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Factors Influencing Experimental Baking Test For Nonfat Dry Milk[1]

Although most of the nonfat dry milk (NFDM) produced at the present time for the baking industry is properly heat treated during processing so that satisfactory baking quality results, the problem of testing these solids for bakery use continues to be of importance and interest to manufacturers of this product and to bakery consumers. The three experimental methods for testing baking quality of NFDM that are most extensively used are measurement of (a) undenatured whey protein nitrogen (4), (b) the consistency of flour-milk powder mixtures as measured by the farinograph (5), and (c) the experimental bread-baking test (1). The first two methods offer advantages in time, materials, equipment, and personnel, but do not attempt to duplicate actual baking conditions and are less likely to be understood by bakers.

The experimental baking tests that are in use by various laboratories are usually modifications of the standard American Association of Cereal Chemists experimental baking test designed for testing the baking behavior of wheat flour. This baking test for wheat flour has received a great amount of attention. The review of Cathcart (3) describes its status and presents the problems connected with it. It is apparent that complete standardization of the wheat flour baking test has not been agreed upon, and it is not surprising that even less agreement has been reached with respect to the experimental baking test for NFDM.

Attention has been given to methods for measuring baking quality of nonfat milk solids (NFMS). The most recent surveys are those published by Larson *et al* (6) and by Bradley and co-workers in 1953 (2). In the latter, a collaborative study, the experimental baking test was included as one of the experimental methods for determining baking quality of NFDM, but standardization of baking procedure was not required. Each collaborator employed his own baking procedure, and few details of the methods and formulas used were included in the published report. This study indicated that the experimental baking test was not the most precise in distinguishing NFMS suitable for baking, that the tests were not uniform, and that agreement between laboratories was only fair. In view of this situation, it seemed desirable to attempt a preliminary investigation of the effect of the kind of flour and of the amounts of some of the other principal ingredients of the baking formula on the results of the experimental baking test for determining baking quality of NFDM. If standards could be set for some of these variables, inherent defects of the determination could be corrected and greater uniformity and accuracy

Methods and Materials

The effect of shortening on milk bread formulas containing Australian wheat flour has been investigated by Lee (7), but little data have been accumulated indicating the effect of other formula ingredients of milk bread. All possible bread formula ingredients could not be used as variables in this preliminary study; and some ingredients would not significantly influence the baking quality of the NFDM. Four variables were selected which seemed most likely to influence baking quality of NFMS, and their effect on loaf volume was measured and analyzed statistically. The effect of these variables on dough and crumb characteristics also was noted, although in all cases undesirable dough or crumb characteristics were directly associated with decreased loaf volume.

For clarity, the experiments were separated into two series with three variables active in each. To avoid confusion, Series I is referred to as "Effect of Flour Strength"; in this series, flour strength, fat level, and NFMS level were the variables. In Series II, referred to as "Effect of Milk Solids Water Absorption," the active variables were NFMS water absorption, fat, and NFMS. The last two variables in both series are identical.

Four flour strengths were obtained by varying the protein content of commercial bakers' patent bread flour

[1] This work was done with funds delegated by the Agricultural Marketing Service.

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lower protein content. Thus the flour mixture containing three parts of unbleached pastry flour and one part strong bread flour was used in the formula as the flour of weakest strength; the mixture containing half pastry flour and half bread flour was considered medium strength flour; that containing one part pastry flour and three parts bread flour was good flour strength; and the undiluted bread flour furnished strong flour strength. Thus, flours of the protein content shown in **Figure 1** at the 14 per cent moisture level were provided.

Other methods of varying the flour strength are possible, but this method produced flours which were unaltered by chemical or physical treatment and represented a protein range that might be encountered in commercial bread flours. The fat used in the experiment was leaf lard, selected because of the absence of emulsifiers and because of its general acceptability by the baking industry. The fat level was varied to include one, three, and six parts per 100 parts of flour, thus covering the usual range of fat in typical bread formulas. Nonfat dry milks of commercial grade were used, and both low-heat and high-heat processed types were included at levels of three, six, and nine per cent, based on flour weight. The three variables, flour strength, shortening level, and NFDM level, were baked in all possible combinations following the basic formula given in **Figure 2.**

Three loaves (approximately one pound each) were baked from each dough following a standardized straight dough procedure for mixing, fermenting, and baking. All doughs were mixed in a Fleischmann laboratory-size vertical mixer for seven minutes; fermentation was carried out at 82° F. and consisted of periods of 135, 45, and 20 minutes, with handworking of the dough after the first and second periods. The last fermentation period was followed by molding and a proofing period of 60 minutes at 92° F. and 85-90 per cent humidity. Baking time at 400° F. was 30 minutes for doughs scaled at 500 grams. Loaf volume was measured by seed displacement after one hour's cooling at room temperature.

A single day's baking represents one variable baked with both the high- and low-heat treated types of NFDM. Comparisons were not made until tables including all variables were complete.

