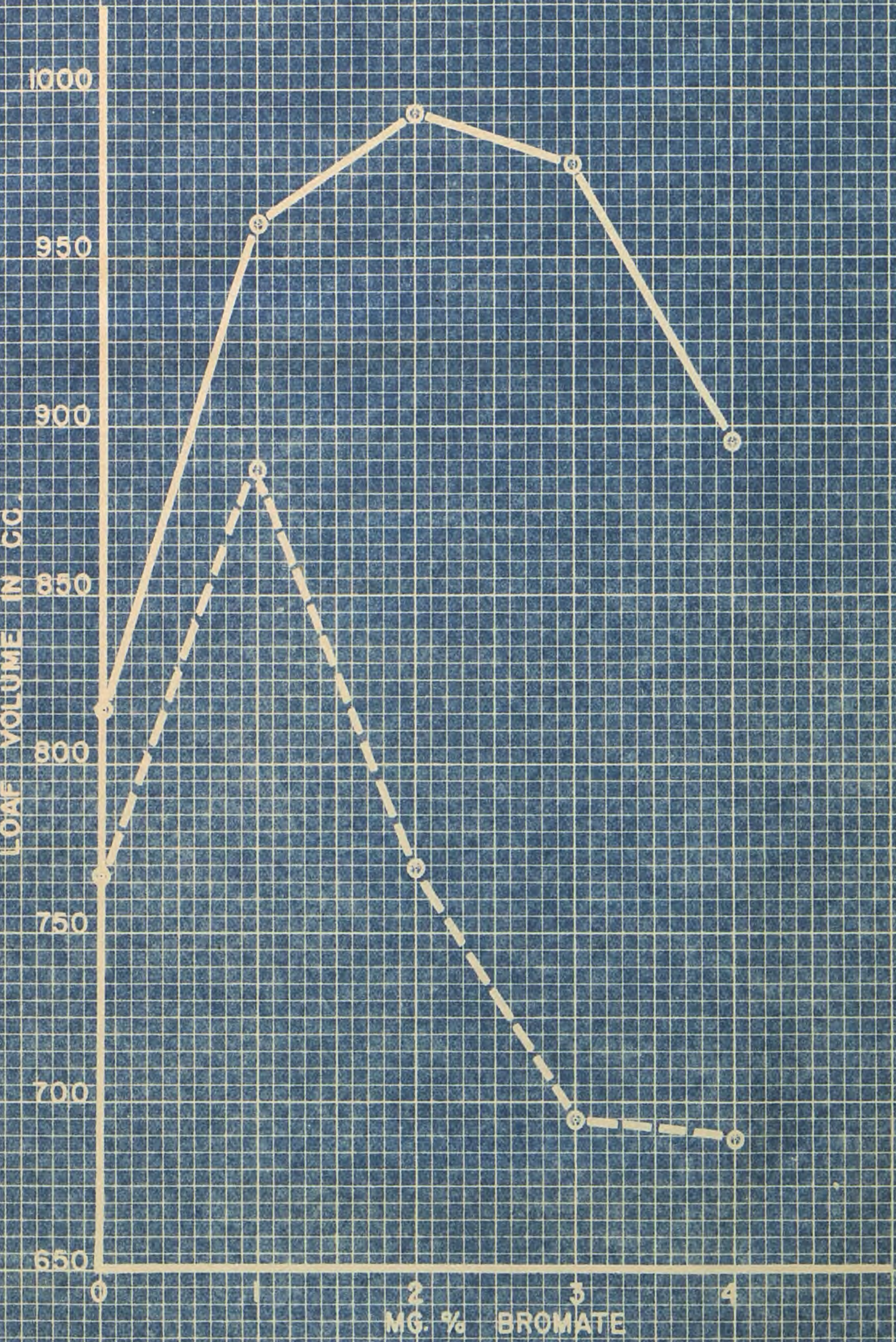

FIG. 2. EFFECT OF DRY MILK SOLIDS IN RELATION TO INCREMENTS OF BROMATE ON A HARD SPRING WHEAT FLOUR (UNBLEACHED).

——— 6 % DRY MILK SOLIDS.

– – – – MILK FREE DOUGHS.

Table 4. Baking data on an unbleached, freshly milled Canadian spring wheat flour showing the comparative effects of $KBrO_3$ on milk-free doughs and doughs containing six per cent dry milk solids (DMS).

$KBrO_3$ mg. per 100 g. flour.	Milk-free doughs		Six per cent DMS	
	Volume in cc.	Score of crumb	Volume	Score of crumb
0	688	83	823	93
1	710	79	888	92
2	635	73	888	92
3	570	64	845	84
4	568	60	813	68
5	538	54	733	65

Table 5. Baking data on a bleached commercial hard red winter wheat flour showing the comparative effects of $KBrO_3$ on milk-free doughs and doughs containing six per cent of dry milk solids (DMS).

$KBrO_3$ mg. per 100 g. flour.	Milk-free doughs		Six per cent DMS	
	Volume in cc.	Score of crumb	Volume	Score of crumb
0	715	95	770	96
1	735	90	835	98
2	693	83	825	98
3	690	79	860	89
4	673	73	822	93
5	663	71	803	93

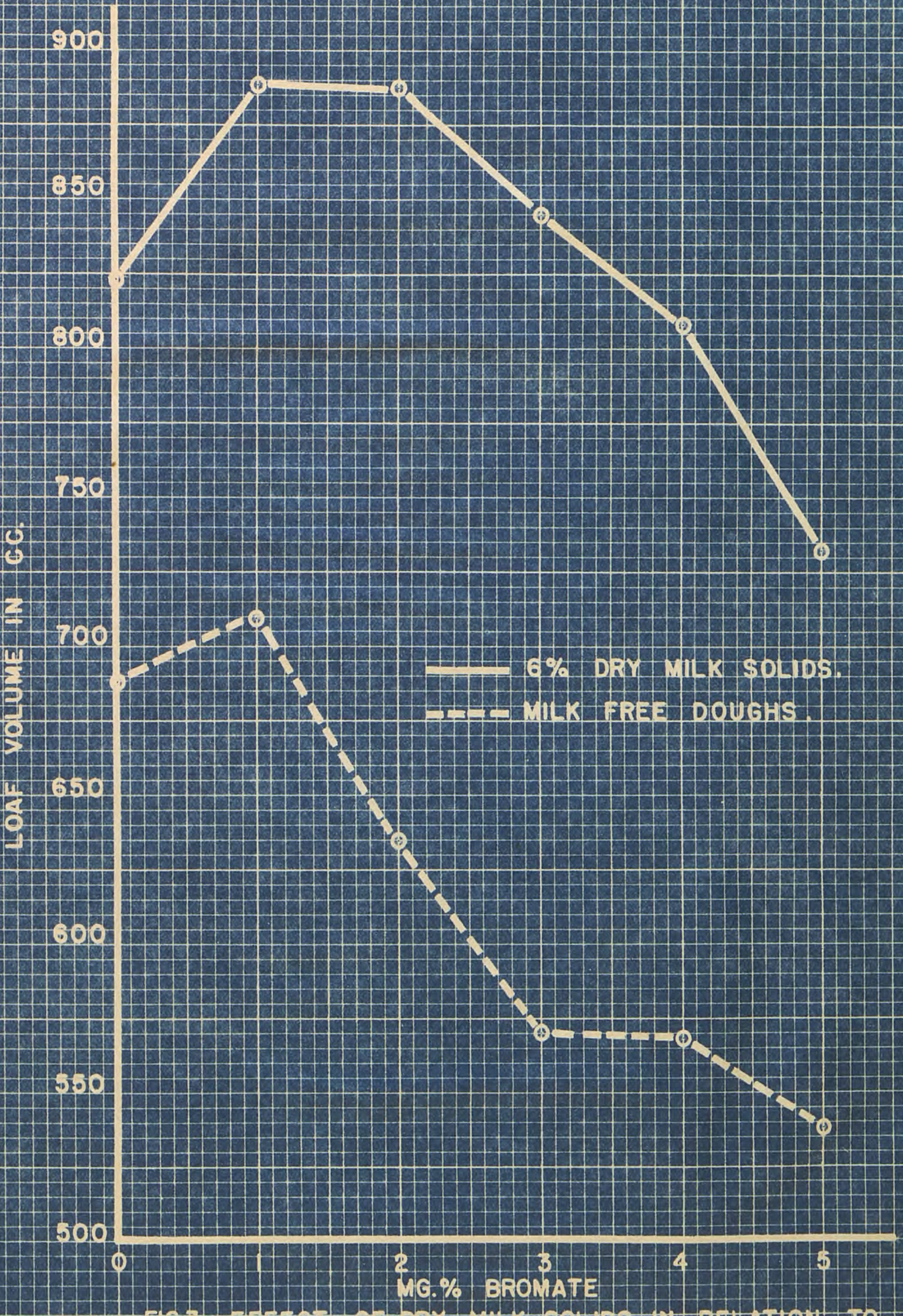

FIG.3. EFFECT OF DRY MILK SOLIDS IN RELATION TO INCREMENTS OF BROMATE ON AN UNBLEACHED CANADIAN HARD SPRING WHEAT FLOUR.

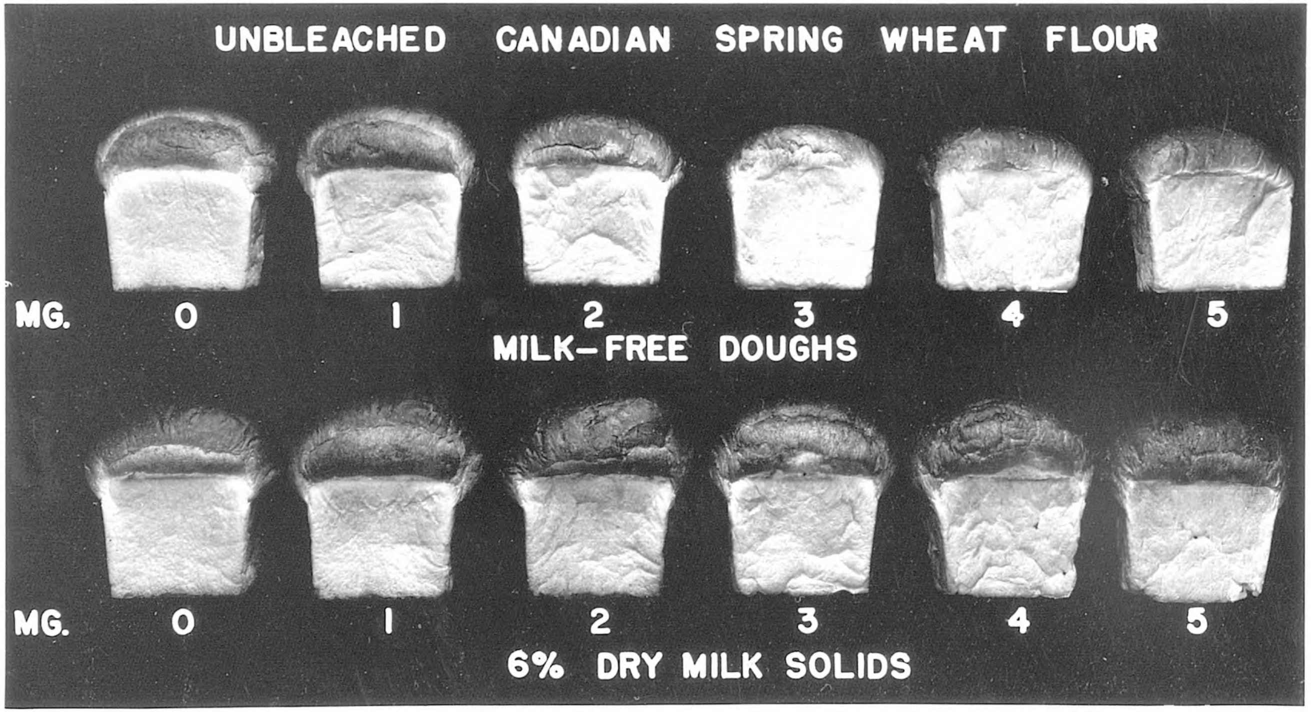

Fig. 3a. Effects of dry milk solids in relation to increments of $KBrO_3$ on loaf exterior. Unbleached Canadian hard spring wheat flour.

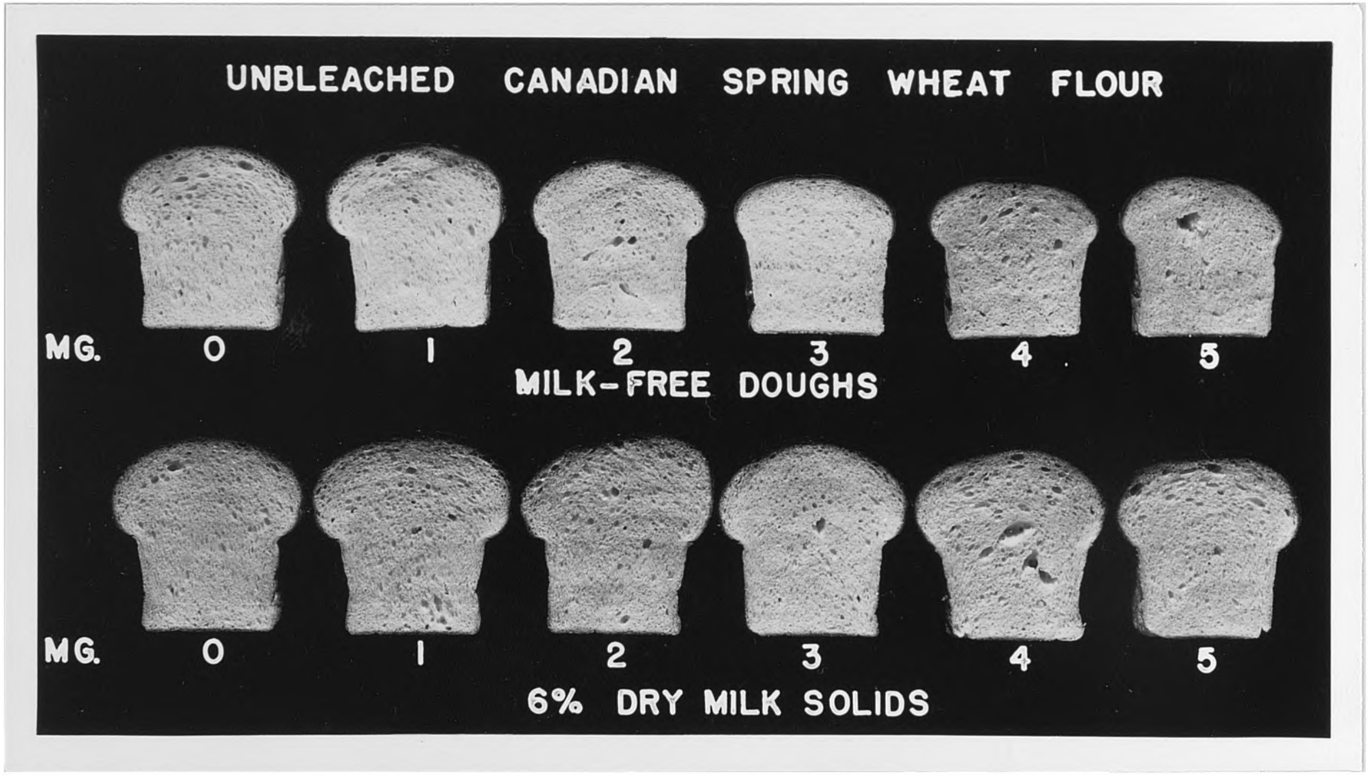

Fig. 3b. Effects of dry milk solids in relation to increments of $KBrO_3$ on loaf interior. Unbleached Canadian hard spring wheat flour.

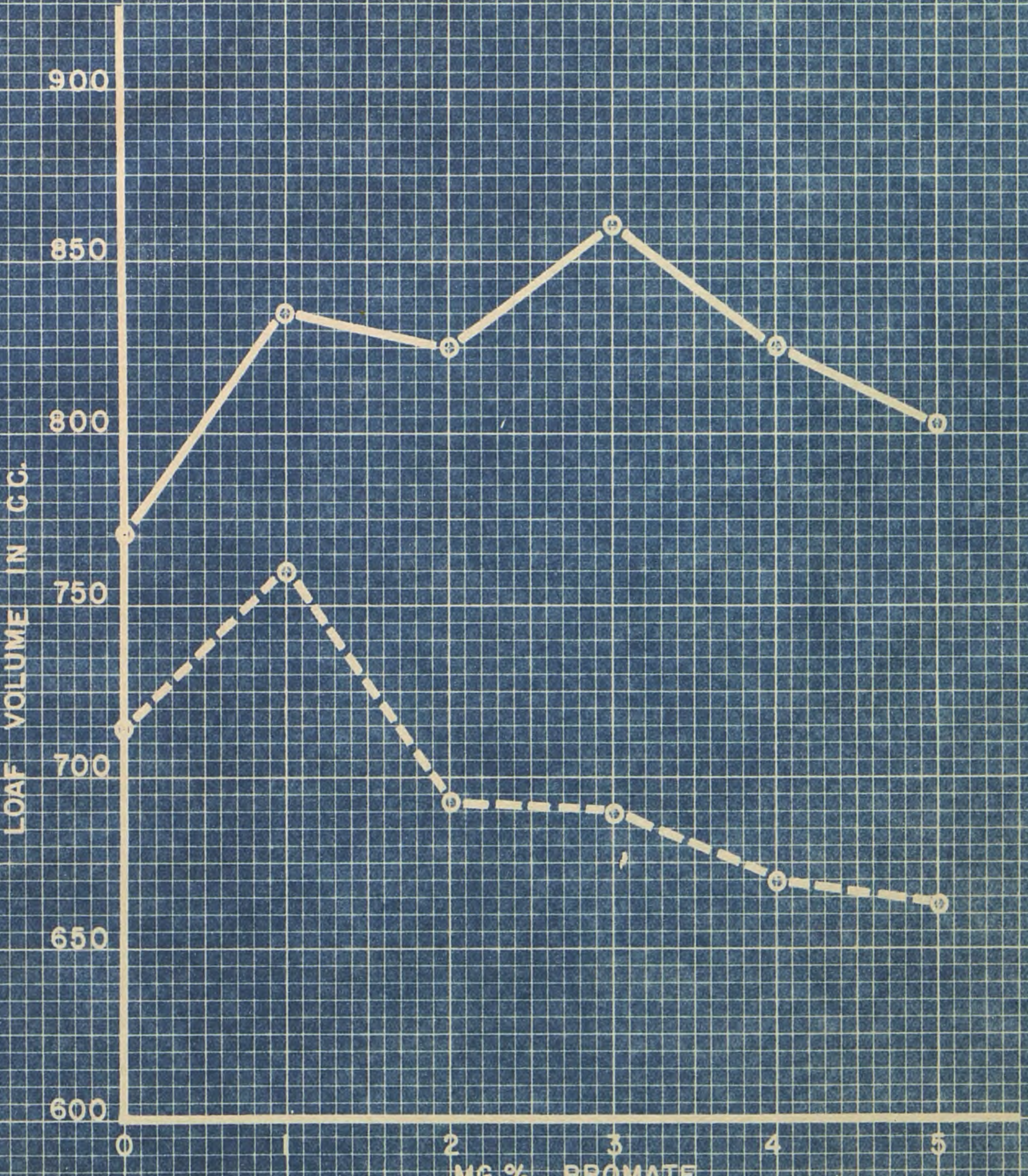

FIG. 4. EFFECT OF DRY MILK SOLIDS IN RELATION TO INCREMENTS OF BROMATE ON A BLEACHED HARD RED WINTER WHEAT FLOUR.

