THE USE OF DRIED DAIRY PRODUCTS IN SOME MANUFACTURED FOODS

by 45

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PART I

The Use of Hydrogen Peroxide Treated Nonfat Dry Milk in Continuous Bread Production

INTRODUCTION

The baking industry has been one of the major buyers of nonfat dry milk (NDM). In recent years, however, there has been a considerable decrease in sales of NDM to the baking trade. For example, in 1953, 256 million pounds of NDM, or 42 percent of the total NDM produced, was sold to the baking industry (1). In contrast, in 1965, this total decreased to 241 million pounds or 26 percent of the total NDM produced (2). This decrease in NDM sales to the baking industry has been due partially to the advent of continuous dough mixing methods of bread production.

Six percent NDM has been used successfully in the sponge dough process. However, with the application of continuous dough mixing methods more than one percent NDM in the formula has given deleterious effects to the bread (5). The main defects have been found to be decreased loaf volume, very fine grain, bright crumb and soft texture.

Several advantages have been cited for the use of NDM in bread. Probably the most important reason for its use is the nutritive qualities that it possesses. Wheat proteins are generally considered to be deficient in the amino acids lysine, tryptophane, and methionine. With the addition of six percent NDM to the bread dough formula, the lysine content of bread can be increased 46 percent, tryptophane 10 percent and methionine 23 percent. Also, with the use of six percent NDM in the formula the calcium and riboflavin content can be increased 66 percent and 13 percent, respectively (6). In addition, NDM has been reported to impart desirable physical properties to bread made by the sponge dough process (5). NDM gives bread the capacity to hold more water.

This in turn has been found to improve the keeping quality and develop more desirable grain, texture and loaf volume in bread made by the sponge dough process. The use of NDM has been thought to impart a richer flavor to bread. Reports from industry state that continuous mix bread made with lower levels of NDM has been criticized for lack of desirable flavor. Also, the addition of NDM contributes to a rich brown loaf color. This study is an extension of work done on continuous mix bread at this University by Mr. R. B. Patel. The objectives of the investigation were to study further, the effects on bread quality of adding to the dough NDM which had been treated with hydrogen peroxide (H_2O_2) prior to drying.

REVIEW OF LITERATURE

NDM Used in Bread

Proper heat treatment of skimmilk prior to drying is necessary for production of good loaf volume, grain, and texture in bread containing NDM. The necessity of heat treating was first recognized by Greenbank in 1927 (9), when skimmilk was scalded before being used in bread and compared to low heat treated milk. High heat treatment of milk imparted a greater water holding capacity to the dough resulting in increased loaf volume and more desirable grain and texture than low heat-treated milk. Milk which had received a low heat treatment had a slight binding effect upon the dough which greatly decreased loaf volume. Grewe et al. (10) heat treated skimmilk before drying at temperatures of 50, 63, 73, 83, 93 and 100 C for 30 min. and used these dry milks in baking experiments. The poorest bread was obtained when NDM was added that had been preheated to 50 C. There was great improvement in the bread made with NDM which was given the four highest heat treatments. The phenomenon of low heat treatment of milk producing low loaf volume was given the name "loaf depressant factor." Skovholt and Bailey (25) observed that heat treatment of skimmilk at temperatures of 88 and 96 C increased significantly the water absoprtion capacity of the dough.

Stamberg and Bailey (27) made quantitative estimations of the sulfhydryl, (-SH) groups in raw milk samples and found them to be present in amounts sufficient to cause pronounced dough softening comparable to the dough softening effect of equal amounts of cysteine hydrochloride. After separating the casein from the whey protein

fractions, it was shown by farinogram studies that the loaf depressant factor was present in the whey or serum protein fraction of the NDM. It was concluded that the low molecular weight lactablumin fraction with -SH groups exposed combined during the heat treatment to give higher molecular weight proteins. The -SH groups were thought to be oxidized to the more stable disulfide (S-S) linkages and thus occluded in the reaction. Harland et al. (12), also observed that it was the nondialyzable material of the whey protein fraction which was detrimental to baking if not properly heat treated. This fraction contains non-casein nitrogen, natural enzymes of milk and cellular constituents. They observed that the baking quality of bread containing both acid and rennet wheys were improved by heat treatment.

Larson et al. (16) heated the major components of NDM; casein, lactose, and the serum proteins at 70, 75, and 80 C for 30 minutes, and incorporated these fractions in dough at levels equivalent to six percent NDM. The unheated fractions all were found to depress loaf volume with lactose having the greatest effect. Minimum heat treatment of the milk fractions at 73 C for 30 minutes was found to destroy the loaf depressant factor. These workers concluded that the improvement in quality of separated milk for bread making which is brought about by heat treatment was associated with changes in the serum proteins. Casein and lactose fractions also were found to lower loaf volume but this influence was independent of heat treatment.