100% bread flour ..... **13.3% protein**

"Mixture" containing 75% bread flour, 25% pastry flour ..... **12.2% protein**

"Mixture" containing 50% bread flour, 50% pastry flour ..... **11.2% protein**

"Mixture" containing 25% bread flour, 75% pastry flour ..... **10.1% protein**

Figure 1

Flour	**100 parts**
Sugar	**5 parts**
Salt	**2 parts**
Fat	**1, 3, or 6 parts**
Nonfat dry milk	**3, 6, or 9 parts**
Water	**(variable depending on flour strength)**
$KBrO_3$	**.001 parts**
Compressed yeast	**2 parts**

Figure 2

Results and Discussion

The average of three loaf volumes obtained in series I, with flour strength as the nonduplicated variable and with both types of heat-processed NFDM, is recorded in **Table 1.** As shown in **Table 3,** these data were subjected to analysis of variance in order to determine which variables and interactions between these variables caused a significant variation in loaf volume.

It will be seen that the NFMS level was significant for both high- and low-heat-treated products, and the fat levels were significant only for the high-heat-treated product. The flour strength was not statistically significant under the conditions

Table I

Average loaf volumes resulting from series I bakings, "effect of flour strength"*

(Average of three loaves, expressed in cc)

% Nonfat dry milk	3			6			9		
% Fat	1	3	6	1	3	6	1	3	6
				High-heat-treated					
Flour # 1**	2300	2258	2275	2200	2308	2267	1975	2200	2133
Flour # 2	2325	2408	2208	2125	2292	2283	2200	2242	2208
Flour # 3	2267	2375	2185	2200	2325	2283	2100	2075	2083
Flour # 4	2275	2375	2175	2208	2183	2175	2267	2158	2142
				Low-heat-treated					
Flour # 1	2200	2175	2125	2058	2058	2187	1800	1975	1850
Flour # 2	2100	2166	1983	2017	2133	2097	1913	2058	1933
Flour # 3	2117	2233	1983	2050	2008	2042	2067	1925	1933
Flour # 4	2150	2155	2117	2075	2075	2017	2058	2017	2025

* Variables in series I bakings: (1) flour strength, (2) nonfat dry milk (3) fat.

** Flour # 1, 25% bread flour, 75% pastry flour
Flour # 2, 50% bread flour, 50% pastry flour
Flour # 3, 75% bread flour, 25% pastry flour
Flour # 4, 100% bread flour, 0% pastry flour

Table II

Average loaf volumes resulting from series II bakings, "effect of milk solids water absorption"*

(Average of three loaves, expressed in cc)

% Nonfat dry milk	3			6			9		
% Fat	1	3	6	1	3	6	1	3	6
				High-heat-treated					
Water absorption #1**	2475	2483	2167	2442	2533	2237	2312	2542	2225
Water absorption #2	2333	2437	2258	2367	2450	2267	2342	2437	2337
Water absorption #3	2275	2375	2175	2208	2183	2175	2267	2158	2142
				Low-heat-treated					
Water absorption #1**	2233	2300	2212	2133	2092	2225	2075	2117	2158
Water absorption #2	2250	2187	2250	2292	2137	2183	2008	2067	2125
Water absorption #3	2150	2155	2117	2075	2075	2017	2058	2017	2025

* Variables in Series II bakings: (1) milk solids water absorption, (2) nonfat dry milk and (3) fat.
** Water absorption #1, no increase in water absorption of dough.
Water absorption #2, water absorption of dough increased by 50% of weight of NFMS.
Water absorption #3, water absorption of dough increased by 100% of weight of NFMS.

of the experiment for either type of NFDM. It seems likely that the fat level was not significant when used with low-heat-treated NFDM because the accompanying softness of these doughs more than offset the lubricating effect on the gluten of the different fat levels, whereas with the high-heat-treated NFMS the lubricating effect of the different fat levels on the gluten was a significant factor in determining the final loaf volume.

For all of the loaf volume data in which the variables were flour strength, fat level, and NFMS level, the water absorption of the milk product was kept at 100 per cent of its weight. This is an arbitrary but customary absorption value usually required of NFMS of good baking quality, and the introduction of a fourth variable at the start of the experiment would have made statistical analysis cumbersome and unnecessarily complicated.

Since the data unequivocally indicated that flour strength was not significant under any conditions for either type of NFDM, this variable was eliminated at this point and the water absorption of the NFMS was introduced as a variable. This amounted to 0, 50, and 100 per cent, that is, no extra water, water equal to one half the weight of NFMS, and water equal to the weight of these solids. The loaf volumes obtained using the variables of water absorption, fat, and NFMS with only strong bread flour are given in **Table 2,** and the analysis of variance for these data is presented in **Table 4.** From the latter table it is seen that water absorption of the NFMS was significant in determining the loaf volume for both high- and low-heat-treated NFMS bread. The variable of fat level remains significant with high-heat-treated milk solids, possibly due to the necessity of lubricating the gluten. When considering high-heat-treated NFMS, it is seen that the amount or level is not significant as measured by loaf volume in conjunction with the variables of water absorption of these milk solids and with fat. Apparently the latter two variables permitted sufficient dough expansion that was more predominant than any influence on loaf volume introduced by the different NFMS levels of the high-heat-treated type.