——— 6 % DRY MILK SOLIDS.

- - - - MILK FREE DOUGHS.

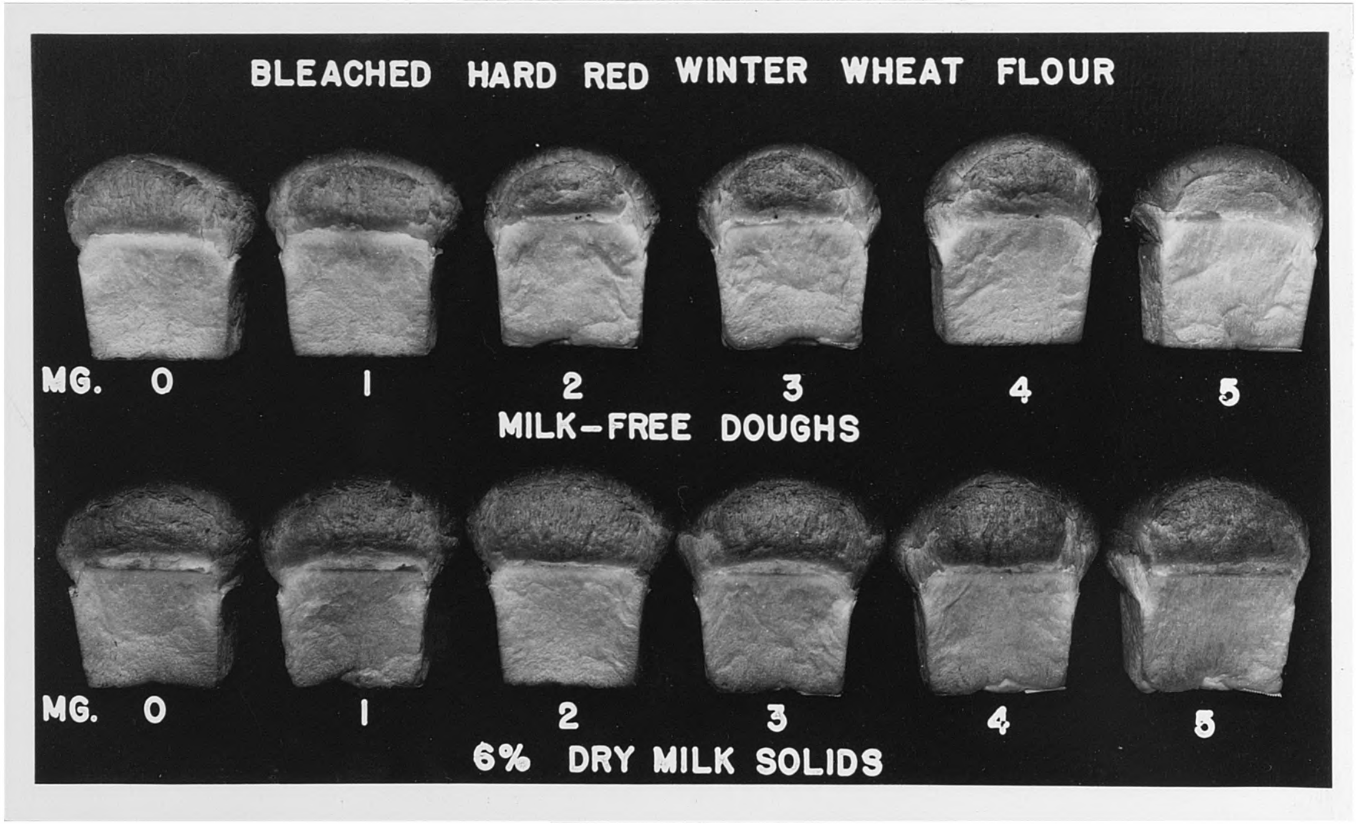

Fig. 4a. Effects of dry milk solids in relation to increments of $KBrO_3$ on loaf exterior. Bleached hard red winter wheat flour.

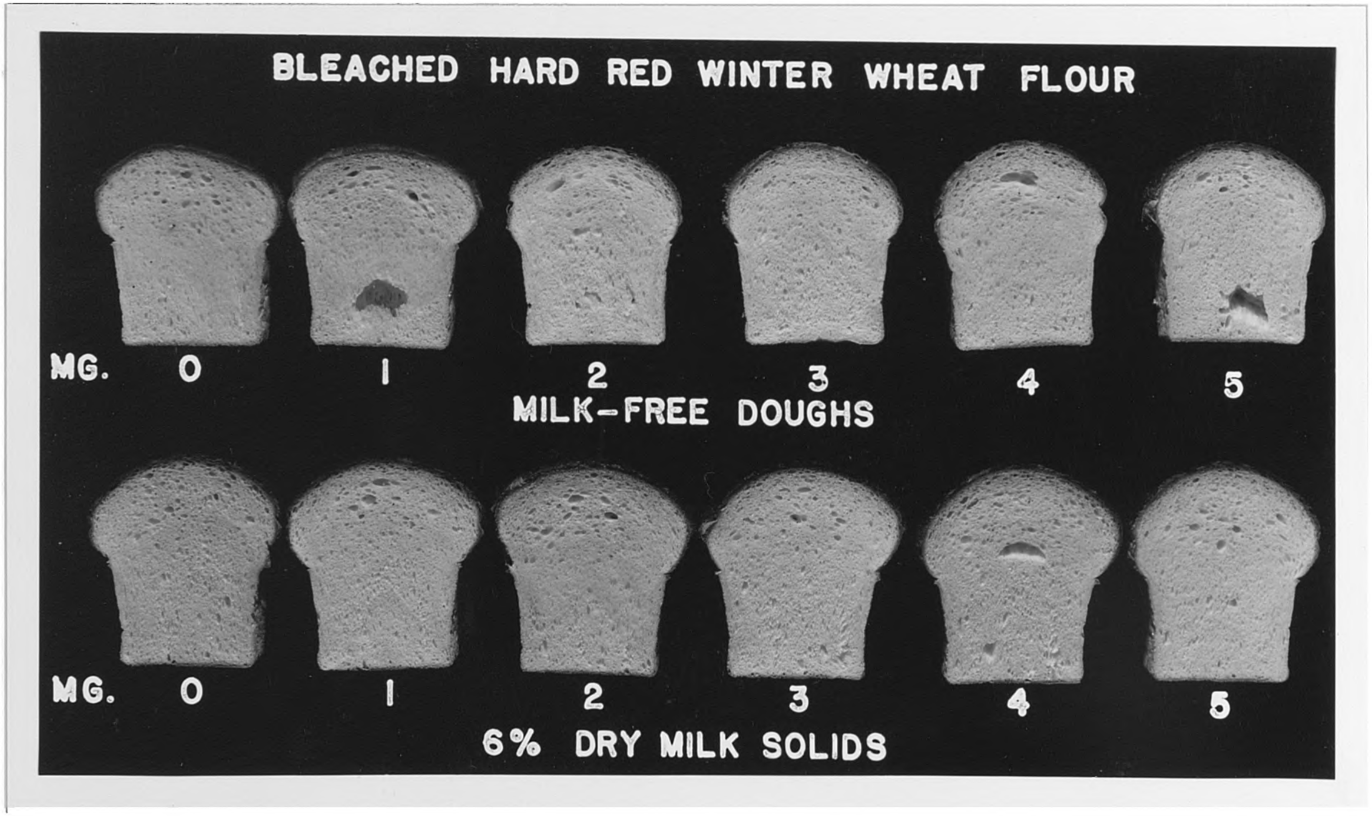

Fig. 4b. Effects of dry milk solids in relation to increments of $KBrO_3$ on loaf interior. Bleached hard red winter wheat flour.

Table 6. Baking data on an unbleached commercial soft red winter wheat flour showing the comparative effects of $KBrO_3$ on milk-free doughs and doughs containing six per cent dry milk solids (DMS).

$KBrO_3$ mg. per 100 g. flour.	Milk-free doughs		Six per cent DMS	
	Volume in cc.	Score of crumb	Volume	Score of crumb
0	618	65	768	79
1	625	71	790	77
2	622	49	790	83
3	595	50	818	78
4	600	52	780	78
5	578	47	762	70

Table 7. Baking data on a bleached commercial soft red winter wheat flour showing the comparative effects of $KBrO_3$ on milk-free doughs and doughs containing six per cent of dry milk solids (DMS).

$KBrO_3$ mg. per 100 g. of flour.	Milk-free doughs		Six per cent DMS	
	Volume in cc.	Score of crumb	Volume in cc.	Score of crumb
0	600	68	720	88
1	565	55	738	85
2	550	55	700	83
3	533	50	708	80
4	530	50	700	75
5	515	45	675	75

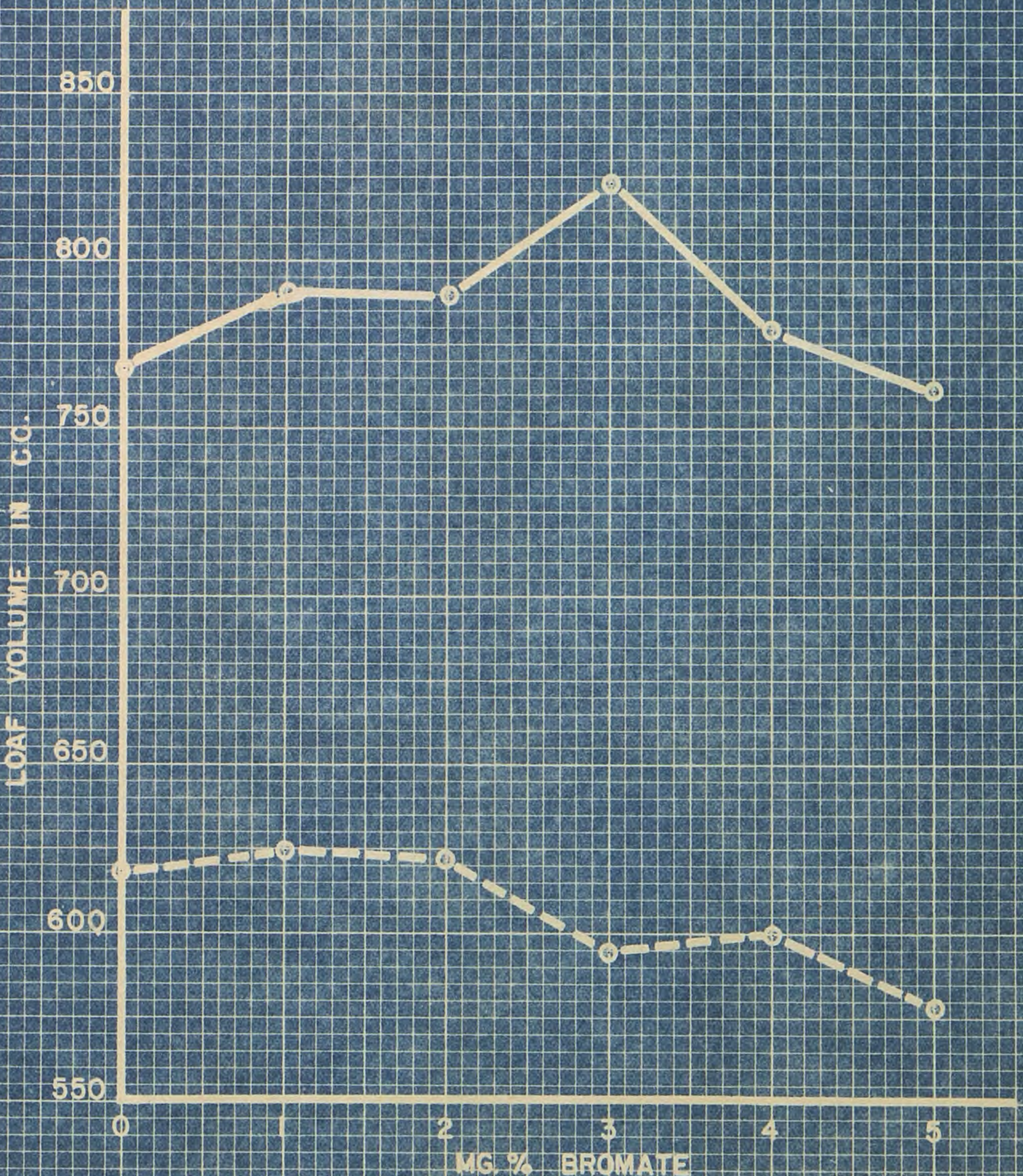

FIG. 5. EFFECT OF DRY MILK SOLIDS IN RELATION TO INCREMENTS OF BROMATE ON AN UNBLEACHED SOFT RED WINTER WHEAT FLOUR.

——— 6% DRY MILK SOLIDS.

- - - - MILK FREE DOUGHS.

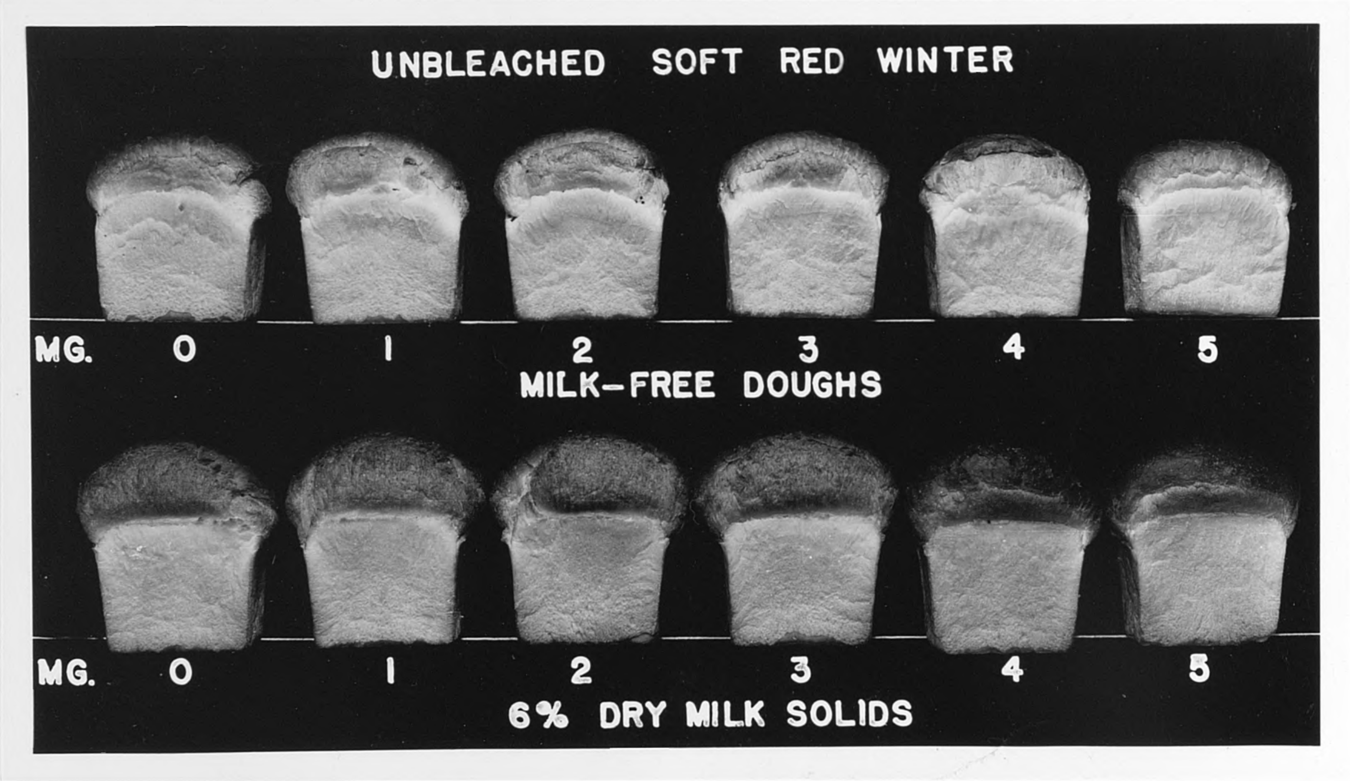

Fig. 5a. Effects of dry milk solids in relation to increments of $KBrO_3$ on loaf exterior. Unbleached soft red winter wheat flour.

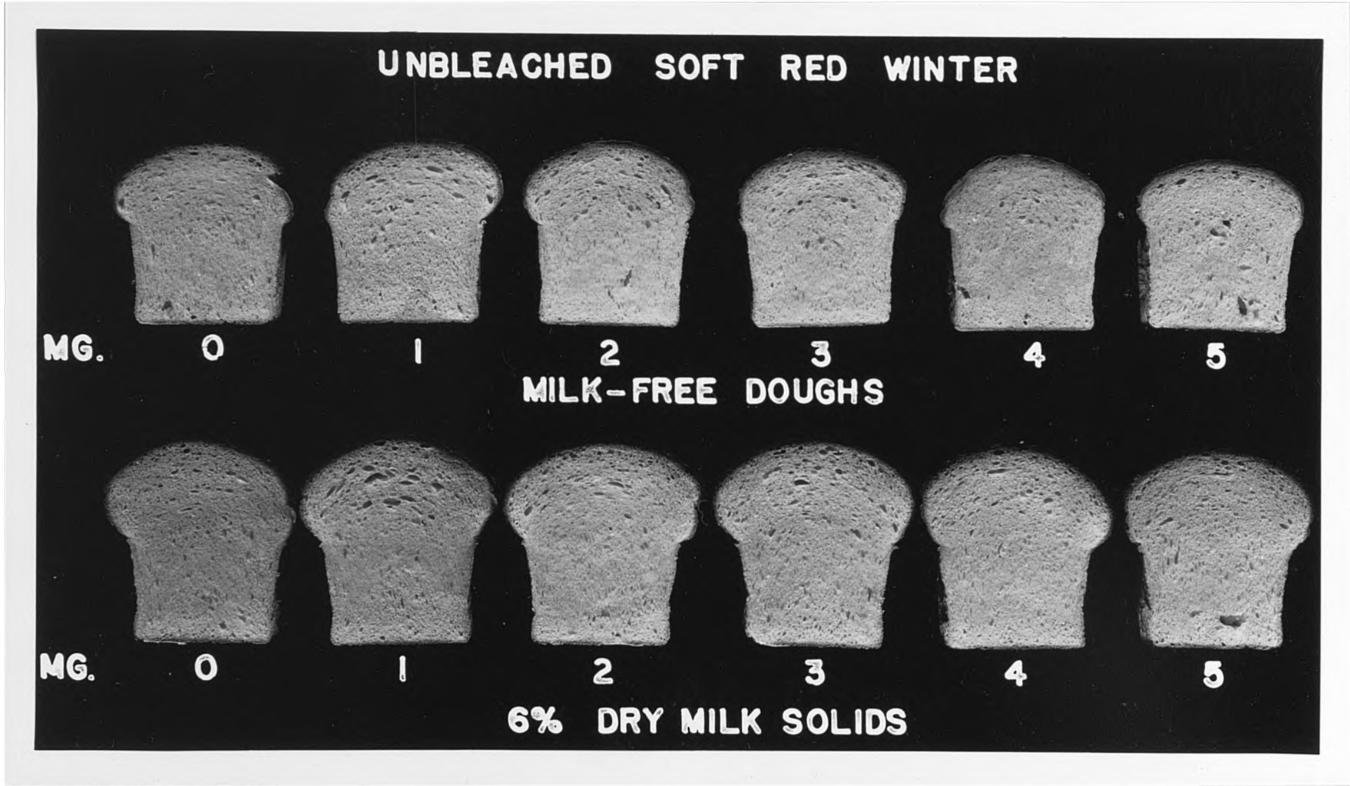

Fig. 5b. Effects of dry milk solids in relation to increments of $KBrO_3$ on loaf interior. Unbleached soft red winter wheat flour.