Larson et al.(17), studied purified milk serum protein fractions and found that B-lactoglobulin did not affect dough consistency and loaf volume when incorporated into dough. These workers concluded that the

effect of unheated serum proteins commonly attributed to -SH groups were apparently due to an unknown action of some other component of the serum protein other than the B-lactoglobulin fraction.

Gordon et al. (8) tested several fractions of milk serum protein for baking quality. Neither B-lactoglobulin nor the insoluble protein exhibited the loaf depressant factor. Tests on the entire lactalbumin fraction indicated that it did not contain high concentrations of the loaf depressant factor. The loaf depressant factor was thought to be present in the lactoglobulin fraction of the serum proteins.

Further work on the nature of the loaf depressant factor was done by Jenness (14). He isolated a component of milk from acid whey that moved electrophoretically, slightly behind casein. As little as 5 mg of the component per 100 g of NDM was sufficient to reduce loaf volume of bread when used in baking studies.

Harland et al. (13) reported that denaturation of serum proteins could be used as an index of the extent of heat treatment of milk and dried milk products. The index was reported as the percentage denaturation of the original serum protein content or as the amount of undenatured serum protein remaining in the product. If the amount of denaturation is relatively high as for NDM used for baking purposes, direct determination of the amount of undenatured serum protein is then practical. However, for low heat NDM the actual amount of denatured serum protein may be more practical than the percentage. Harland et al. (13) collected samples of fresh bulk milk in ten regions of the United States in winter, spring, and fall seasons and analyzed them for serum protein nitrogen distribution, sulfhydryl content and susceptibility of the

serum proteins to heat denaturation. It was found that variability in serum protein content and their heat denaturability imposes serious limitations on the use of serum protein analysis for determining whether dry milks of an unknown history were suitable for specific uses. The sulfhydryl content was variable and was affected by aging and contamination with copper.

Ashworth et al. (4) incorporated samples of NDM into a straight dough formula. The baking quality of these milks tended to be inversely proportional to the amount of undenatured whey protein remaining in the range of which 50-90 percent of the whey protein had been denatured by heat. Maximum loaf volumes were obtained when the undenatured whey protein nitrogen amounted to less than 2 mg per g of NDM. Minimum loaf volumes were obtained when only 15-30 percent of the whey protein nitrogen had been denatured by heat.

Sokol et al. (26), observed that sulfhydryl losses in dough varied after 20 minutes of mixing from 38-64 percent of the original sulfhydryl content. After 2-5 min., a rapid decrease in sulfhydryl content was noticed, and with continued mixing, relatively large differences were found in the rate of decrease. They suggested that the -SH groups are oxidized to disulfide bonds during mixing.

Mecham and Knapp (19) observed that when moderate amounts of NDM (three to six percent of the flour weight) were added, generally fewer -SH groups were lost during mixing than in the absense of milk solids. When a large amount of NDM (15 percent) was added, the effect was reversed. It was concluded that some association of milk and flour proteins protect

-SH groups. At high levels of NDM, the capacity of wheat proteins for such combination were exceeded and the milk -SH groups combined readily with the milk proteins. Mecham (18), used -SH blocking agents; N-ethylmaleimide, P-chloromercuribenzoate, and iodoacetamide in amounts equivalent to the -SH content of the flour. When the farinograph mixing procedure was used, the reagents shortened the time to maximum resistance slightly increased maximum resistance, and greatly increased the rate of breakdown after the maximum. Due to the reacting or blocking of the -SH groups with these reagents there was not oxidation of the -SH groups to disulfide (S-S) bonds; thus, there was a rapid breakdown of the dough upon mixing.

The P-chloromercuribenzoate-dithizone method (24) has been used for estimating -SH and S-S content in milk and gives reproducible results.

Sullivan et al. (28) postulated that intramolecular S-S bonds were changed to intermolecular S-S cross linkages by means of small amounts of -SH groups. While S-S bonds may be primarily responsible for roughness and strength of a dough, there are probably weaker linkages such as thiol ester, amide, or hydrogen bonds that require less energy to break.

Sanderson and Swanson (23), preheated condensed skimmilk to 74-96 C for 30 min. and 129-146 C for 60 sec. before spray drying. The samples were condensed to 35 and 45 percent total solids before being heat treated. They found that the 1.5 mg per g limit of undenatured whey protein nitrogen required for a high heat product was obtained at temperatures of 79 C and above for 30 min, and at 129 C and above for 60 sec. Also, they found by heating the concentrated skimmilk that the

level of undenatured whey protein nitrogen was reduced at the lowest forewarming temperature but produced an increase at the higher temperatures. This increase in undenatured whey protein nitrogen was found to be dependent on total solids content at the time of heating and the intensity of the heat treatment given to the concentrate.