In the results using the low-heat-treated NFMS, only the variables of their level and of water absorption of these solids were found significant.

It is also noted from the data of **Tables 3** and **4** that the level of NFMS appears as a significant variable three times, while the variables of water absorption and amount of fat are each significant twice. Under the conditions of these experiments, these comprise the variables influencing the final loaf volume which was taken as the criterion for measuring the baking quality of NFMS.

To formulate any baking test for NFDM, the amounts of these solids, of water absorption, and of fat must be indicated and, if possible, standards should be proposed. Although the experiments carried out in this work were not intended to be conclusive in establishing such standards for a baking test to distinguish baking quality of high- or low-heat-treated NFDM, some relationships between the variables are noted that might be used for subsequent experiments aimed at distinguishing types of NFDM. From the data in **Table 2,** loaf volume differences were obtained between loaves differing only in heat treatment of the powder used in the formula, and are presented in **Table 5.** If the volume differences associated with the three levels of NFDM are added separately, it is found that the greatest sum total is reached at the nine per cent NFMS level. When the volume differences associated with the three fat levels are added similarly, the greatest sum total is found in connection with the three per cent

Table III

Mean squares for loaf volume data of table I

Source of variation	Degrees of freedom	Type of heat treatment of NFMS High	Low
Flour strength	3	3,856	3,023
NFMS levels	2	57,899	79,351**
Fat levels	2	16,461	8,972
Flour x NFMS	6	6,675	8,597
Flour x Fat	6	3,611	4,568
Fat x NFMS	4	7,430	5,922
Error	12	3,707	3,874
Standard Error		60.9	62.2

Note: * indicates statistical significance at the 5% level.
** indicates statistical significance at the 1% level.

Table IV

Mean squares for loaf volume data of table II

Source of variation	Degrees of freedom	Type of heat treatment of NFMS High	Low
NFMS water absorption levels	2	69,889**	27,643*
NFMS levels	2	1,298	38,288*
Fat levels	2	74,418**	1,188
Absorption x NFMS	4	4,154	3,243
Absorption x fat	4	12,084	2,518
Fat x NFMS	4	2,127	2,353
Error	8	3,503	2,630
Standard Error		59.2	51.3

Note: * indicates statistical significance at the 1% level.
** indicates statistical significance at the 0.1% level.

fat level. In a like manner, the greatest total of volume differences obtained with the three NFMS water absorption levels, is at the 0 per cent level. From **Table 5,** it is noted that the volume difference at 0 per cent NFMS water absorption level, three per cent fat level, and nine per cent NFMS level is one of the highest numerical differences in the table; and under the conditions of this experiment, these levels should provide the most sensitive set of conditions for distinguishing high- and low-heat-treated NFMS as indicated by loaf volume differences. These suggested levels of significant variables for an experimental baking formula are not necessarily typical of the customary levels for average commercial bread formulas, with the exception of the fat level. Usually the water absorption of satisfactory baking quality NFDM is approximately equal to the weight of the solids themselves (i.e. 100 per cent water absorption by weight), but for the purpose of an experimental bake test for distinguishing high- and low-heat-treated NFDM, the water absorption level for NFMS of 0 per cent, and a milk solids level of nine per cent were more critical than customary levels, since they produced the greatest loaf volume differences. To test the reliability of a baking test based on these variables, NFDM samples of unknown heat treatment should be experimentally baked under these conditions and the resulting classification of the solids checked by other procedures for determining baking quality.

It has been recognized previously that the role of NFMS level, milk solids water absorption, and fat level (under certain conditions) are important in determining baking quality of NFDM. The data and conclusions shown in this work provide statistical confirmation of the importance in the bake test of the amounts of these components in a bread formula and also indicate at what levels they are most suitable for a sensitive baking test for NFDM.

Note: We wish to thank E. L. LeClerg, chief, Biometrical Services A.R.S., for his assistance in presenting the statistical data.

Summary

The statistical significance on loaf volume of four white bread formula ingredients was determined following an experimental bread baking test based on the one for wheat flour. Using high- and low-heat nonfat dry milk, it was found that the water absorption level was significant for both types of powder; the fat level was significant for high-heat, but not for low-heat powder; the reverse was true for the milk solids level; and the strength of flour within the range of 10 to 13 per cent protein had no effect on loaf volume in either case. Tentative levels of the significant factors are suggested for establishing an experimental baking test designed for determining the baking behavior of nonfat dry milk.

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THE END

Table V

Increase in loaf volumes obtained with high-heat-treated milk solids in series II bakings*

(Volume difference expressed in cc.)

% Nonfat milk solids	3			6			9		
% Fat	1	3	6	1	3	6	1	3	6
Water absorption #1**	242	183	45	309	441	12	237	425	67
Water absorption #2	83	250	8	75	313	84	334	370	212
Water absorption #3	125	250	58	133	108	158	209	141	117

* Variables in Series II bakings: (1) milk solids water absorption, (2) nonfat milk solids, (3) fat.

** Water absorption #1, no increase in water absorption of dough.
Water absorption #2, water absorption of dough increased by 50% of NFMS weight.
Water absorption #3, water absorption of dough increased by 100% of NFMS weight.