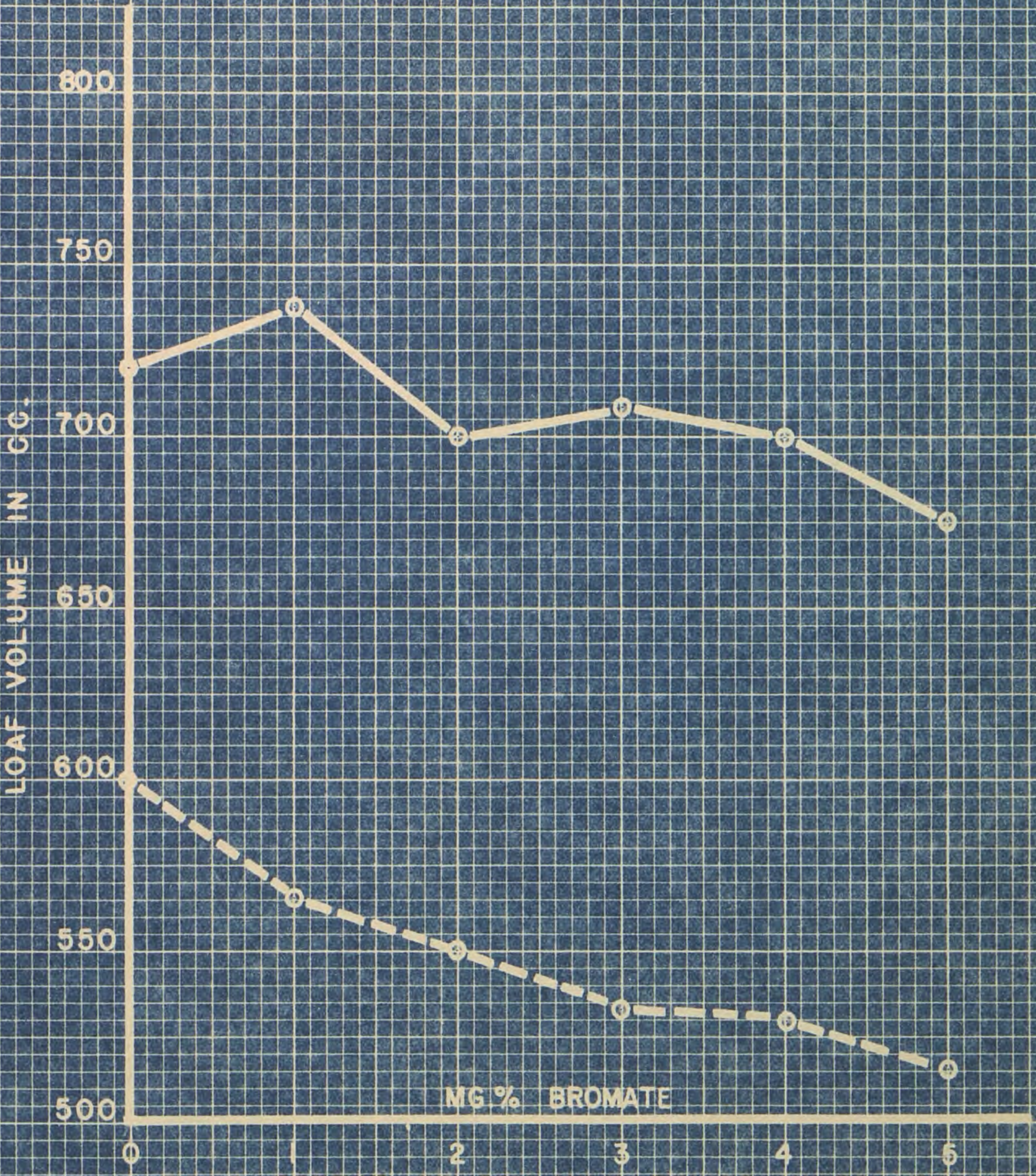

FIG. 6. EFFECT OF DRY MILK SOLIDS IN RELATION TO INCREMENTS OF BROMATE ON A BLEACHED SOFT RED WINTER WHEAT FLOUR.

——— 6% DRY MILK SOLIDS.

– – – – MILK FREE DOUGHS.

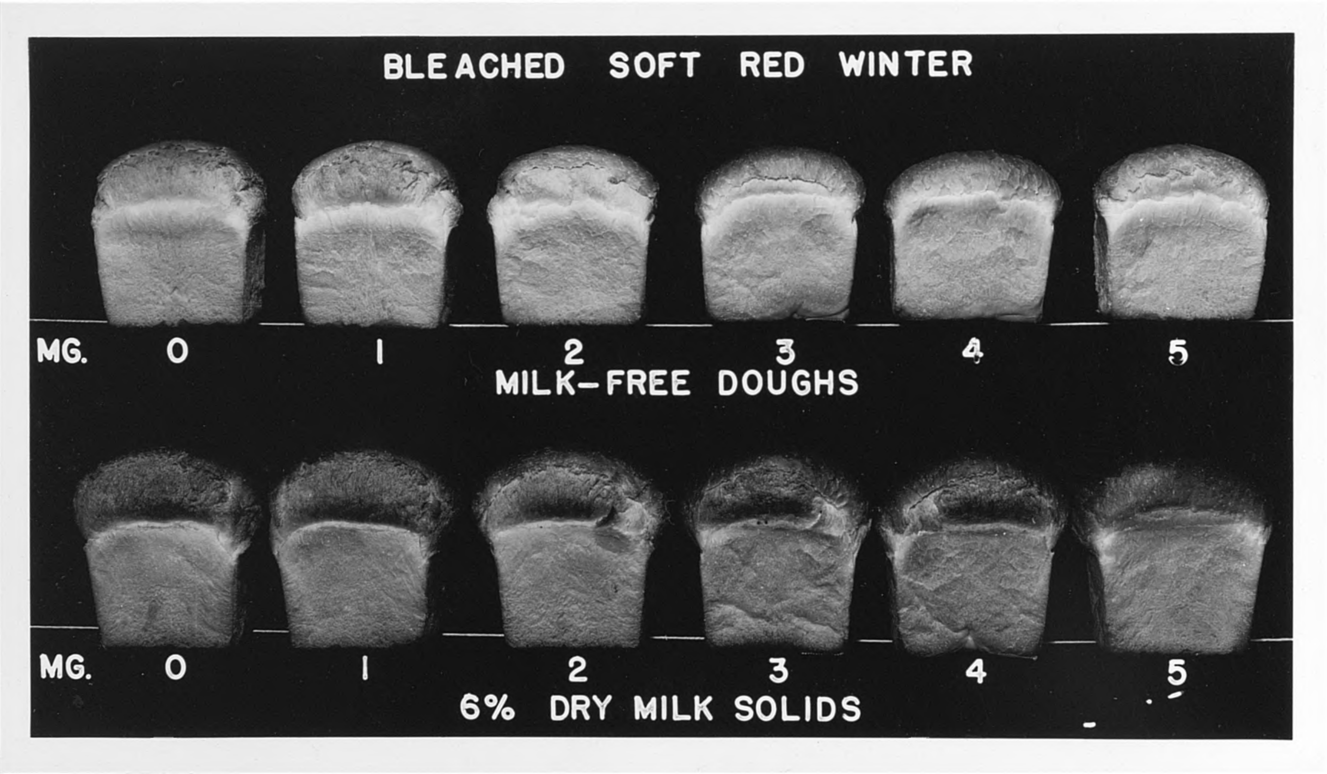

Fig. 6a. Effects of dry milk solids in relation to increments of $KBrO_3$ on loaf exterior. Bleached soft red winter wheat flour.

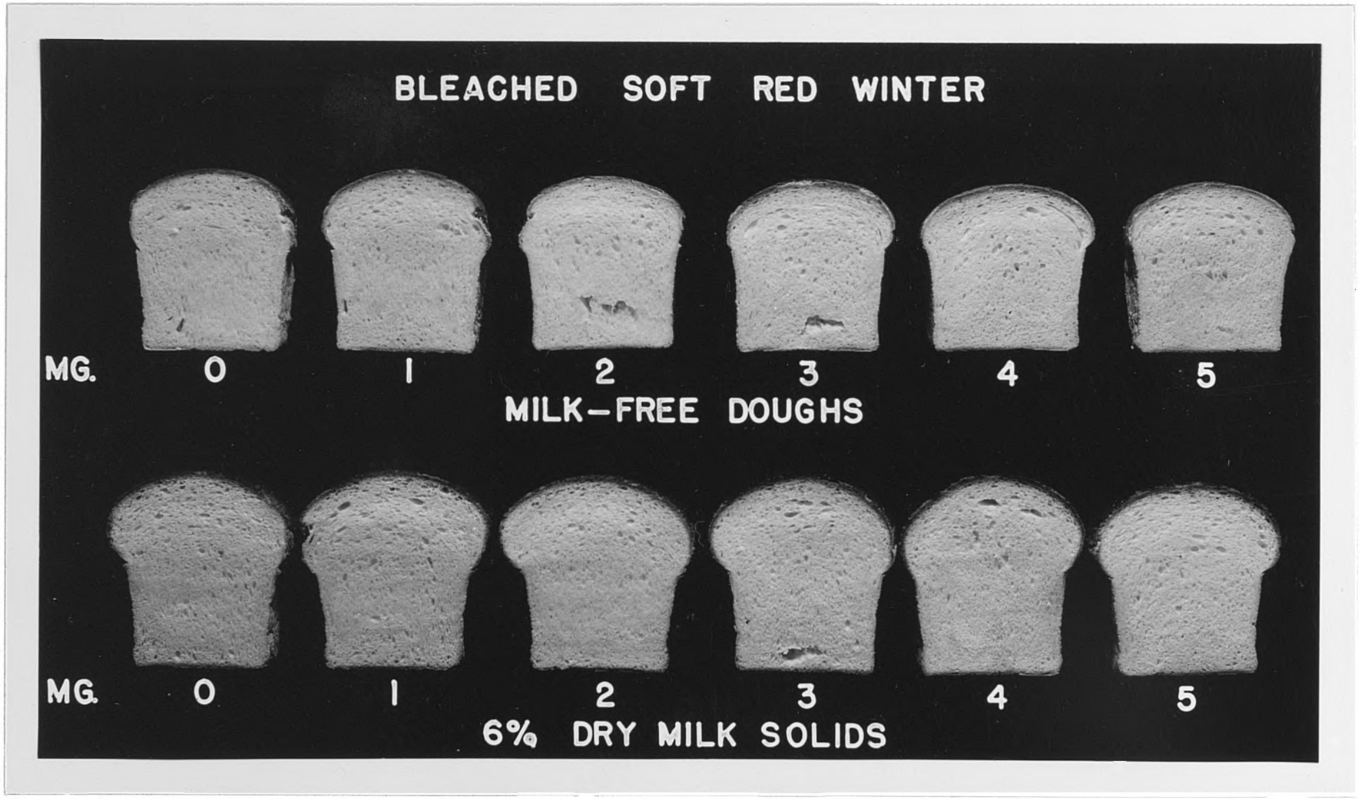

Fig. 6b. Effects of dry milk solids in relation to increments of $KBrO_3$ on loaf interior. Bleached soft red winter wheat flour.

Table 8. Baking data on a Pacific short patent flour showing the comparative effects of $KBrO_3$ on milk-free doughs and doughs containing six per cent dry milk solids (DMS).

$KBrO_3$ mg. per 100 g. flour.	Milk-free doughs		Six per cent DMS	
	Volume in cc.	Score of crumb	Volume in cc.	Score of crumb
0	490	50	580	53
1	455	45	560	49
2	463	43		
3	460	43	—[3]	
4	440	40		
5	438	40		

Table 9. Baking data on an unbleached flour from Tenmarq wheat showing the comparative effects of $KBrO_3$ on milk-free doughs and doughs containing six per cent of dry milk solids (DMS).

$KBrO_3$ mg. per 100 g. flour.	Milk-free doughs		Six per cent DMS	
	Volume in cc.	Score of crumb	Volume in cc.	Score of crumb
0	600	60	730	65
1	593	60	750	70
2	558	55	752	75
3	550	50	720	80
4	543	50	690	80
5	545	50	680	75

[3] This flour would not carry the added dry milk solids. The doughs became very slack and too sticky to handle.

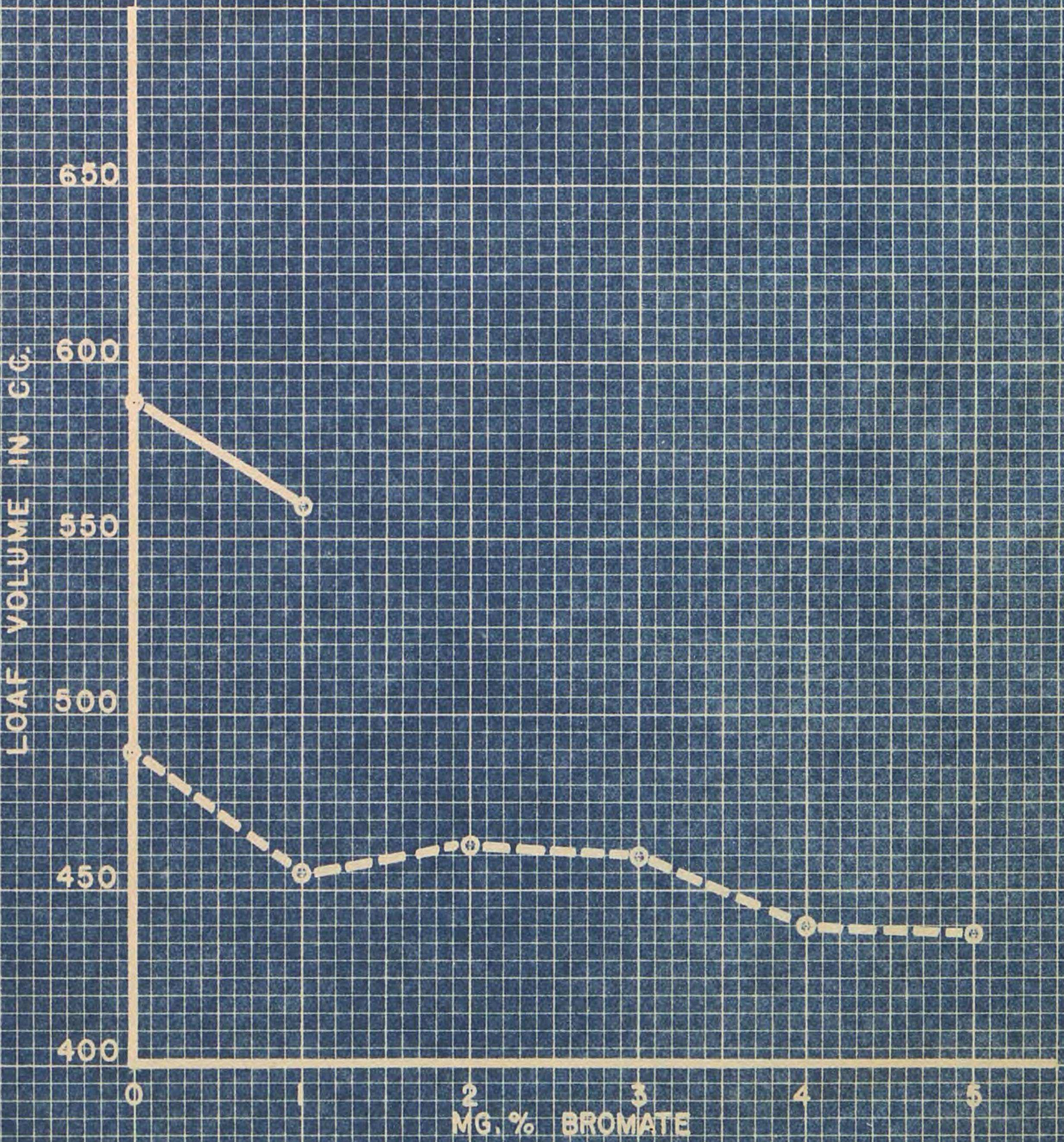

FIG. 7. EFFECT OF DRY MILK SOLIDS IN RELATION TO INCREMENTS OF BROMATE ON A BLEACHED PACIFIC SHORT PATENT FLOUR.

——— 6 % DRY MILK SOLIDS.

– – – – MILK FREE DOUGHS.