H_2O_2 Treatment of NDM

In 1967, Patel et al. (20) treated skimmilk with hydrogen peroxide (H_2O_2) at three levels prior to preheating and drying. The H_2O_2 treated NDM samples were used in continuous mix bread baking experiments. They found that comparable bread could be obtained at the three and six percent level of NDM if the milk was treated with 0.05 or 0.10 percent H_2O_2. The samples of NDM used subsequently were found to contain considerable amounts of residual H_2O_2 which may have influenced the results. It was found that undenatured whey protein nitrogen values of the H_2O_2 treated NDM samples were higher than the non-treated samples. This indicated that the H_2O_2 may have had a protective effect on denaturation of serum proteins upon heat treatment.

Grindrod and Nickerson (11), studied the changes produced in milk proteins upon treatment with H_2O_2 by the use of polyacrylamide gel electrophoresis. They found following H_2O_2 treatment of individual proteins that migration rates on polyacrylamide gel electrophoresis were reduced for a_s-casein and B-lactoglobulin but were increased for B-casein and bovine serum albumin. Migration rates did not change for K-casein or a-lactalbumin. Whey protein nitrogen was found to decrease as a function of H_2O_2 concentration and time. Fish and Mickelsen (7) investigated the effect of H_2O_2 on the whey protein nitrogen value of heated skimmilk by the use of disc electrophoresis. Electrophoretic

patterns were compared for normal, heated, H_2O_2 - heated and H_2O_2 - heated - catalase - treated samples of a-lactalbumin, bovine serum albumin, B-lactoglobulin and acid whey. The a-lactalbumin band was lighter in the H_2O_2 - treated sample than in the normal or heated sample. Bovine serum albumin was found to be denatured by heat treatment. Hydrogen peroxide treatment prevented total denaturation of bovine serum albumin. B-lactoglobulin was denatured by heat treatment and greatly modified by H_2O_2 treatment.

MATERIALS & METHODS

Preparation of Nonfat Dry Milk

Six samples of skimmilk were treated with increasing amounts of H_2O_2. A control and five levels of H_2O_2 in concentrations of 0.025, 0.05, 0.075, 0.1 and 0.2 percent of the skimmilk were used. The H_2O_2 was added to the skimmilk in a jacketed vat and held at 31-32 C for ten minutes. Holding at this temperature, after the addition of the H_2O_2, was desirable to allow the reaction with the milk to take place. The H_2O_2 treated samples were then heat treated at 85 C for 30 minutes in a steam jacketed vat.

After the heat treatment, the samples were cooled to 32--36 C for treatment with catalase. At this temperature, catalase catalyzes the decomposition of H_2O_2 according to the following equation (21).

$$2\ H_2O_2 \xrightarrow{\text{catalase}} O_2 + H_2O$$

Catalase with a concentration of 30,000 units per ml was used in the treatment. Catalase treatments are shown in Table 1.

Table 1. Ml of catalase added per 100 gal of skimmilk.

H_2O_2 Percent of Liquid Milk	Ml Catalase (30,000 units/ml) per 100 gal of Skimmilk
0	0
0.025	3
0.050	9
0.075	10
0.100	10*
0.200	18*

* Not sufficient to destroy completely all H_2O_2 present.

The samples were checked for presence of H_2O_2 before and after catalase treatment using a potassium iodide test (22). Three drops of KI were added to five ml of treated milk. If a yellow color developed within 20 minutes, H_2O_2 was presumed to be present.

Following treatment with catalse the skimmilk was condensed to 38 percent total solids with a Mojonnier "Lo-Temp" evaporator. The samples were introduced into the evaporator at temperatures between 32 and 35 C. After condensing, the samples were spray dried.

Analyses of NDM Samples

Moisture determinations were made immediately after drying by use of an Ohaus moisture determination balance (Model No. 6000).

Chemical analyses on the samples of H_2O_2 treated NDM included; whey protein nitrogen values (WPN), residual H_2O_2, and -SH content.

The amount of undenatured (WPN) present in the treated samples was determined by the method of Harland and Ashworth as modified by Kuramoto (15).

The amount of residual H_2O_2 remaining in the dried milk samples was determined by the method of Amin and Olson (3) as follows:

Reagents

70 percent (w/v) trichloracetic acid (TCA)

Titanium dioxide solution, 2.5 g of titanium dioxide was dissolved in 100 ml of concentrated sulfuric acid by boiling in Kjeldahl flask over a hot plate. During slow heating, the solution was shaken continuously by hand to avoid settling of undissolved residue. The volume was cooled to room temperature, and the clear liquid decanted and the volume measured. An equal volume of distilled water was added to the clear acidic solution. The diluted solution was allowed to equilibrate overnight at room temperature and centrifuged at 3,000 X g for 30 minutes to remove the residue.