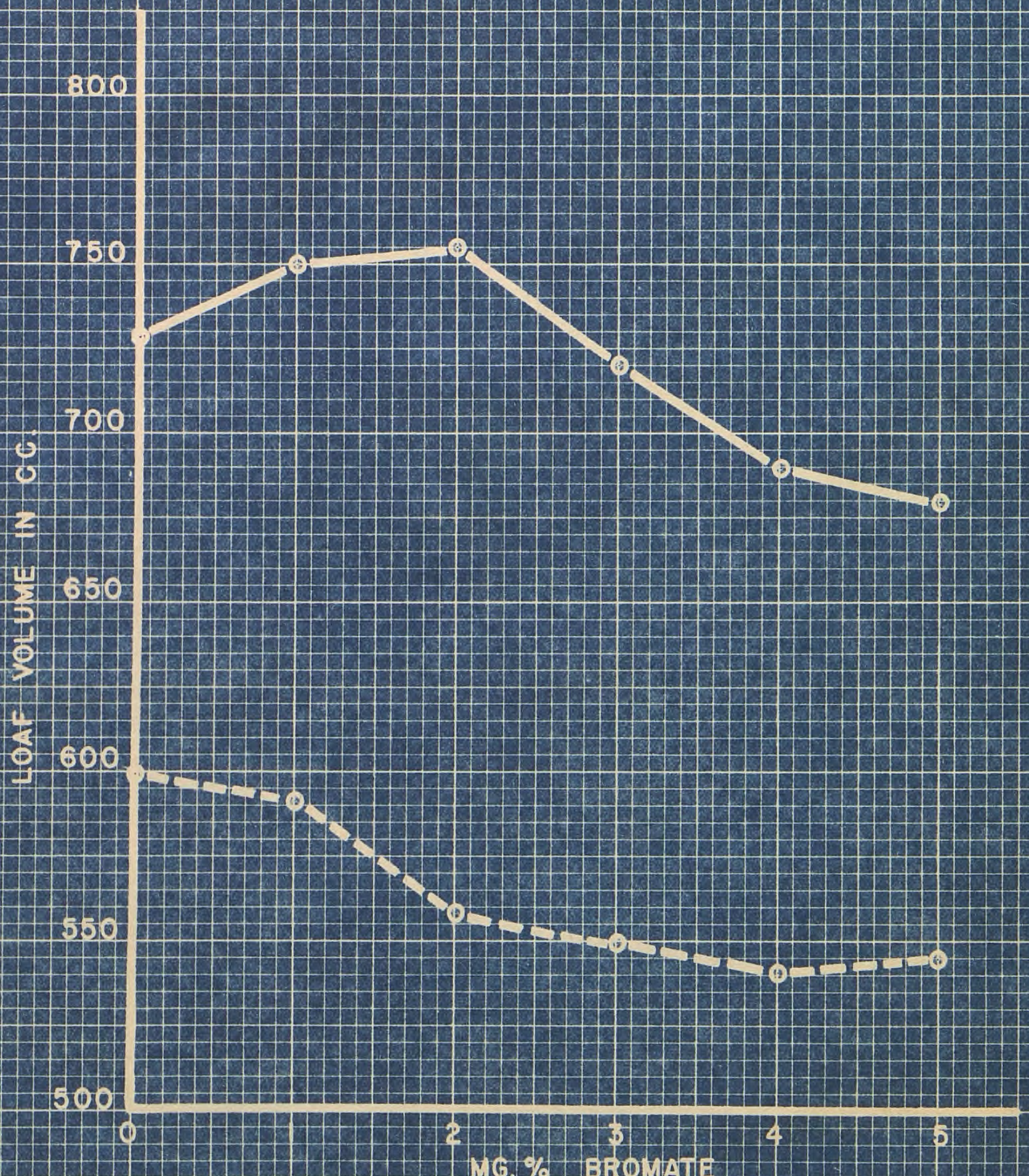

FIG. 8. EFFECT OF DRY MILK SOLIDS IN RELATION TO INCREMENTS OF BROMATE ON AN UNBLEACHED TENMARQ FLOUR.

——— 6% DRY MILK SOLIDS.

- - - - MILK FREE DOUGHS.

Fig. 8a. Effects of dry milk solids in relation to increments of $KBrO_3$ on loaf exterior. Unbleached Tenmarq flour.

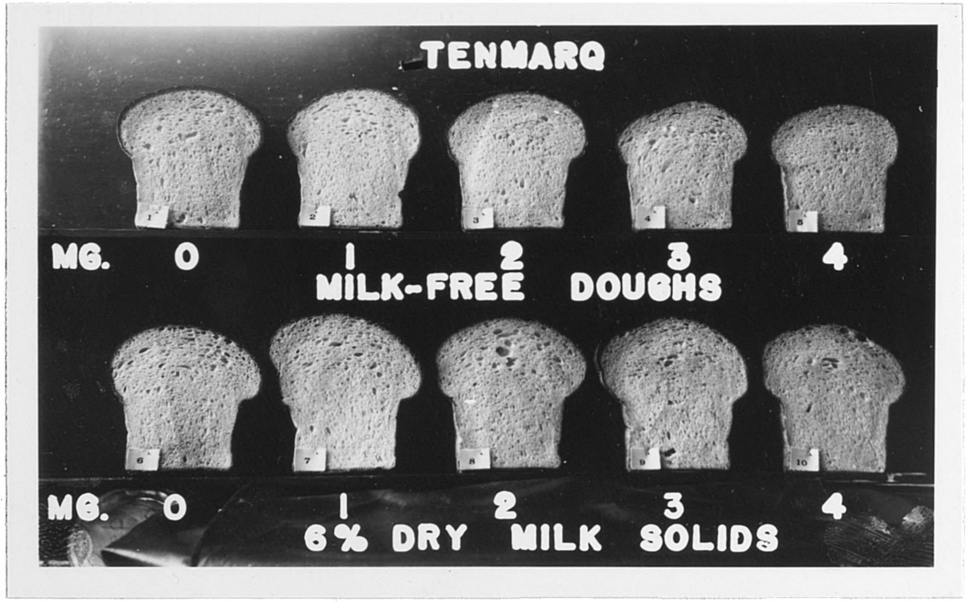

Fig. 8b. Effects of dry milk solids in relation to increments of $KBrO_3$ on loaf interior. Unbleached Tenmarq flour.

Table 10. Baking data on an unbleached flour from Chiefkan wheat showing the comparative effects of $KBrO_3$ on milk-free doughs and doughs containing six per cent added dry milk solids (DMS).

$KBrO_3$ mg. per 100 g. flour.	Milk-free doughs		Six per cent DMS	
	Volume in cc.	Score of crumb	Volume in cc.	Score of crumb
0	535	39	572	20
1	688	81	717	75
2	680	81	750	100
3	650	78	792	100
4	638	78	730	95
5			710	80

Table 11. Baking data on a 50-50 blend of unbleached flours from Chiefkan and Tenmarq wheats showing the effects of $KBrO_3$ on milk-free doughs and doughs containing six per cent added dry milk solids (DMS).

$KBrO_3$ mg. per 100 g. flour.	Milk-free doughs		Six per cent DMS	
	Volume in cc.	Score of crumb	Volume in cc.	Score of crumb
0	593	53	608	45
1	635	73	685	74
2	650	73	740	79
3	658	64	740	78
4	623	65	733	70
5	618	63	758	70

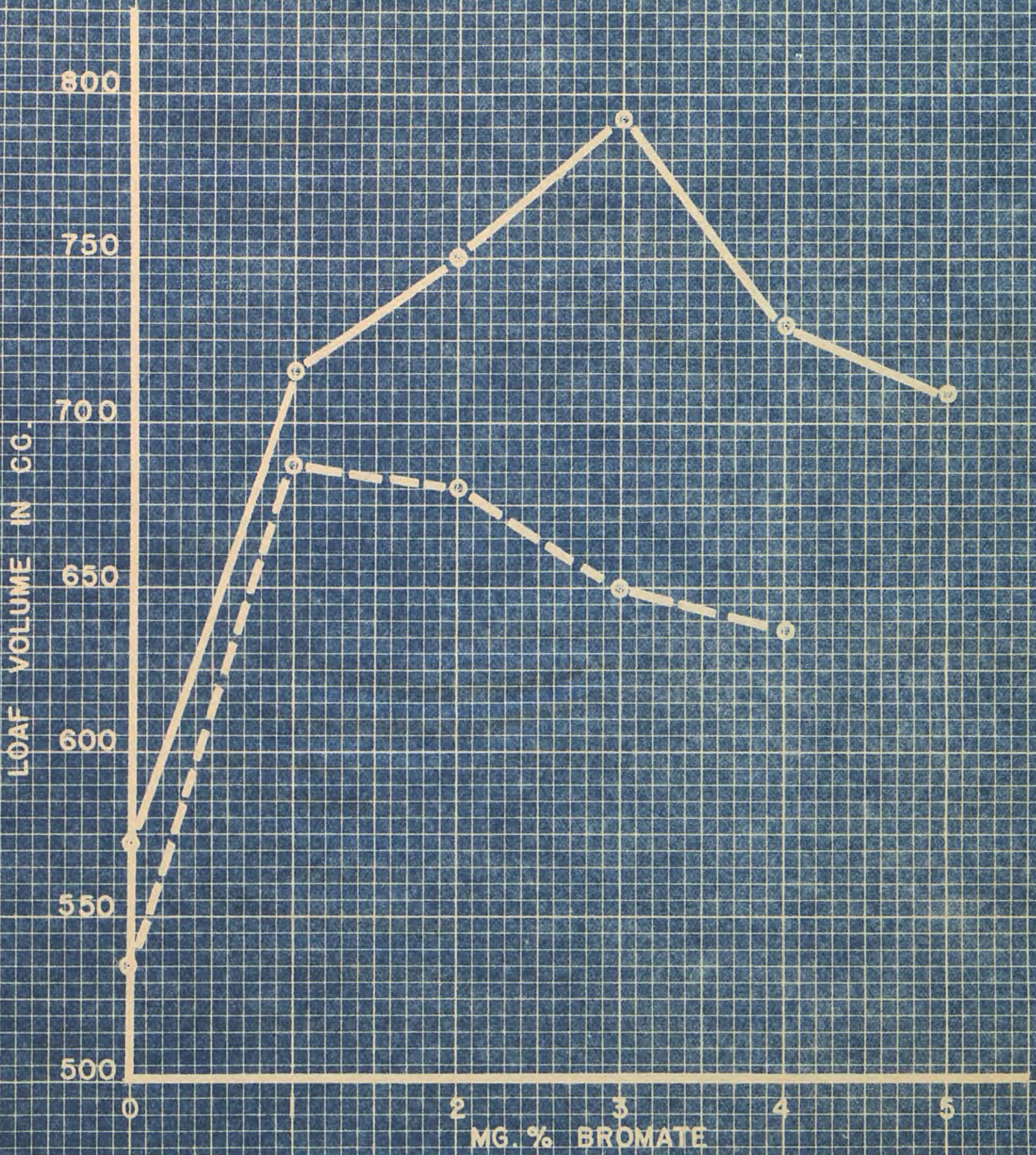

FIG. 9. EFFECT OF DRY MILK SOLIDS IN RELATION TO INCREMENTS OF BROMATE ON AN UNBLEACHED CHIEFKAN FLOUR.

——— 6% DRY MILK SOLIDS.

– – – – MILK FREE DOUGHS.

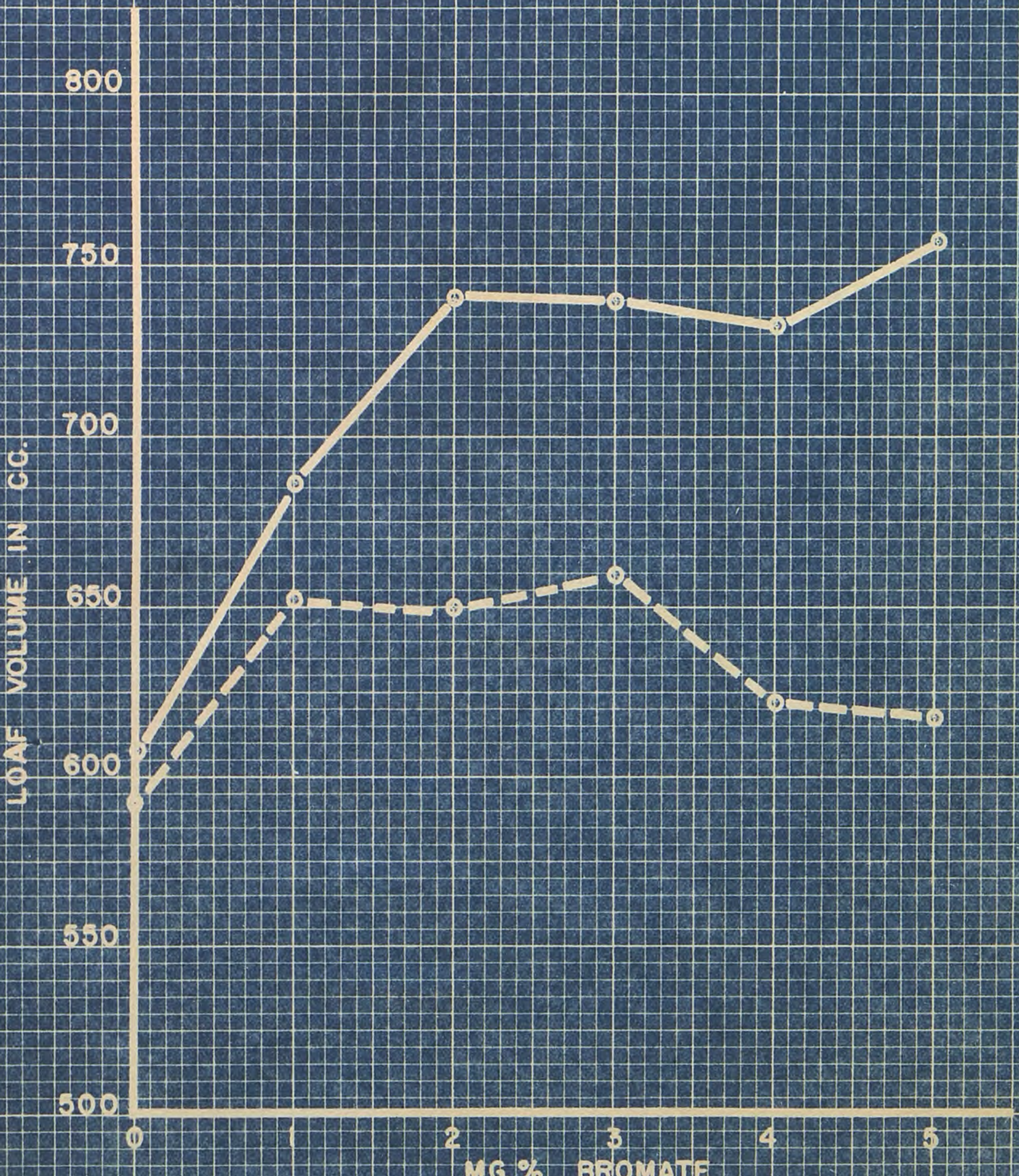

FIG. 10. EFFECT OF DRY MILK SOLIDS IN RELATION TO INCREMENTS OF BROMATE ON A BLEND OF CHIEFKAN AND TENMARQ UNBLEACHED FLOURS (50% TENMARQ- 50% CHIEFKAN).

Fig. 10a. Effects of dry milk solids in relation to increments of $KBrO_3$ on loaf exterior. 50-50 blend of unbleached Chiefkan and Tenmarq flour.

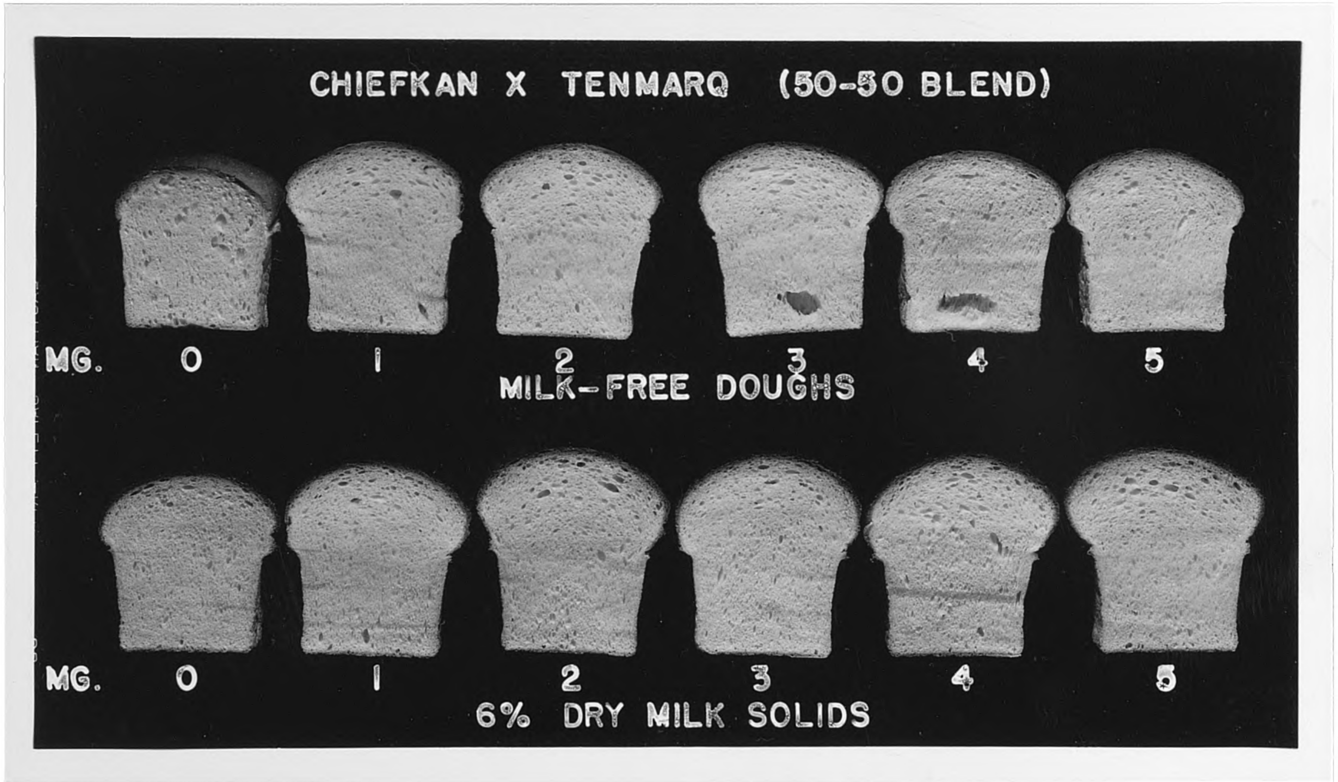

Fig. 10b. Effects of dry milk solids in relation to increments of $KBrO_3$ on loaf interior. 50-50 blend of unbleached Chiefkan and Tenmarq flour.

Table 12. Baking data on a blend of unbleached Chiefkan flour and Pacific short patent showing comparative effects of $KBrO_3$ on milk-free doughs and doughs containing six per cent dry milk solids (DMS).

$KBrO_3$ mg. per 100 g. flour.	Milk-free doughs		Six per cent DMS	
	Volume in cc.	Score of crumb	Volume in cc.	Score of crumb
0	538	63	637	60
1	565	70	680	80
2	530	68	710	80
3	523	68	725	95
4	518	65	680	90
5				75

Table 13. Baking data on a low-protein composite of unbleached flours from Turkey, Tenmarq and Blackhull wheats showing the comparative effects of $KBrO_3$ on milk-free doughs and doughs containing six per cent dry milk solids (DMS).

$KBrO_3$ mg. per 100 g. of flour.	Milk-free doughs		Six per cent DMS	
	Volume in cc.	Score of crumb	Volume in cc.	Score of crumb
0	610	68	738	75
1	655	68	770	75
2	625	63	805	73
3	603	50	808	78
4	600	55	805	77
5	555	40	770	71

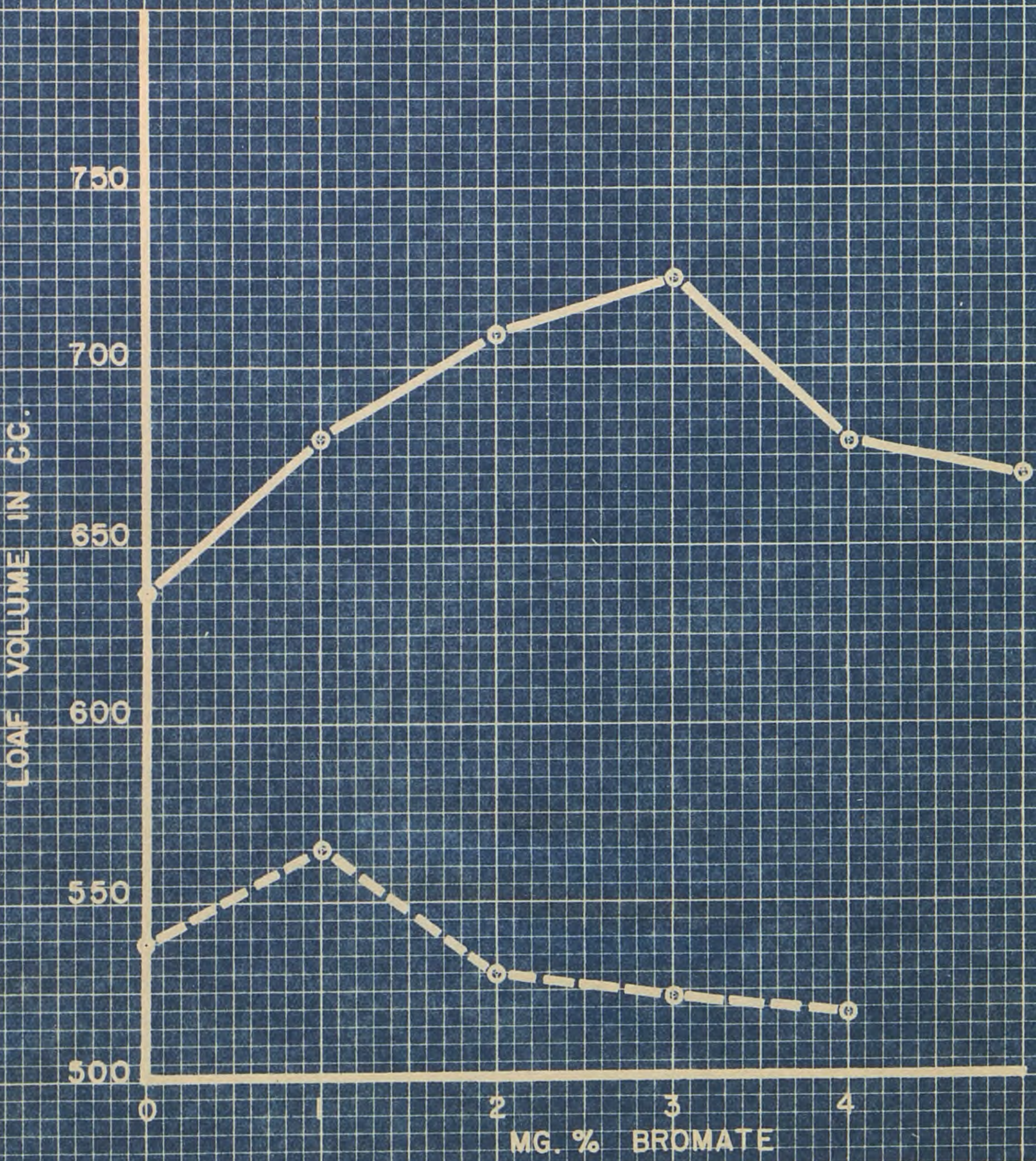

FIG. 11. EFFECT OF DRY MILK SOLIDS IN RELATION TO INCREMENTS OF BROMATE ON A 50–50 BLEND OF CHIEFKAN AND PACIFIC SHORT PATENT FLOURS.

——— 6% DRY MILK SOLIDS.

- - - - MILK FREE DOUGHS.

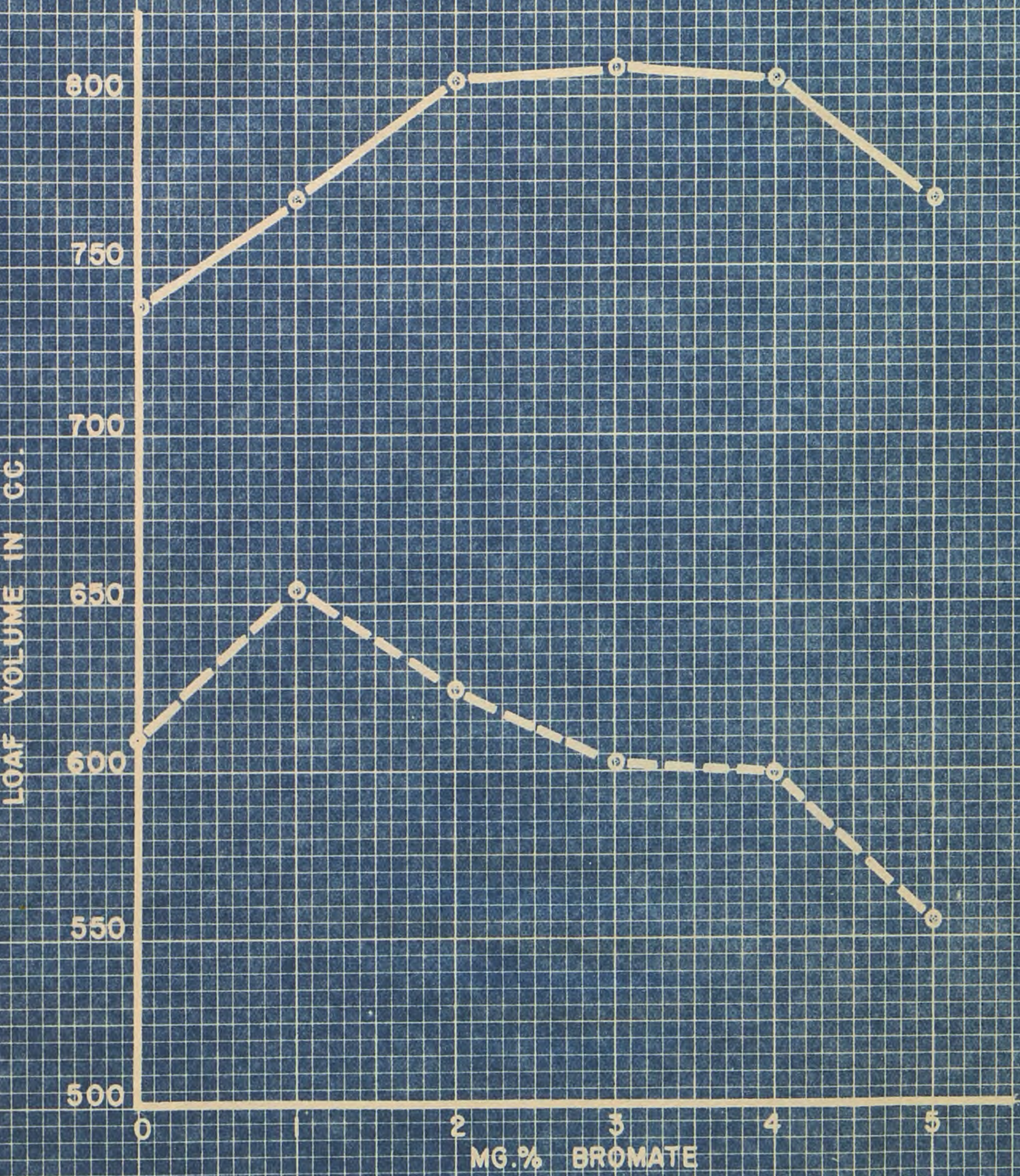

FIG. 12. EFFECT OF DRY MILK SOLIDS IN RELATION TO INCREMENTS OF BROMATE ON A LOW-PROTEIN COMPOSITE FROM UNBLEACHED EXPERIMENTALLY MILLED FLOURS.

—— 6% DRY MILK SOLIDS.

– – – MILK FREE DOUGHS.

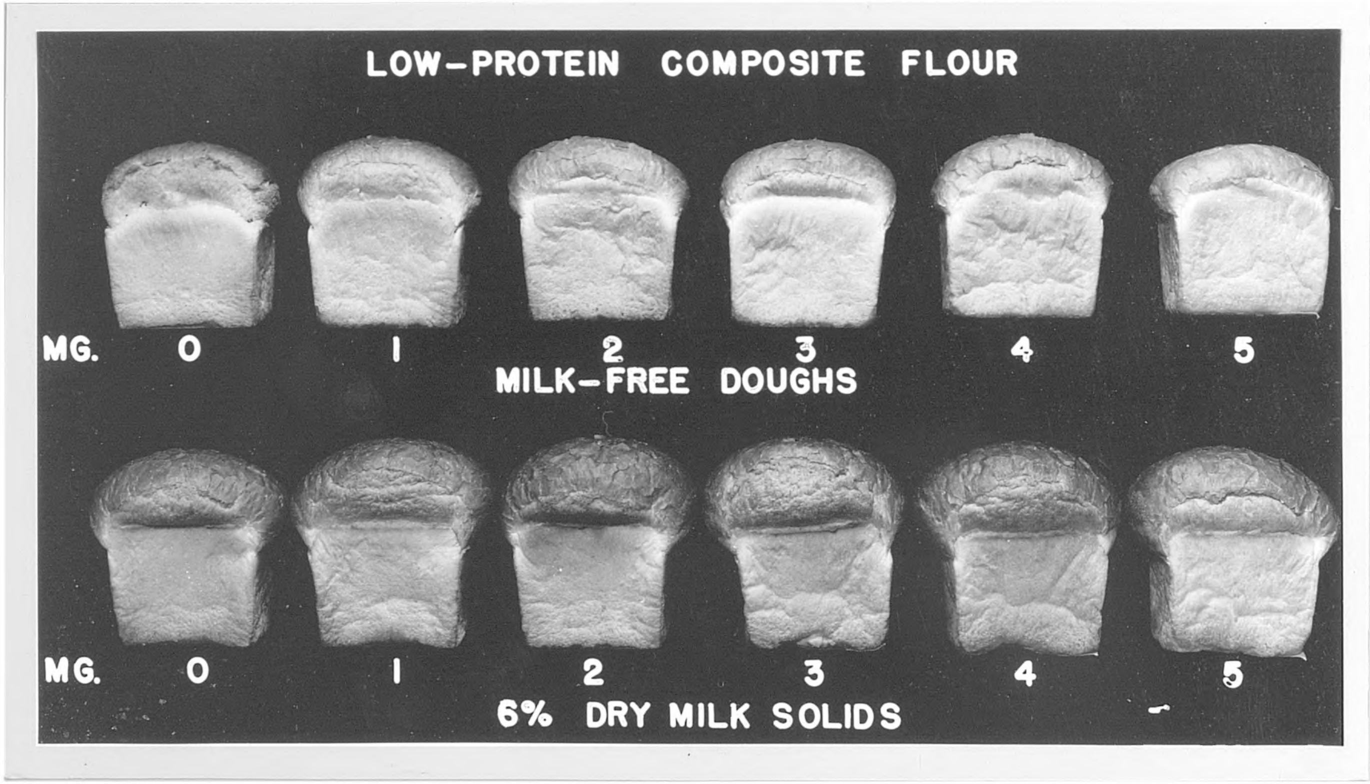

Fig. 12a. Effects of dry milk solids in relation to increments of $KBrO_3$ on loaf exterior. Unbleached experimentally milled flour from a low-protein composite of hard red winter wheats.

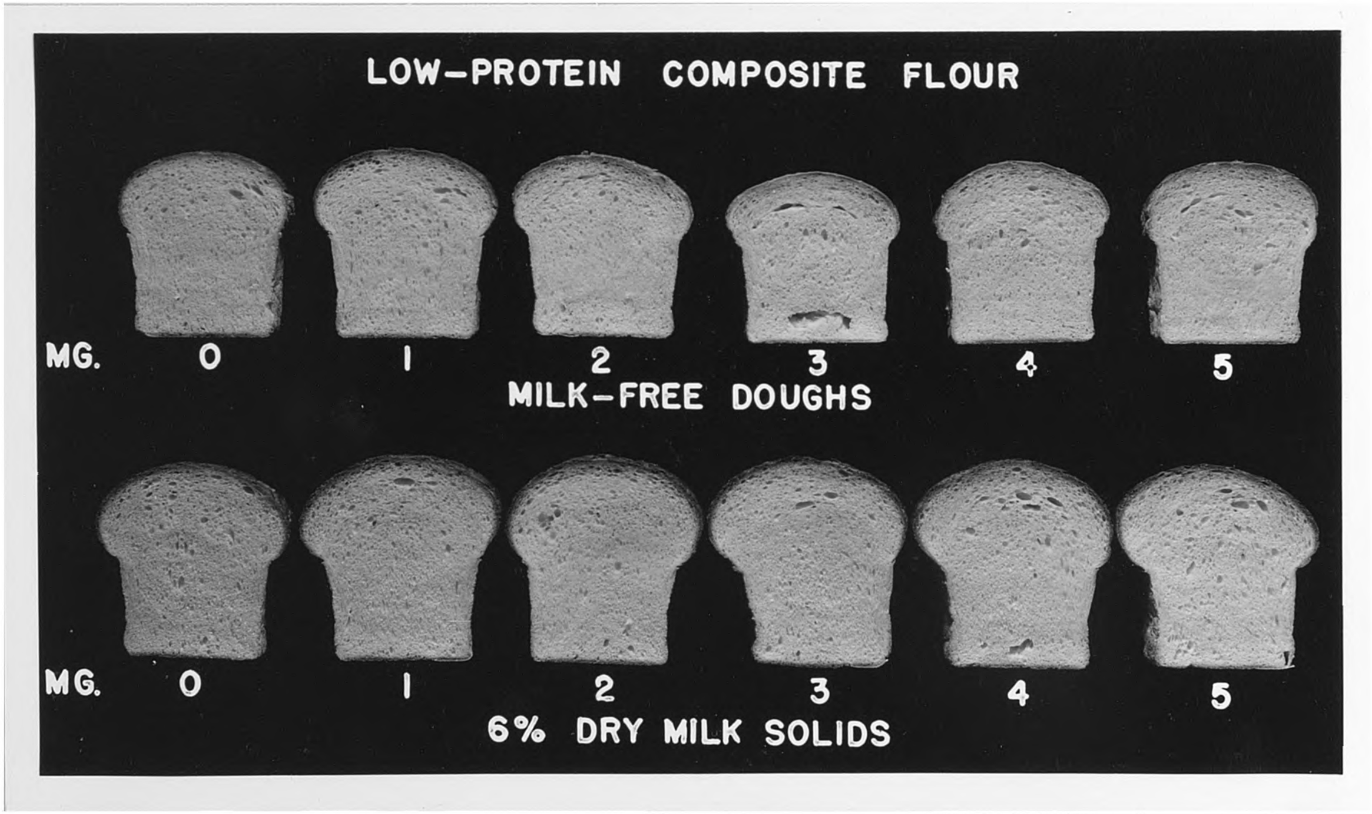

Fig. 12b. Effects of dry milk solids in relation to increments of $KBrO_3$ on loaf interior. Unbleached experimentally milled flour from a low-protein composite of hard red winter wheats.

Table 14. Baking data on a high-protein composite of unbleached flours from Turkey, Tenmarq, and Blackhull wheats showing the comparative effects of $KBrO_3$ on milk-free doughs and doughs containing six per cent dry milk solids (DMS).

$KBrO_3$ mg. per 100 g. of flour.	Milk-free doughs		Six per cent DMS	
	Volume in cc.	Score of crumb	Volume in cc.	Score of crumb
0	708	76	755	69
1	883	93	865	88
2	905	85	913	90
3	830	78	925	89
4	745	75	998	89
5	760	75	1003	89

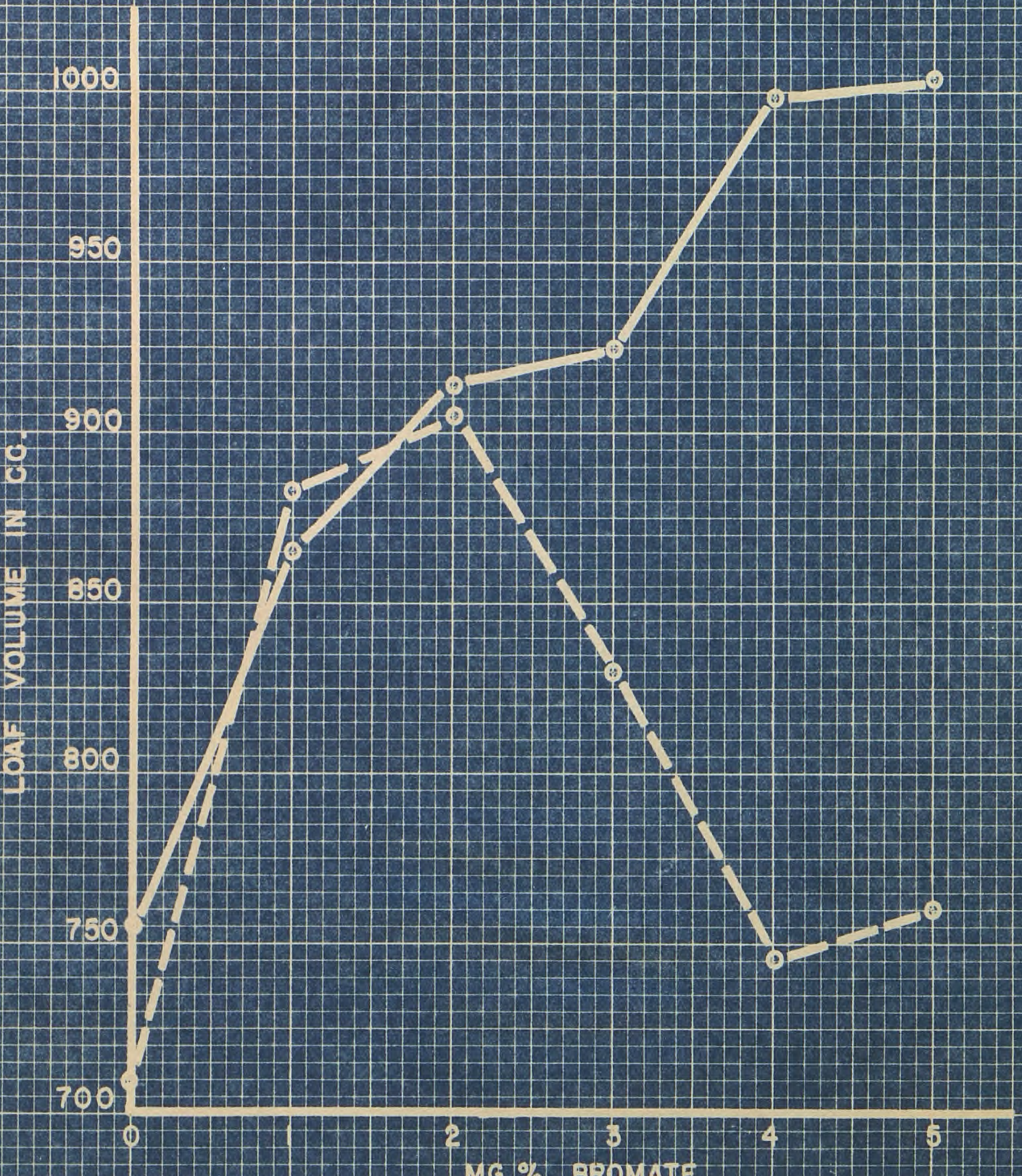

FIG. 13. EFFECT OF DRY MILK SOLIDS IN RELATION TO INCREMENTS OF BROMATE ON A HIGH-PROTEIN COMPOSITE FROM UNBLEACHED EXPERIMENTALLY MILLED FLOURS.