Standard hydrogen peroxide solution: A solution containing 3,750 g per ml of 30 percent H_2O_2 was prepared. This solution was further diluted with reconstituted NDM to give a range of concentration of H_2O_2 for establishment of the standard curve.

Reconstitution of NDM: Ten g of NDM were dissolved in 100 ml of distilled H_2O. The reconstituted samples were allowed to equilibrate overnight at 4 C before the determination of residual hydrogen peroxide.

Procedure

Two ml of 70 percent TCA solution were added to 3 ml of reconstituted NDM to precipitate the milk proteins. After one minute and not more than three minutes, this solution was diluted to 100 ml with distilled water and filtered through two thicknesses of Whatman No. 42 filter paper.

Two ml of titanium dioxide reagent were added to five ml of TCA - milk filtrate and allowed to stand for five minutes. The samples containing H_2O_2 developed a yellow color, the intensity of which was directly related to the concentration of H_2O_2. The intensity of yellow color was determined at 400 m on a "Spectronic 20" colorimeter.

The concentration of residual H_2O_2 in the NDM samples was calculated from a standard curve.

Sulfhydryl content of the NDM samples was measured by the P.C.M.B. Dithizone method of Sasago et al. (24) with slight modification.

Reagents

P.C.M.B. solution: A 0.5 mM solution of the soidum salt of p-chloromercuribenzoic acid (Nutritional Biochemical Corp.) was prepared fresh daily.

Dithizone solution: Diphenyl carbozone (200 mg) (Dithiazone, Fisher Scientific Company) was dissolved in carbon tetrachloride and the volume made to 1,000 ml. Three ml of this solution was further diluted to 200 ml with carbon tetrachloride. The stock and diluted solution were made fresh on the day of the experiment.

Urea buffer solution: Sixty g of urea, 10 ml of 1 M phosphate buffer pH 7.0, 10 ml of 0.5 M Na_2SO_4, and 37.2 mg of disodium ethylendiamine tetraacetate (EDTA) were mixed and the volume made to 100 ml with distilled H_2O. The pH of this buffer solution was adjusted to 7.0 with 50 percent sulfuric acid.

Reconstitution of NDM: Ten g of NDM were dissolved in 100 ml of distilled H_2O. The reconstituted samples were allowed to equilibrate overnight at 4 C before the determination of sulfhydryl content was begun.

Standard cysteine solution: A 0.5 mM solution of cysteine monohydrochloride was prepared for developing a standard curve.

Procedure

Ten ml of diluted dithizone solution were added to each tube containing 0.5 ml of reconstituted NDM. The solutions were shaken vigorously by hand for one minute and then allowed to stand for 30 min. at 1-2 C. At the end of 30 minutes, the carbon tetrachloride layer was drawn off and filtered through Whatman No. 40 filter paper. The color intensity was measured at 620 mμ using a "Spectronic 20" colorimeter. Carbon tetrachloride was used as a blank.

A standard curve was plotted and the sulfhydryl content of the reconstituted NDM samples calculated.

Physical Dough Characteristics

Physical dough characteristics, using control and H_2O_2 treated samples at three and six percent of the flour weight, were measured on the Brabender farinograph. Water absorption to optimum dough consistency, optimum (peak) mixing time, mixing tolerance index, and valorimeter values were calculated and recorded. Physical dough characteristics were measured on flour-milk doughs to give an indication of their hydration and mixing characteristics. The flour and milk were placed in the mixing bowl and sufficient water added so that the consistency of the dough was such that the mixing curve was centered on the 500 Brabender Unit (B.U.) line at the point of maximum development. All flour-milk mixtures were centered on this line so that comparisons could be made at what was considered uniform consistency. Water absorption is the percentage of water in the dough at the consistency when the farinograph curve centers on the Brabender Unit line at the point of maximum development. Optimum or peak mixing time is the time in minutes from the start of the mixing curve to the peak of the curve. The mixing tolerance index is the time in minutes from when the top of the curve goes above the 500 B.U. line until the top of the curve goes below this line.

The valorimeter value is an empirical figure based on dough development time and mixing tolerance and is determined from the farinograph curve by means of a special template.

Continuous Dough Mixing Experiments

The samples of H_2O_2 treated NDM and the control were evaluated in continuous dough mixing experiments. A liquid sponge with 2.5 hr. fermentation was used. Mixing speeds of 125, 147, and 171 r.p.m. were used for mixing with an AMF laboratory continuous dough mixer. The continuous dough mixing formula used is shown in Table 2.

Table 2. Continuous mix formula.

Ingredient	% of Flour
Flour[1]	100
Water	variable
Sugar	6.00
Yeast	3.00
Shortening	3.00
Milk	3 or 6
Salt	2.00
Arkady	0.50
Malt	0.50
Oxidation[2]	30, 60, 90 p.p.m.

[1]Moisture 13.7%, protein 11.9%, ash 0.41%

[2]Potassium bromate

The factorial design shown in Table 3 was used for the continuous dough mixing experiment.

Table 3. Factorial design.

	Heated 85 C/30 min.		
Skimmilk treatment:	0% Control, 0.025%H_2O_2, 0.05%H_2O_2, 0.075%H_2O_2, 0.10%H_2O_2, 0.20%H_2O_2		
Amount of NFDM:	3%	6%	
Dough oxidation:	30 p.p.m.	60 p.p.m.	90 p.p.m.
Mixing speed:	$m_1m_2m_3$	$m_1m_2m_3$	$m_1m_2m_3$
No. of loaves:	$L_1L_2L_3L_4$		

$m_1m_2m_3$ = 125 4.p.m. 147 r.p.m. 171 r.p.m.

$L_1L_2L_3L_4$ = 4 loaves

The parameters involved in the study were:(a) NDM used in amounts of 3 and 6 percent of the flour weight; (b) dough oxidation at 30, 60, and 90 p.p.m.; and (c) mixing speeds of 125, 147, and 171 r.p.m. For each variable, four loaves of bread were taken and the specific loaf volume, exterior appearance, grain, texture, and total loaf score were recorded and statistically analyzed. A panel of 4 experienced judges evaluated and scored the bread.

Loaf volume was measured by the rape seed displacement method. The volumes were converted to a score with a maximum of 25 points so that a total loaf score could be calculated taking into account the specific volume. Exterior appearance was given a maximum score of 15 points. This was based on overall general appearance of the loaf prior to being sliced. Symmetry was the main criterion for this score.

Grain was given a maximum score of 30 points. This score was based on the visual analysis of the cross section of the loaf. Factors taken into account were cell size and uniformity.

Texture, also, was given 30 points maximum score. This score was determined by touching a cross section of the loaf and evaluating it as to softness and coarseness.

Total loaf score was obtained by adding the scores obtained from loaf volume, exterior appearnce, grain and texture.

Crust color was determined on a photoelectric reflection meter and measured in percentage of the reflectance of magnesium oxide. A green tristimulus filter from the Munsell standard of color was used in the determination.

Power requirements at the different mixing speeds were calculated

by converting kilowatt readings to horsepower per pound per minute according to the following formula:

$$\text{H.P. per lb per min.} = \frac{\text{Watt reading}}{746 \times \text{through put (lbs/min)}}$$

RESULTS & DISCUSSION

Whey Protein Nitrogen

Whey protein nitrogen (WPN) values, determined by the modified method of Harland and Ashworth (15), for the control and the five samples of H_2O_2 treated NDM are shown in Table 4.

Table 4. Undenatured whey protein values of NDM, heated 85 C for 30 minutes.

	Undenatured whey protein nitrogen
	g nitrogen / g NDM
Control	
Hydrogen peroxide	3.52
0.025%	6.40
0.050%	5.18
0.075%	5.83
0.100%	5.50
0.200%	7.22

Treatment with H_2O_2 was found to decrease the heat denaturation of whey protein. These results agree with the observation of Patel *et al*. (20) which alos was verified by work done by Fish and Mickelsen (7) and Grindrod and Nickerson (11). There was an apparent protective effect of serum protein denaturation upon treatment with H_2O_2. There was not a linear relationship between the amount of the H_2O_2 treatment and the amount of whey protein denaturation. However, the

highest H_2O_2 treatment resulted in the least denaturation of whey protein. The amount of heat denaturation of serum protein in NDM, is used as an index of suppression of the loaf volume depressant factor. It is obvious from these data that it cannot be used with confidence when the milk has been treated with H_2O_2.

Residual Hydrogen Peroxide

The amount of residual H_2O_2 present in the NDM samples measured by the method of Amin and Olson (3) is shown in Table 5.

Table 5. Residual hydrogen peroxide present in NDM samples after first catalase treatment.

Samples	μ g H_2O_2/ml
Control	0
Hydrogen peroxide	
0.025%	0
0.050%	0
0.075%	0
0.100%	275
0.200%	570

At the lower levels of H_2O_2 treatment, 0.025 to 0.075 percent, all of the H_2O_2 was destroyed by the treatment with catalase. The samples with the two highest levels of H_2O_2, 0.10 and 0.20 percent, contained residual hydrogen peroxide after heat treatment, catalase treatment and drying. These two samples were reconstituted and treated with

more catalase before use in the continuous mix baking experiments. The samples were re-examined for residual H_2O_2 after the second catalase treatment and found to be negative. This indicated that all of the residual H_2O_2 had been destroyed by the second catalase treatment. This was done to prevent over-oxidation of the doughs, which may have occurred in earlier work, due to the presence of residual H_2O_2.