——— 6% DRY MILK SOLIDS.

– – – MILK FREE DOUGHS.

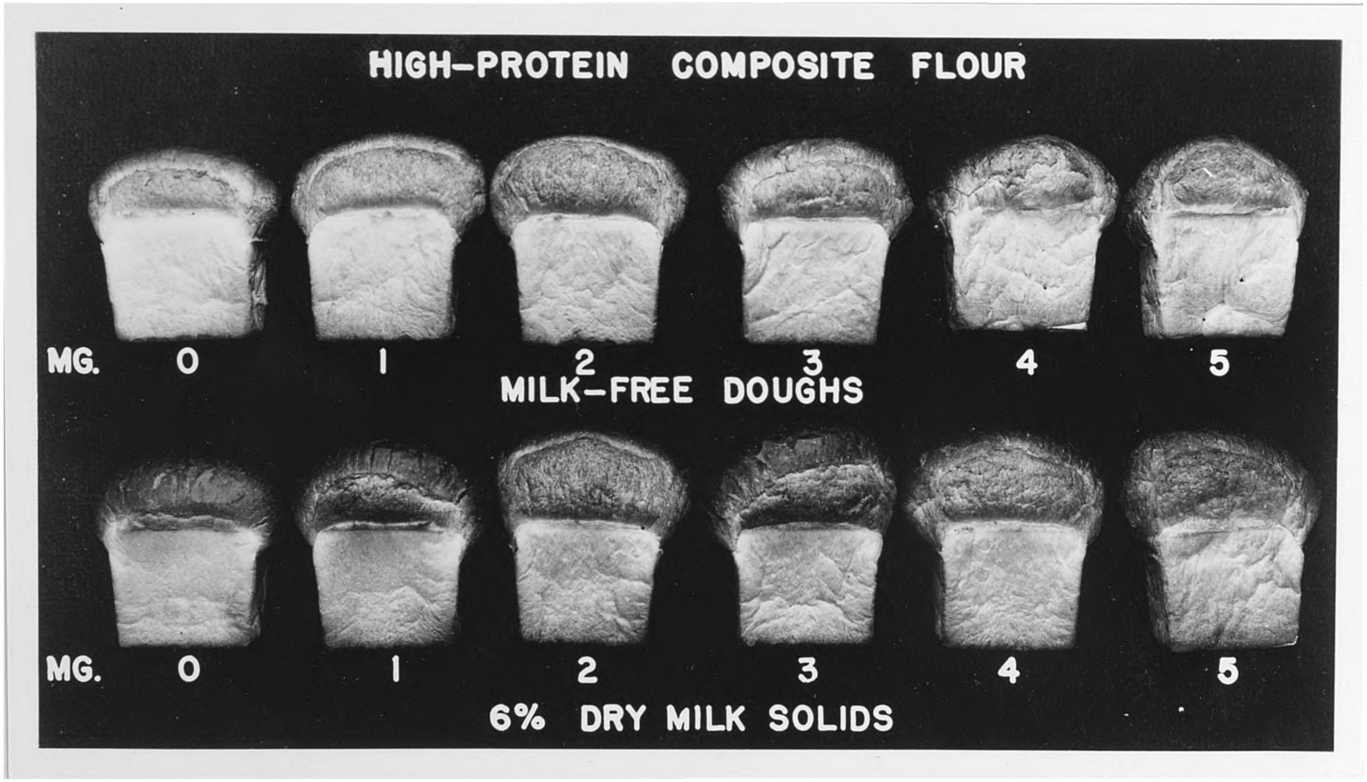

Fig. 13a. Effects of dry milk solids in relation to increments of $KBrO_3$ on loaf exterior. Unbleached experimentally milled flour from a high-protein composite of hard red winter wheats.

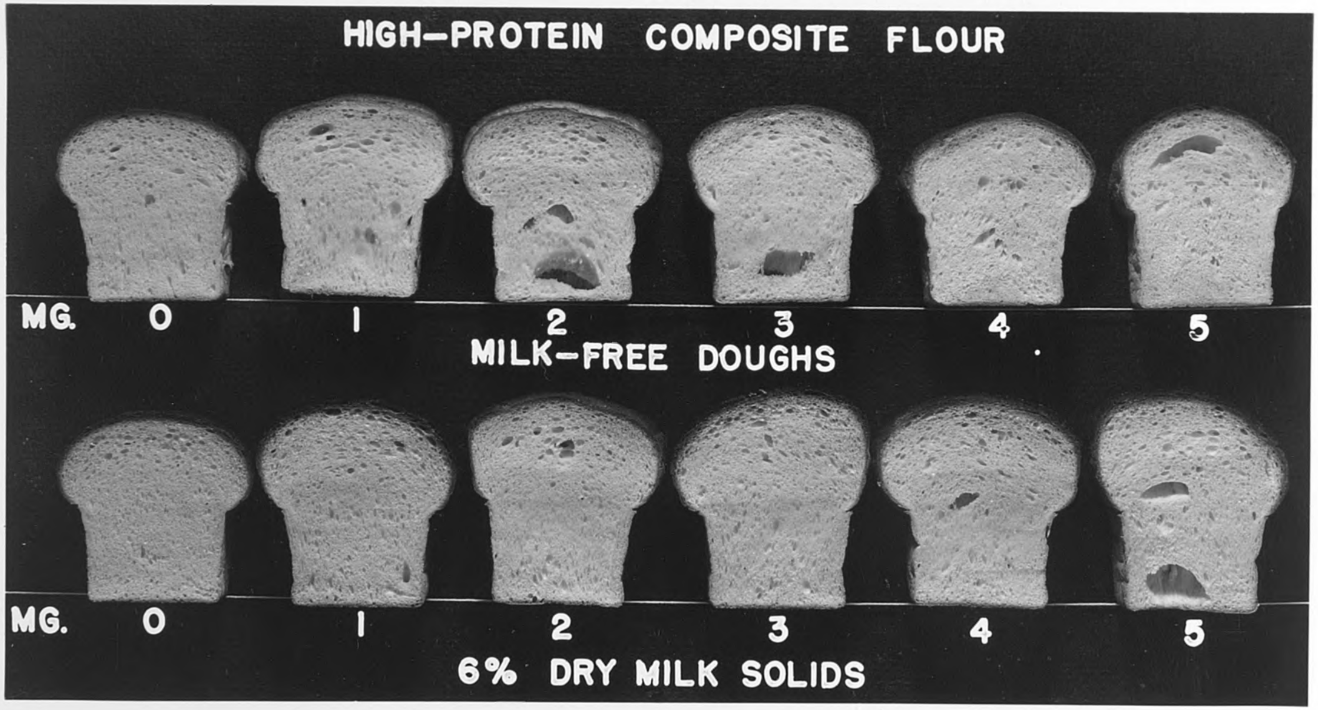

Fig. 13b. Effects of dry milk solids in relation to increments of $KBrO_3$ on loaf interior. Unbleached experimentally milled flours from a high-protein composite of hard red winter wheat.

loaf obtainable with each flour but also brings out the remarkable fact that dry milk solids conferred a high degree of tolerance toward bromate on flours which have a low natural tolerance.

The action of dry milk solids in conferring a tolerance toward bromate on a low-protein flour may be specifically exemplified by reference to Figure 12. In the milk-free doughs the optimum conditions for loaf volume were at a definite maximum at 1 mg. of bromate per 100 g. of flour and further additions of bromate caused a sharp and constant decrease in optimum loaf characteristics. With the doughs containing 6 per cent added dry milk solids, the optimum conditions were not nearly as critical with reference to bromate. The optimum loaf volume was reached at 2 mg. of bromate per 100 g. of flour and continued to retain this volume with no significant decrease through a bromate value as high as 5 mg. per 100 g. of flour. The action of added dry milk solids in relation to bromate on a high-protein flour may be specifically shown by reference to Figure 13. In this instance the milk-free doughs attained a maximum at 2 mg. of bromate per 100 g. of flour. In sharp contrast, the doughs which contained 6 per cent dry milk solids continued to increase in loaf volume up to a value of 5 mg. of bromate per 100 g. of flour. This action of bromate so strikingly demonstrated in these two figures occurred with bleached and unbleached flours, in hard spring wheat flours, hard winter wheat flours, soft winter wheat flours, and even with the Durum flour investigated. The only exception noted was the Pacific short patent flour which did not have the strength to carry the added dry milk solids. The doughs became too slack and too sticky to handle and could not be carried through the baking procedure with added dry milk solids.

It is obvious from the data given that flours which have a very definite optimum for bromate may be used with amounts of bromate varying over a wide range without injury to baking quality if dry milk solids are added. Thus enough bromate may be added to flours of unknown bromate requirement to be certain of attaining the maximum dough conditioning as the result of optimum oxidation if the flour has a high natural bromate requirement and without fear of over-oxidation if the flour has a naturally low bromate requirement.

The question arose whether this effect is attributable to the presence of dry milk solids in any quantity at random or whether there is one specific level at which this effect is greatest. As a consequence the Chiefkan flour was baked at levels of 2, 4, 6, and 8 per cent dry milk solids. The results of these bakes are given in Table 15 and in Figures 14 to 14b inclusive. The Tenmarq flour was baked at levels of 2, 4 and 6 per cent dry milk solids and the results are given in Table 16 and Figure 15. It is quite evident from a study of these data that the 6 per cent level of added dry milk solids gave the best results with the flours used. It is interesting to note that not only the volume but the interior structure of the loaf was improved and maintained its improvement over a wide range of bromate treatment. This improvement of loaf interior was apparent at all levels of dry milk solids used.

Doughs produced from Chiefkan flours have been described frequently by observers as having the characteristics of doughs produced from aged flours. It is a known fact that the baking quality of a flour, which has deteriorated from storage, may be recovered to a great extent by extraction of the aged flour with ether. It occurred to the author that the properties of Chiefkan doughs and doughs from aged flours might be attributable to a common cause. For this reason two flours, Tenmarq and Chiefkan were extracted with ether and later used in this investigation.

The two ether extracted flours were baked with 6 per cent dry milk solids and increments of bromate up to 5 mg. per 100 g. of flour. A similar series of milk-free

Table 15. Baking data on unbleached Chiefkan flour showing the effects of bromate on milk-free doughs and doughs containing varying concentrations of added dry milk solids (DMS).

$KBrO_3$ mg. per 100 g. of flour.	Milk-free doughs		Six per cent DMS		Four per cent DMS		Two per cent DMS		Eight per cent DMS
	Volume in cc.	Score of crumb	Volume in cc.	Score of crumb	Volume in cc.	Score of crumb	Volume in cc.	Score of crumb	Volume in cc.
0	535	39	572	20	580	30	575	33	545
1	688	81	717	75	625	40	618	45	615
2	680	81	750	100	660	55	653	63	665
3	650	78	792	100	688	63	683	67	705
4	638	78	730	95	720	83	710	78	747
5			710	80	733	84	730	86	727
6					697	87	670	80	730
7									728

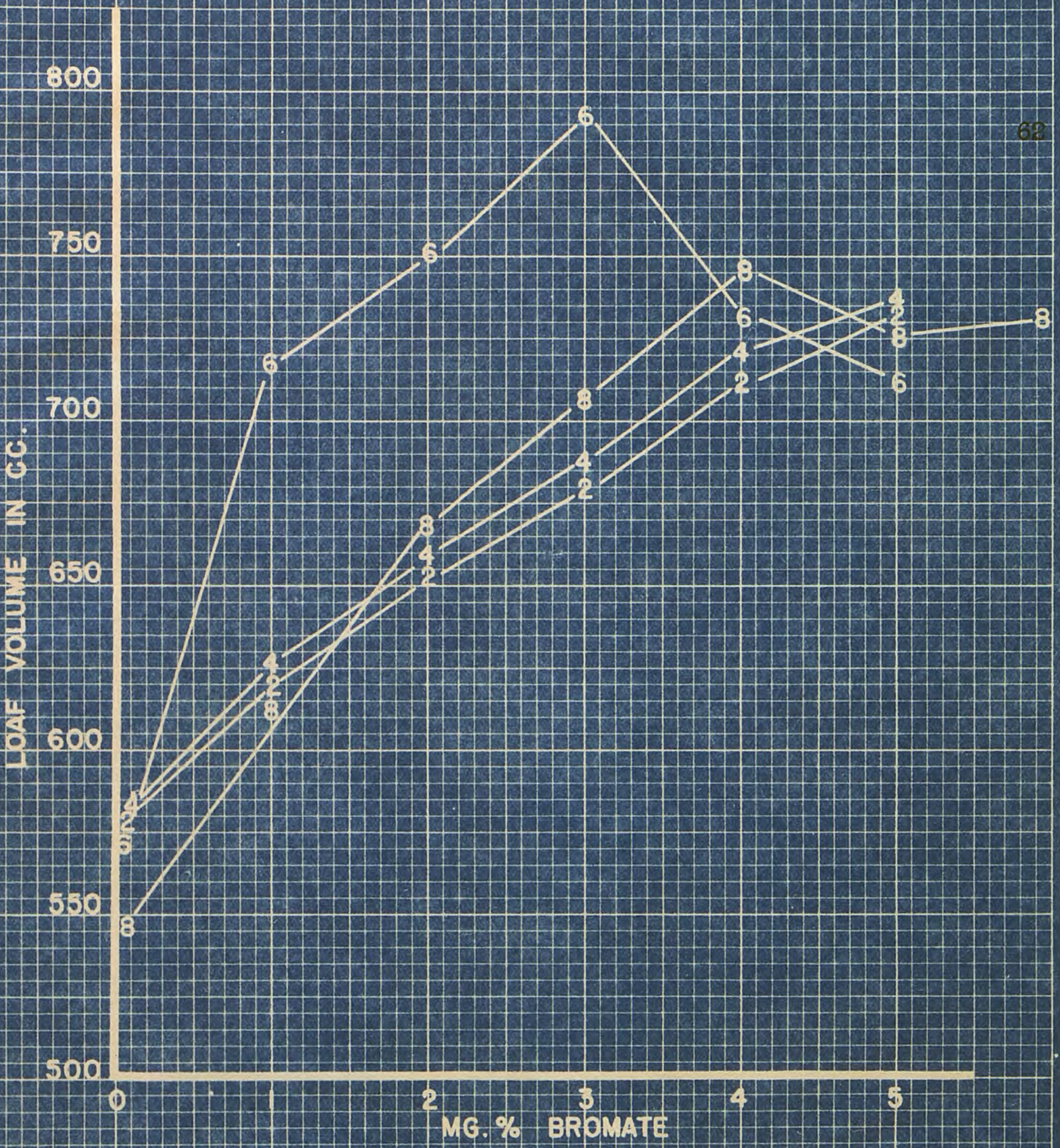

FIG. 14. EFFECTS OF VARYING CONCENTRATIONS OF DRY MILK SOLIDS IN RELATION TO INCREMENTS OF BROMATE ON AN UNBLEACHED CHIEFKAN FLOUR.

2 — 2% DRY MILK SOLIDS.

4 — 4% " " "

6 — 6% " " "

8 — 8% " " "

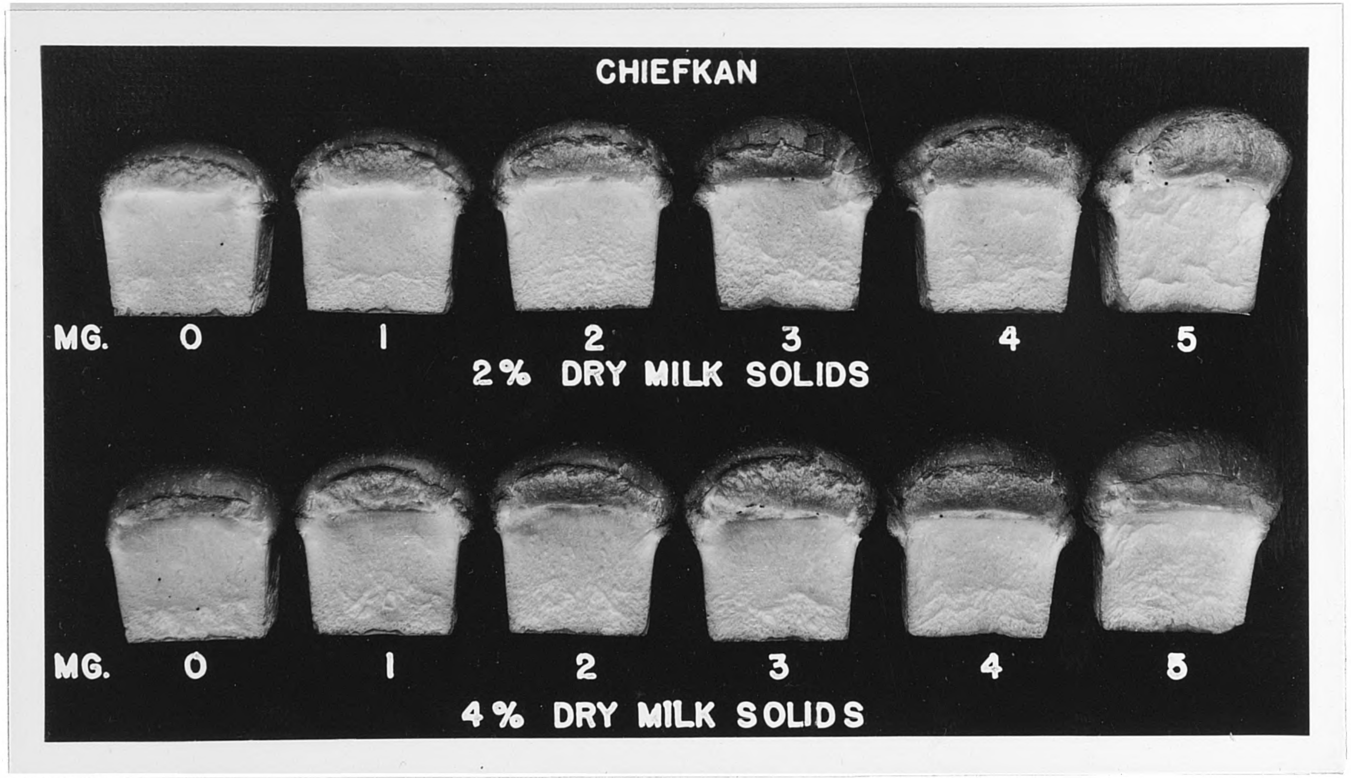

Fig. 14a. Effects of varying concentrations of dry milk solids in relation to increments of $KBrO_3$ on loaf exterior. Unbleached Chiefkan flour.