Sulfhydryl Content

The sulfhydryl content of the H_2O_2 treated NDM samples was measured by the P.C.M.B. - Dithizone method (24) and is summarized in Table 6.

Table 6. Sulfhydryl content of NDM samples heated at 85 C for 30 minutes.

	g[a]
Control	1.050
Hydrogen peroxide	
0.025%	.652
0.05%	.648
0.075%	.425
0.100%	.925
0.200%	.700

[a] g Cysteine/100 ml of reconstituted NFDM of 10% solids

Sulfhydryl content was found to decrease upon treatment with H_2O_2, however, there was not a linear relationship between the severity of H_2O_2 treatment and the -SH content. Patel *et al.* (20) also found

a decrease in -SH content upon treatment with H_2O_2. This may indicate that the -SH groups are oxidized to disulfide (S-S) bonds by treatment with H_2O_2.

Physical Dough Characteristics

Physical dough characteristics, using the control and five levels of H_2O_2 treated NDM samples at 3 and 6 percent of the flour weight, were measured on the Brabender farinograph. The farinograms are shown in Figure 1. A summary of the data taken from the farinograms shown in Figure 1 is shown in Table 7. Water absorption and peak mixing time increased with the addition of 6 percent NDM compared to the 3 percent NDM level. Also, water absorption increased with increasing levels of H_2O_2 treatment. There appeared to be no linear relationship between H_2O_2 treatment and peak mixing time. The mixing tolerance index and the valorimeter values increased at the higher levels of H_2O_2 treatment.

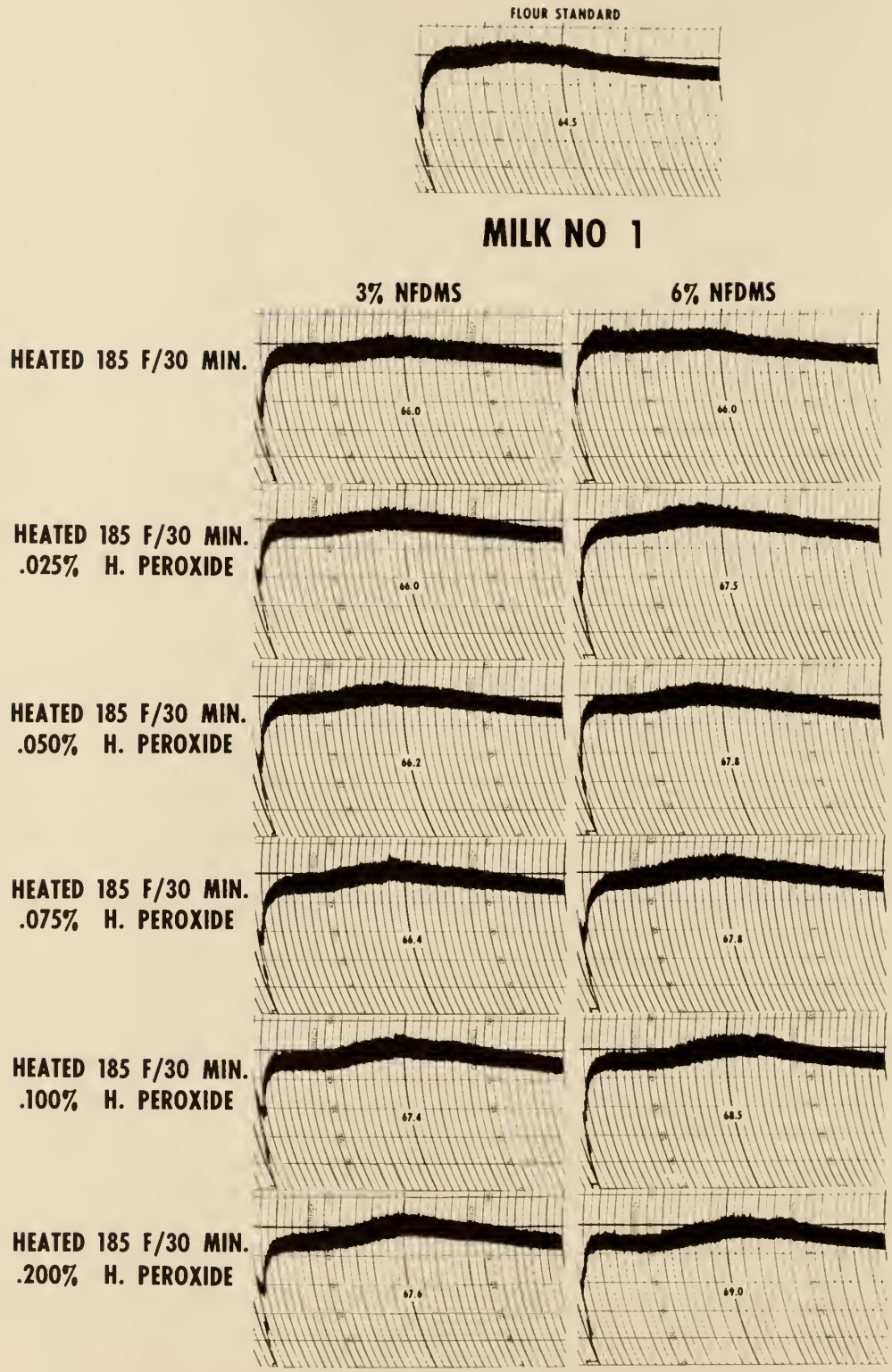

Figure 1. Physical Dough Characteristics as Measured on the Brabender Farinograph.

Table 7. Farinograph water absorption, peak time, mixing tolerance index, and valorimeter value of dough containing NDM samples.

	NDM added							
	3%	6%	3%	6%	3%	6%	3%	6%
	Water Absorption		Peak Time		Mixing Tolerance Index		Valorimeter Value	
			min.	min.	B.U.[1]	B.U.		
Flour standard[2]	64.5		7.5		35		64	
Control	66.0	66.0	10.5	10.0	35	35	75	74
Hydrogen peroxide								
0.025%	66.0	67.5	10.5	9.5	35	35	75	72
0.050%	66.2	67.8	9.0	9.5	40	35	70	72
0.075%	66.4	67.8	9.0	10.0	40	40	70	74
0.100%	67.4	68.5	9.5	12.0	40	50	72	80
0.200%	67.6	69.0	11.0	13.5	40	55	77	83

[1] Brabender Units

[2] Neither 3 or 6% Milk Added

Continuous Mix Baking Experiments

Loaf Volume

Specific loaf volume data are summarized in Figure 2. These data also are summarized in the Appendix, Table 1. Loaf volume was found to be significantly increased at levels of 0.10 and 0.20 percent H_2O_2 treatment of the NDM compared to the untreated control. This occurred at both the 3 and 6 percent levels of NDM. A significant depression in loaf volume was observed with H_2O_2 treatment of 0.05 and 0.075 percent at both the 3 and 6 percent levels of NDM. This may be due to a critical oxidation level with these treatments, or it may be due to experimental error. The loaf volume with the use of 3 percent NDM in the formula was greater in each case than with the 6 percent level of NDM. A commercially acceptable loaf volume, however, was obtained with 6 percent level of NDM with treatments of 0.10 and 0.20 percent H_2O_2.

The effect of milk treatment and dough oxidant on loaf volume is summarized in Table 2 of the Appendix. Dough oxidant at 60 p.p.m. significantly increased loaf volume in all cases except at 0.20 percent H_2O_2 treatment. Apparently doughs were underoxidized with 30 p.p.m. dough oxidant. Loaf volume was significantly decreased at the 6 percent level of NDM as opposed to 3 percent NDM at all levels of dough oxidant (Appendix Table 3). The use of 6 percent NDM had an apparent depressing effect upon loaf volume.

Loaf volume was depressed significantly at the mixing speed of 147 r.p.m., compared to the mixing speed of 125 r.p.m. only with the control (Appendix Table 4). In addition, loaf volume was depressed significantly at the mixing speed of 171 r.p.m. compared to 147 r.p.m. at 0.05 and 0.075