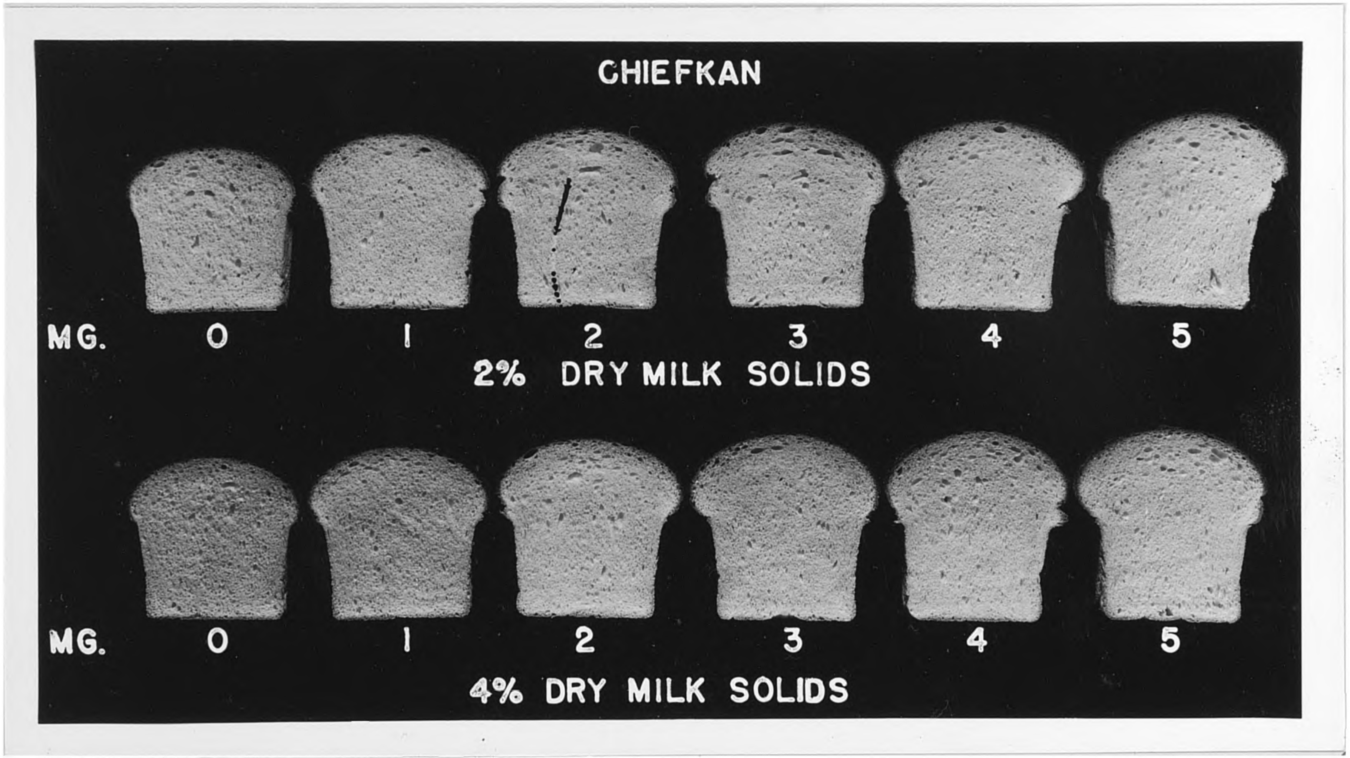

Fig. 14b. Effects of varying concentrations of dry milk solids in relation to increments of $KBrO_3$ on loaf interior. Unbleached Chiefkan flour.

Table 16. Baking data on an unbleached Tenmarq flour showing comparative effects of $KBrO_3$ on milk-free doughs and doughs containing varying concentrations of added dry milk solids (DMS).

$KBrO_3$ mg. per 100 g. of flour	Milk-free doughs		Two per cent DMS		Four per cent DMS		Six per cent DMS	
	Volume in cc.	Score of crumb	Volume in cc.	Score of crumb	Volume in cc.	Score of crumb	Volume in cc.	Score of crumb
0	600	60	628	65	683	88	730	65
1	593	60	663	75	718	95	750	70
2	558	55	665	90	710	95	752	75
3	550	50	633	65	678	83	720	80
4	543	50	615	57	625	50	690	80
5	545	50	590	55	638	50	680	75
6			612	55	630	50		

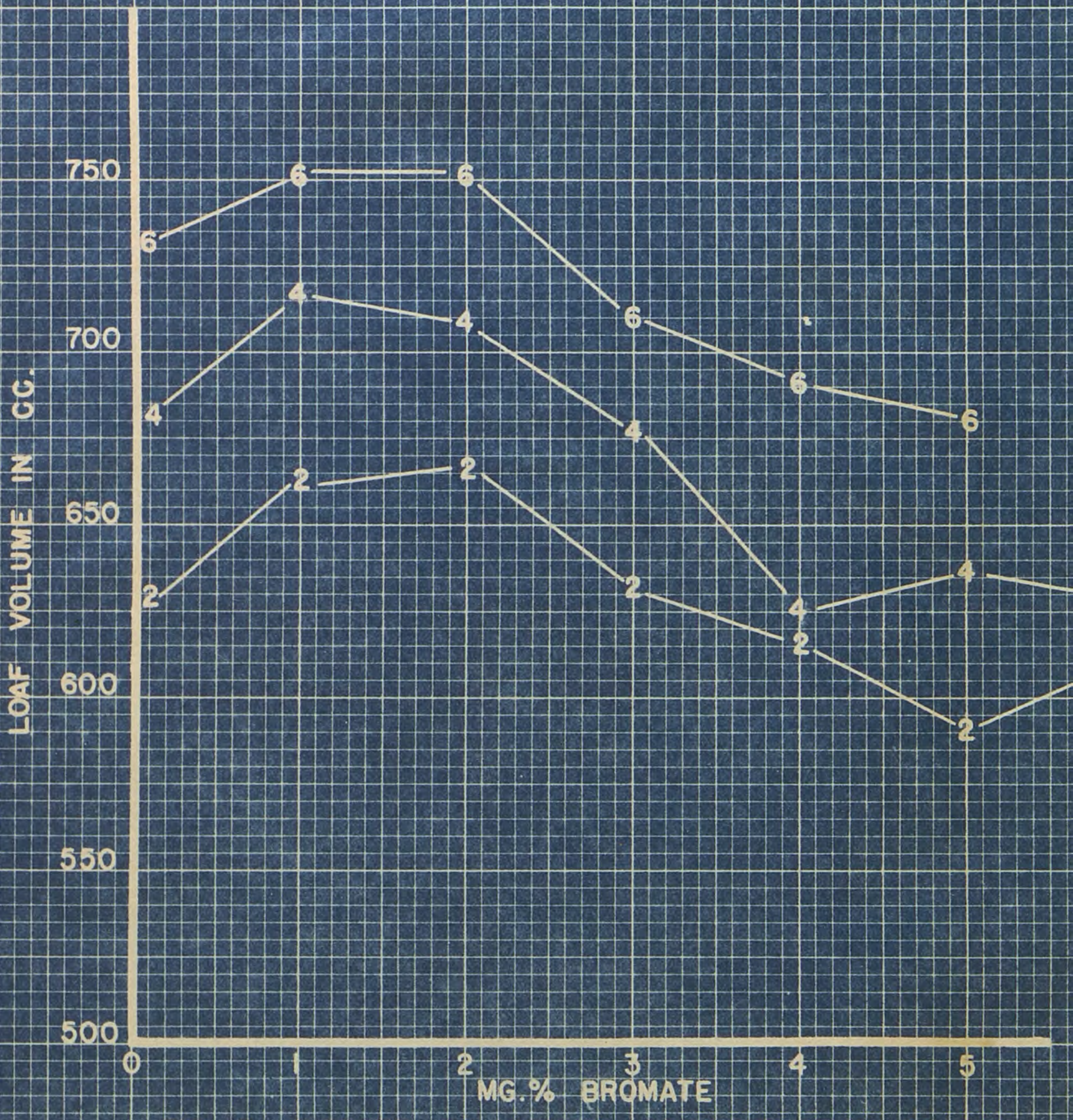

FIG. 15. EFFECTS OF VARYING CONCENTRATION OF DRY MILK SOLIDS IN RELATION TO INCREMENTS OF BROMATE ON AN UNBLEACHED TENMARQ FLOUR.

2 — 2% DRY MILK SOLIDS.
4 — 4% " " "
6 — 6% " " "

doughs was baked for comparative purposes. The results from these bakes are given in Tables 17 and 18 and in Figures 16 to 17 inclusive. Again, in the instance of the ether extracted flours, the loaf volumes of the loaves containing added dry milk solids were greater than those of the milk-free doughs. The loaf volumes of the extracted flours were much less than those of the normal flours. The volumes of the dry milk loaves from the extracted flours, at optimum conditions, were approximately the same as the milk-free doughs of the normal flours. With the Chiefkan the optimum bromate level in the milk-free doughs shifted from 1 mg. in the normal flour to an optimum at 2 mg. with the extracted flour. With the dry milk solids doughs the optimum bromate level dropped from 3 mg. in the normal flour to 2 mg. in the ether extracted flour. There were no appreciable shifts in optimum bromate level as a result of extraction of the Tenmarq flour.

Cysteine has been described as an activator of the proteases in flour doughs in direct contrast to the action ascribed to bromate. Because the Tenmarq flour showed optimum loaf volume at zero bromate level in the milk-free doughs it was decided to determine whether cysteine might affect further improvement. For this reason two flours, the Tenmarq flour and the Chiefkan, were investigated. The Chiefkan and Tenmarq flours were baked with 6 per cent

Table 17. Baking data on an ether-extracted unbleached Tenmarq flour showing the comparative effects of $KBrO_3$ on milk-free doughs and doughs containing six per cent dry milk solids (DMS).

$KBrO_3$ mg. per 100 g. of flour.	Milk-free doughs		Six per cent DMS	
	Volume in cc.	Score of crumb	Volume in cc.	Score of crumb
0	495	50	615	70
1	490	50	605	68
2	480	50	605	70
3	475	50	550[4]	70
4	473	48	613	73
5	480	48	625	70

Table 18. Baking data on an ether-extracted unbleached Chiefkan flour showing the comparative effects of $KBrO_3$ on milk-free doughs and doughs containing six per cent dry milk solids (DMS).

$KBrO_3$ mg. per 100 g. of flour.	Milk-free doughs		Six per cent DMS	
	Volume in cc.	Score of crumb	Volume in cc.	Score of crumb
0	503	45	555	59
1	595	75	658	75
2	618	73	695	75
3	598	63	680	75
4	538	63	680	73

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[4] This sample received improper treatment in the molding equipment.

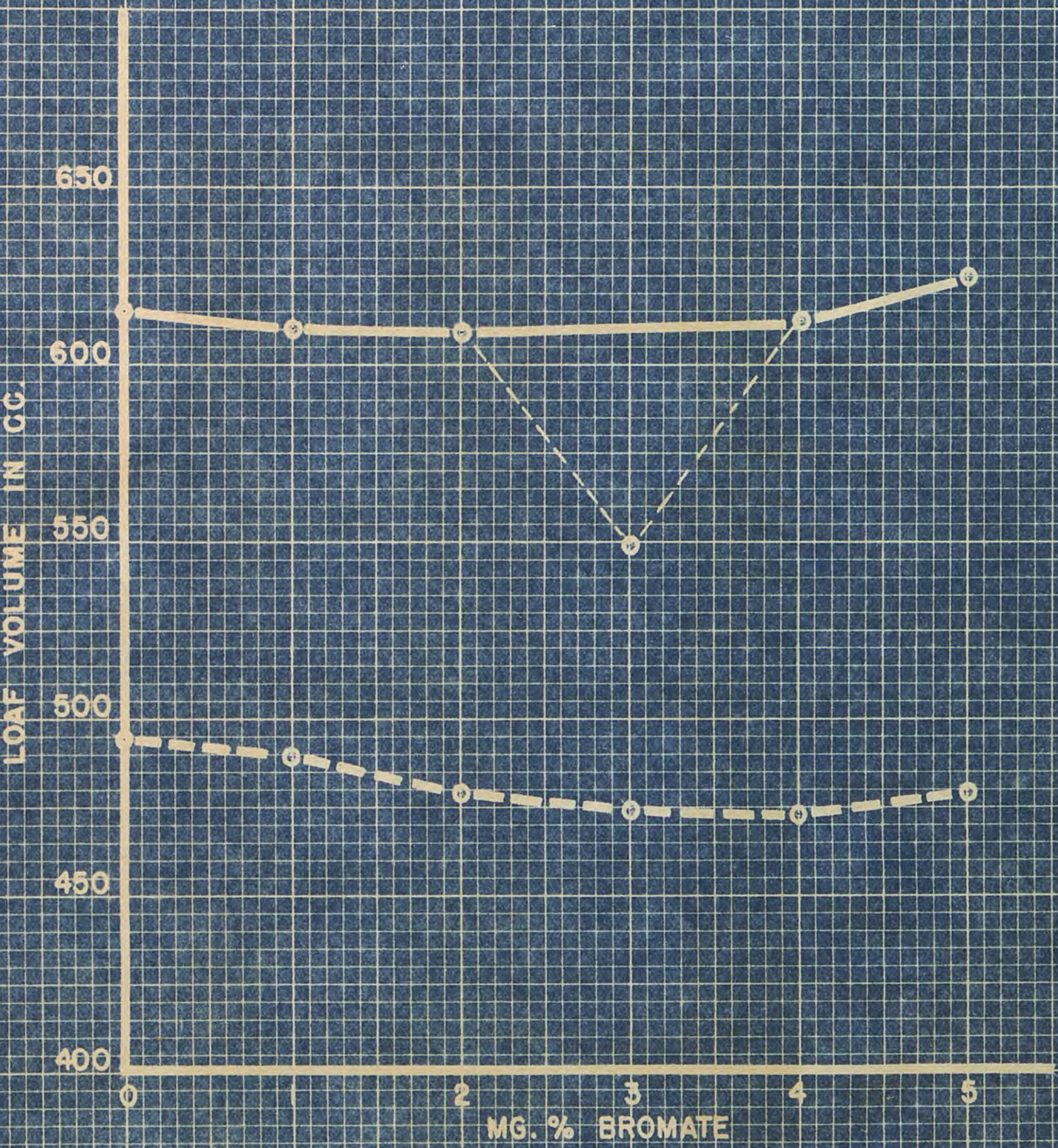

FIG. 16. EFFECT OF DRY MILK SOLIDS IN RELATION TO INCREMENTS OF BROMATE ON AN ETHER-EXTRACTED TENMARQ FLOUR.

——— 6% DRY MILK SOLIDS.

– – – MILK FREE DOUGHS.

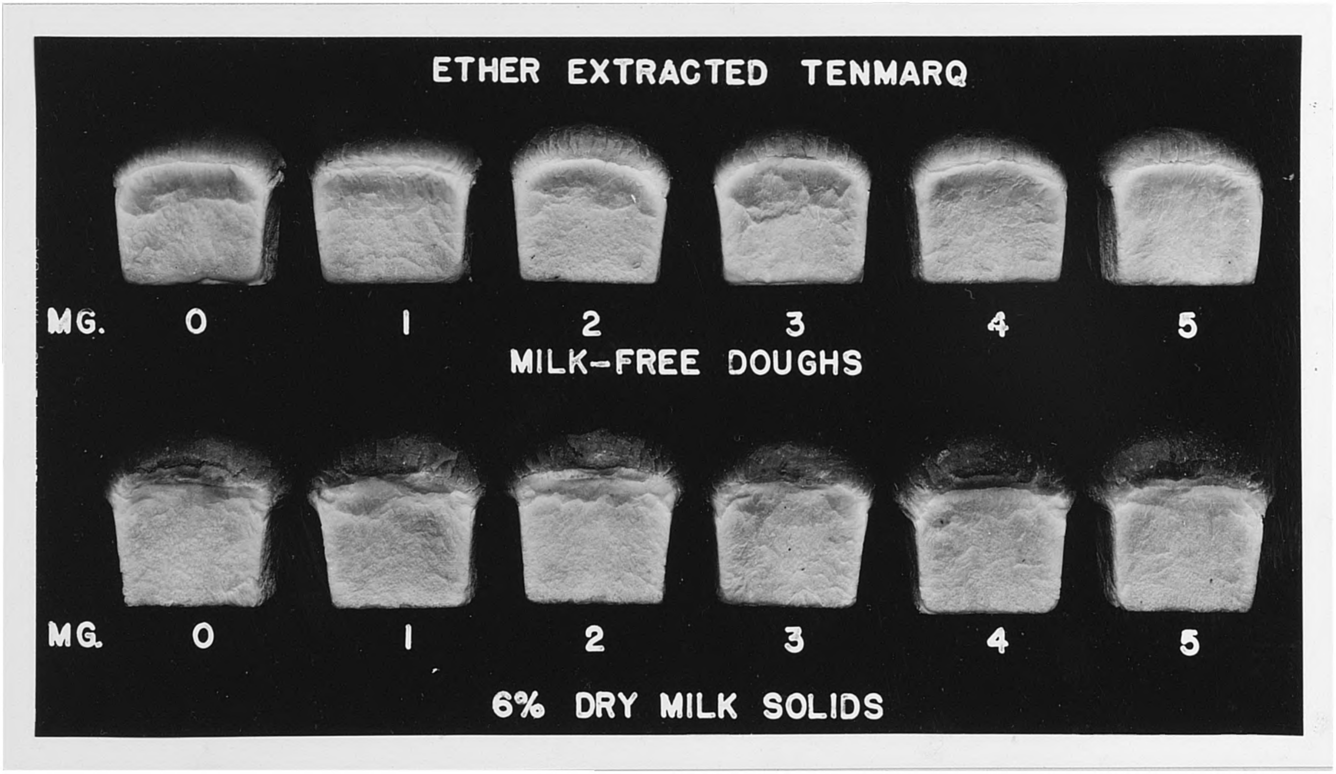

Fig. 16a. Effects of dry milk solids in relation to increments of $KBrO_3$ on loaf exterior. Ether-extracted unbleached Tenmarq flour.

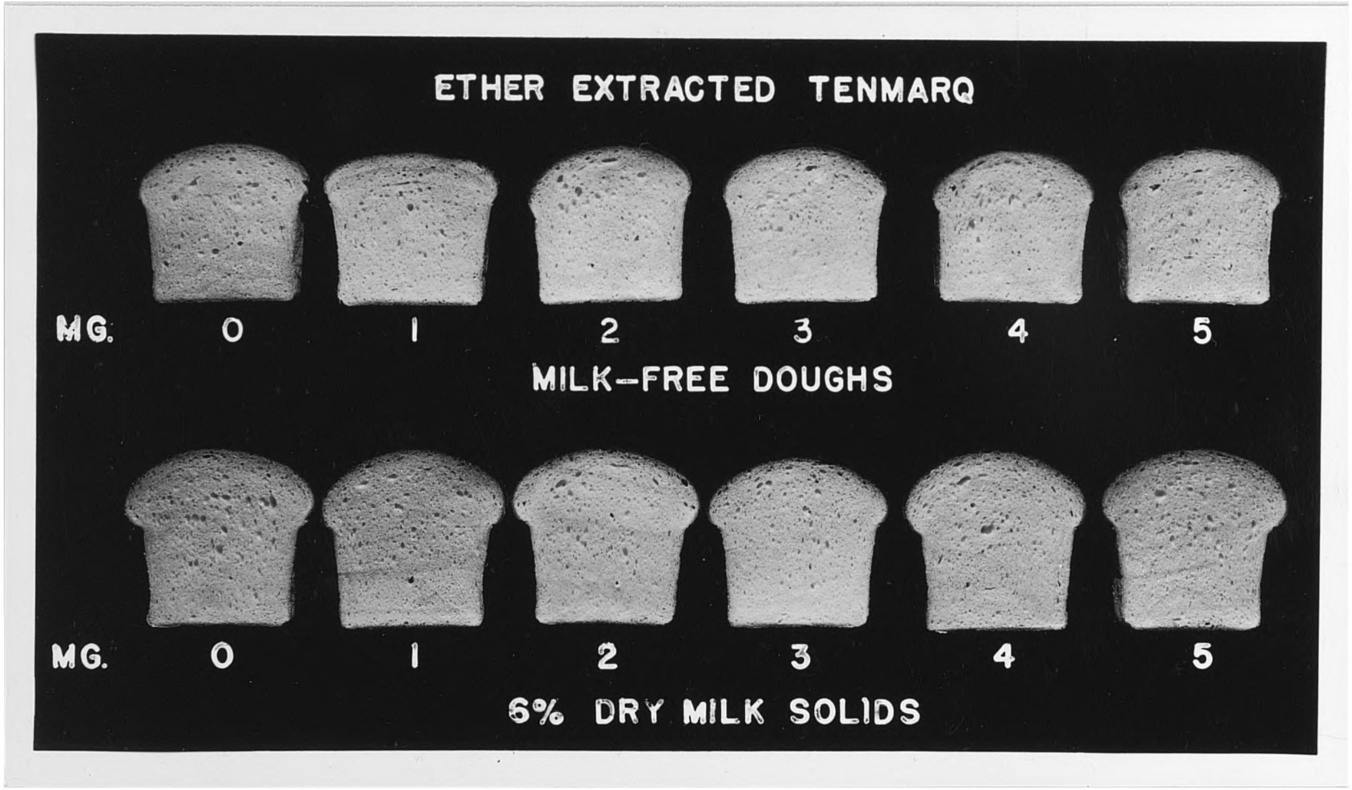

Fig. 16b. Effects of dry milk solids in relation to increments of $KBrO_3$ on loaf interior. Ether-extracted unbleached Tenmarq flour.

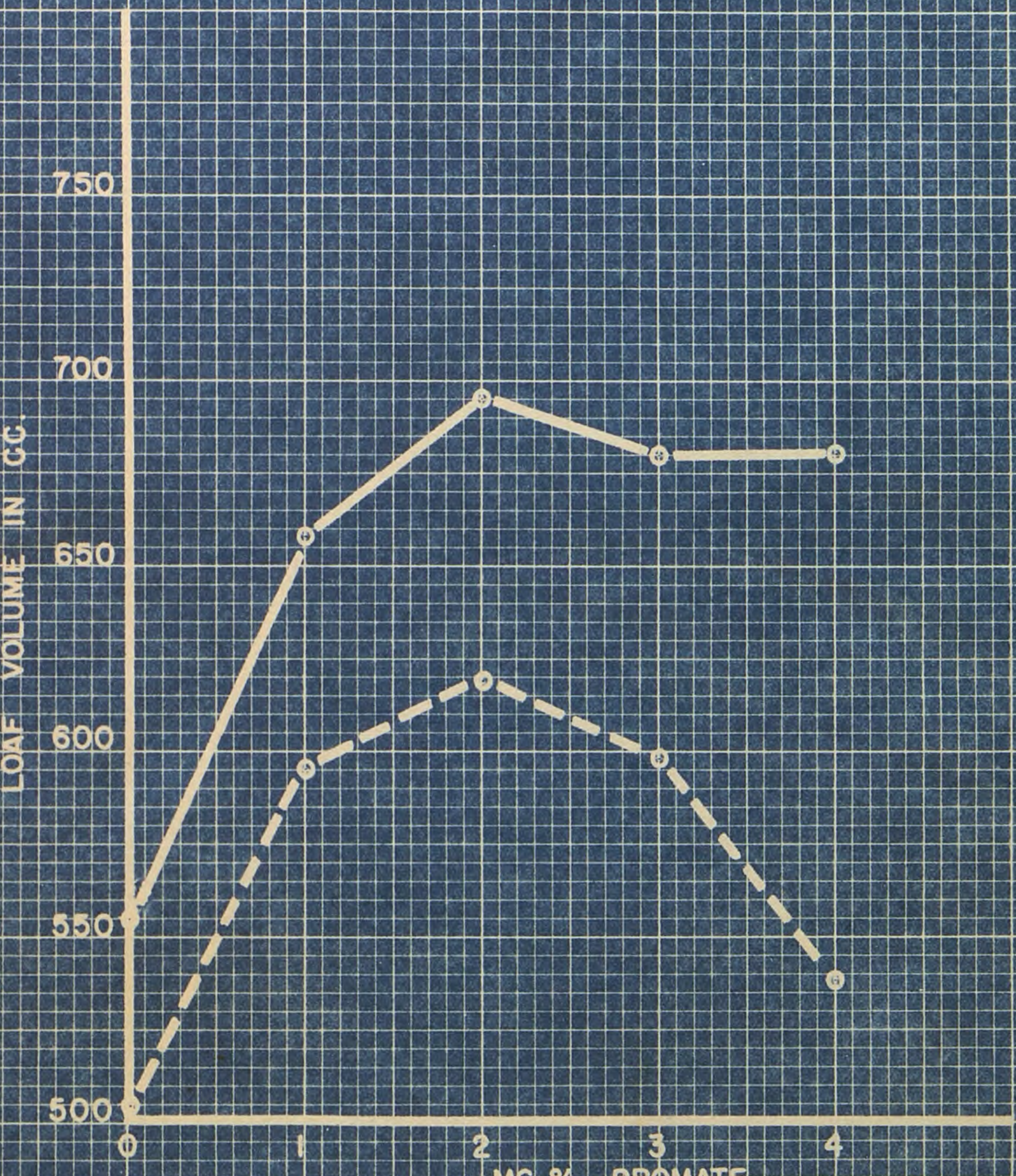

FIG. 17. EFFECT OF DRY MILK SOLIDS IN RELATION TO INCREMENTS OF BROMATE ON AN ETHER-EXTRACTED UNBLEACHED CHIEFKAN FLOUR.

——— 6% DRY MILK SOLIDS.

– – – MILK FREE DOUGHS.

added dry milk solids and increments of 1 and 5 mg. of cysteine monohydrochloride. A similar series was baked using milk-free doughs. The results were approximately the same with the 1 mg. additions of cysteine as with the 5 mg. additions. The results of these bakes are presented in Table 19 and Figures 18 and 18a. With both the Tenmarq and Chiefkan flours the milk-free doughs gave approximately the same results as the normal flours. The addition of dry milk solids caused a decided increase in the volume with the Tenmarq and practically no increase with the Chiefkan. This can be attributed to the fact that the optimum oxidation requirement of the Tenmarq was naturally much lower than that of the Chiefkan and consequently the Tenmarq was baked at conditions much nearer the optimum than was the Chiefkan. When dry milk solids are added to a flour of high oxidation requirement and no bromate is added the results are likely to be detrimental rather than beneficial. The addition of cysteine caused the doughs to be sticky at the time of mixing and lessened the mixing time required to attain smoothness. The addition of 1 mg. of cysteine monohydrochloride shortened the mixing time less than the addition of 5 mg.

There appears to be no record in the literature of any work upon a determination of the fundamental mechanism of the action of dry milk solids in doughs. Any attempt to

Table 19. Baking data on unbleached Tenmarq and Chiefkan flours showing the comparative effects of varying concentrations of cysteine monohydrochloride on milk-free doughs and doughs containing six per cent dry milk solids (DMS) as contrasted with a control.

Flour	Treatment per 100 g. flour	Milk-free doughs		Six per cent DMS	
		Volume in cc.	Score of crumb	Volume in cc.	Score of crumb
Tenmarq	Control (2 mg. $KBrO_3$)			730	78
	1 mg. cysteine monohydrochloride	608	78	695	85
	5 mg. cysteine monohydrochloride	598	78	678	88
Chiefkan	1 mg. cysteine monohydrochloride	535	46	538	33
	5 mg. cysteine monohydrochloride	538	46	543	33

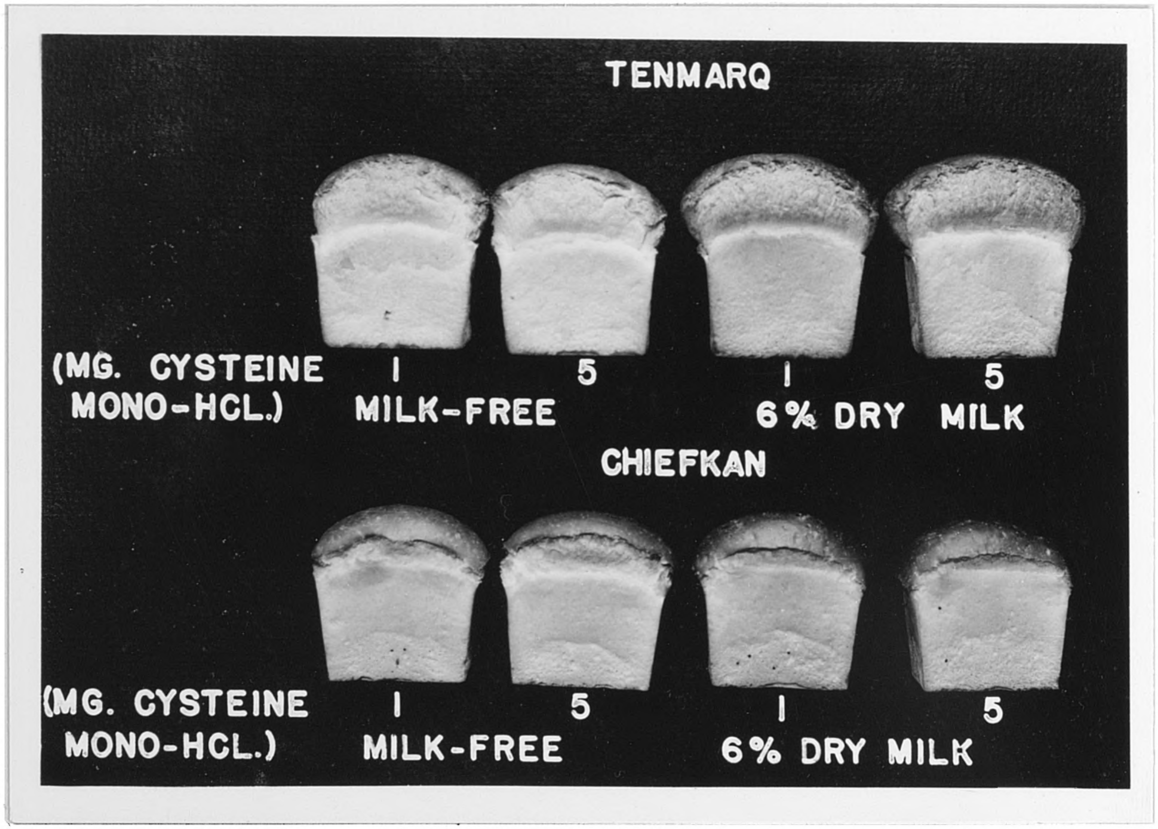

Fig. 18. Effect of dry milk solids in relation to increments of cysteine on loaf exterior. Unbleached Chiefkan and Tenmarq flours.

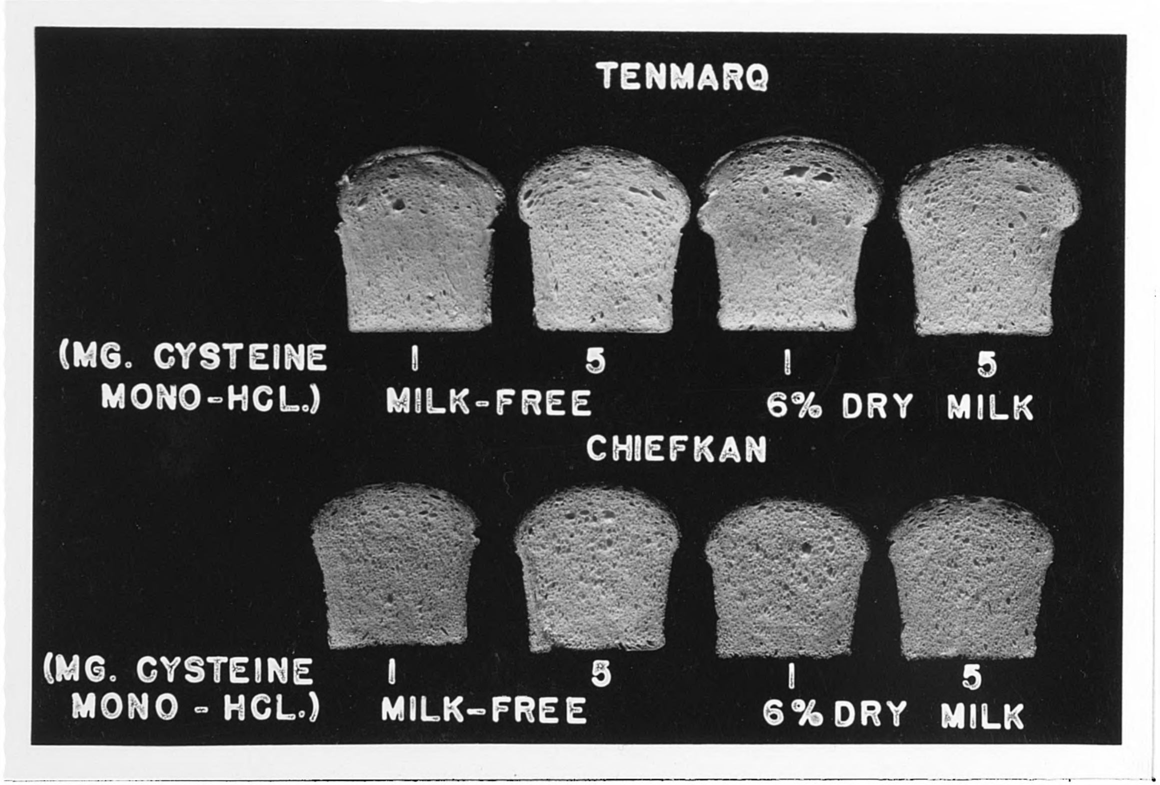

Fig. 18a. Effects of dry milk solids in relation to increments of cysteine on loaf interior. Unbleached Chiefkan and Tenmarq flours.

explain its action must of necessity be purely theoretical. Doughs are highly complex colloid systems and the introduction of dry milk solids makes the systems even more complex by the addition of another ingredient with colloidal properties of its own. It is known that the introduction of any material which influences the oxidation-reduction potential of a system will seriously affect the baking quality of a flour. It may be that the addition of dry milk solids has a stabilizing effect on this system. There may be the possibility that the bromate acts on some factor (A) in the flour which has a relatively high reduction potential to give a beneficial effect. An excess of bromate may react further on some other factor (B) of lower reduction potential to cause a harmful effect. If the added dry milk solids have a reduction potential lower than that of (A) and higher than that of (B), it is possible that the benefits of oxidation might be obtained without the injurious effects of over-oxidation because any excess bromate, over and above that required by factor (A), would act on the dry milk solids in preference to factor (B). Another conceivable explanation is that the added dry milk solids may act as a protective colloid by preferential adsorption on some material which would otherwise be adversely affected by the action of bromate.

The writer did some exploratory work on the adsorption of dry milk solids on the gluten as determined by washing out the gluten after mixing doughs with added dry milk solids and comparing the nitrogen contained in the dried gluten with the quantity obtained from the dried gluten washed from control doughs. There was evidence that the nitrogen content of dried gluten from doughs containing added dry milk solids was greater than that from milk-free doughs. The proteins of dry milk solids combine to some extent with gluten either by adsorption or by some other means. Whether or not this has any connection with the postulates stated above is a matter for extensive investigation.

The observation that dry milk solids has a "buffering action" toward bromate has a practical value of great importance to the milling and baking trades. If it is certain that dry milk solids will be included in the baking formula at a 6 per cent level, the miller can more nearly approach the optimum development of the flour proteins by means of the oxidizing bleaches without fear of having the baker nullify these improvements by the addition of too large a quantity of any of the "flour improvers" which contain bromate. From the bakers standpoint the addition of dry milk solids, after consideration of this "buffering action", may be considered as insurance against over-oxidation and assurance that he will still be able to obtain at least very nearly the optimum results with each flour purchased regardless of flour type.

SUMMARY AND CONCLUSIONS

1. A number of flours were investigated with respect to the inter-relationship between the action of dry milk solids and the action of potassium bromate. The flours chosen for this investigation consisted of a group representing the types used in commercial bread production in most parts of this country. Other flours included in the investigation were a Durum flour, a cake type flour made from soft wheat in the Pacific northwest, a Chiefkan-Tenmarq blend, a Chiefkan-Pacific short patent blend, an ether-extracted Tenmarq, and an ether-extracted Chiefkan flour.

2. All these flours were baked with 6 per cent dry milk solids and with amounts of potassium bromate ranging from zero to as high as 7 mg. per 100 g. of flour in some instances. A similar series was baked with the same flours and using milk-free doughs to determine the comparative effects of the addition of the dry milk solids. The results obtained from this series of bakes clearly indicates

that the presence of 6 per cent added dry milk solids confers a high degree of tolerance toward the action of bromate on flours. This "buffering action" of dry milk solids toward bromate action is of great significance to the commercial baker as it assures him of approximately optimum dough conditioning from proper oxidation without fear of incurring the deleterious effects which are the result of over-oxidation.

3. The Chiefkan was baked in a bromate series and at levels of 2, 4, 6, and 8 per cent added dry milk solids. The Tenmarq was baked in a similar series with milk levels of 2, 4 and 6 per cent added dry milk solids. Optimum results were obtained at the 6 per cent level of added dry milk solids with both of the flours investigated.

4. Tests made with Chiefkan and Tenmarq flours indicate that cysteine monohydrochloride exerts little effect on the final bread quality but does affect the mixing properties. No marked differences were noted between the control doughs and those containing added dry milk solids.

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