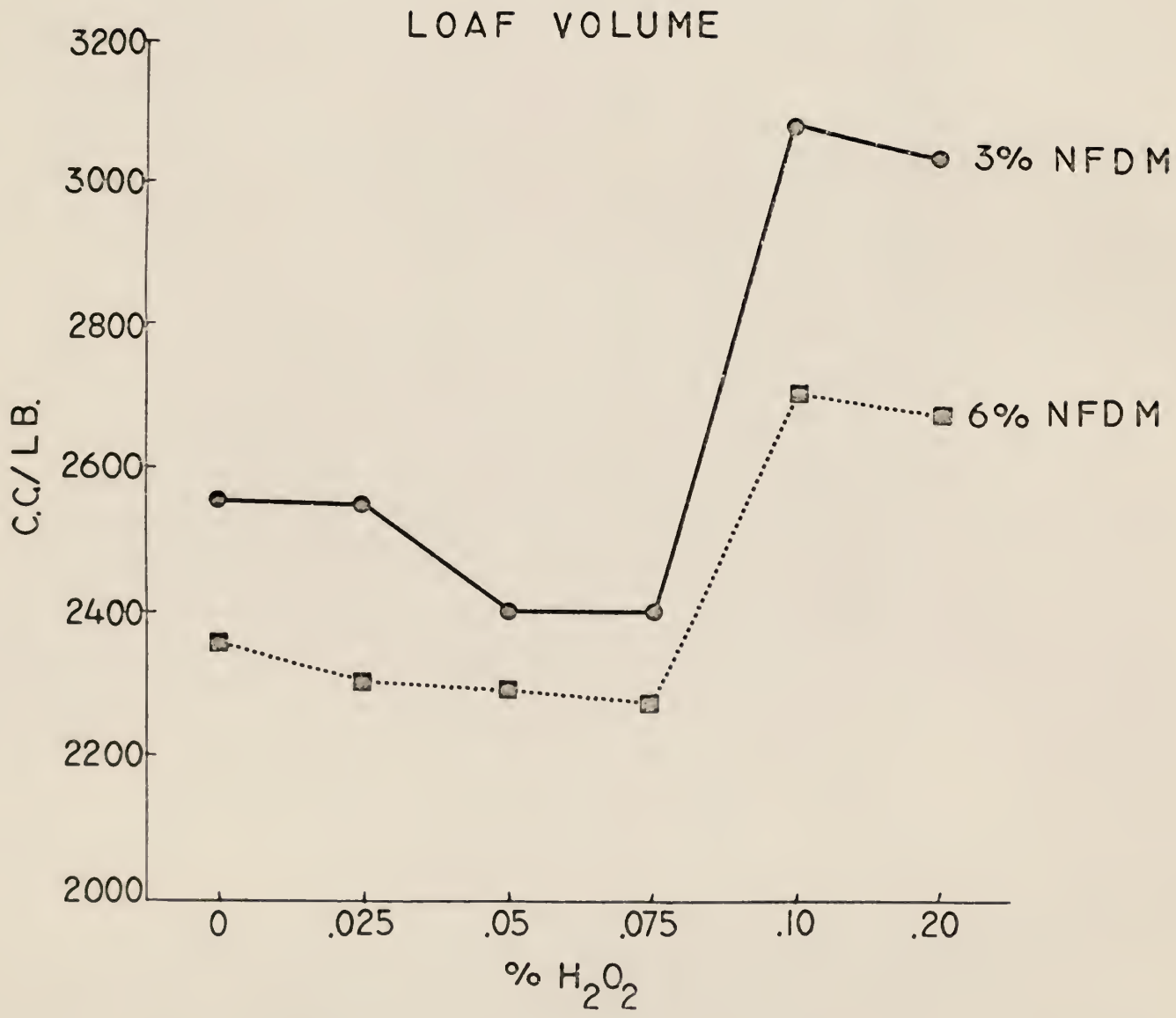

Fig. 2. The Effect of H_2O_2 Treatment of NDM on Loaf Volume

percent H_2O_2 treatment. Under these conditions doughs were apparently overmixed. Loaf volume was decreased significantly at 6 percent NDM compared to 3 percent NDM for all mixing speeds (Appendix, Table 5). Again, this table shows that the use of 6 percent NDM had a depressing effect upon loaf volume. The effects of milk treatment, dough oxidant and the amount of milk on loaf volume are summarized in Table 6 of the Appendix.

Appendix Tables 7 - 12 pertain to loaf volume score where specific loaf volume was converted to a maximum score of 25 points so that a total loaf score could be calculated taking into account loaf volume.

Exterior Appearance

Exterior appearance scores (15 pts. max.) are summarized in Fig. 3. and Table 13 of the Appendix. These scores were based on the overall general appearance of the loaves before being sliced. As shown in Fig. 3, the highest exterior appearance scores were obtained at the 0.10 percent H_2O_2 treatment at the 6 percent level of NDM and at the 0.20 percent H_2O_2 treatment with 3 percent NDM in the formula. The severe depression in exterior appearance score with 0.10 percent H_2O_2 treatment at 3 percent NDM can be explained partially as experimental error. At this point in the experiment the proof cabinet developed a high relative himidity. Water condensed in some of the bread pans and had a noticeable effect on the appearance of the loaf after baking.

Exterior appearance score was significantly increased with 60 p.p.m. dough oxidant with the control and the 0.20 percent H_2O_2 treatment over 30 p.p.m. dough oxidant (Appendix, Table 14). At 90 p.p.m. dough oxidant, exterior appearance score was significantly increased over 60 p.p.m. dough oxidant at the 0.025 percent H_2O_2 treatment.

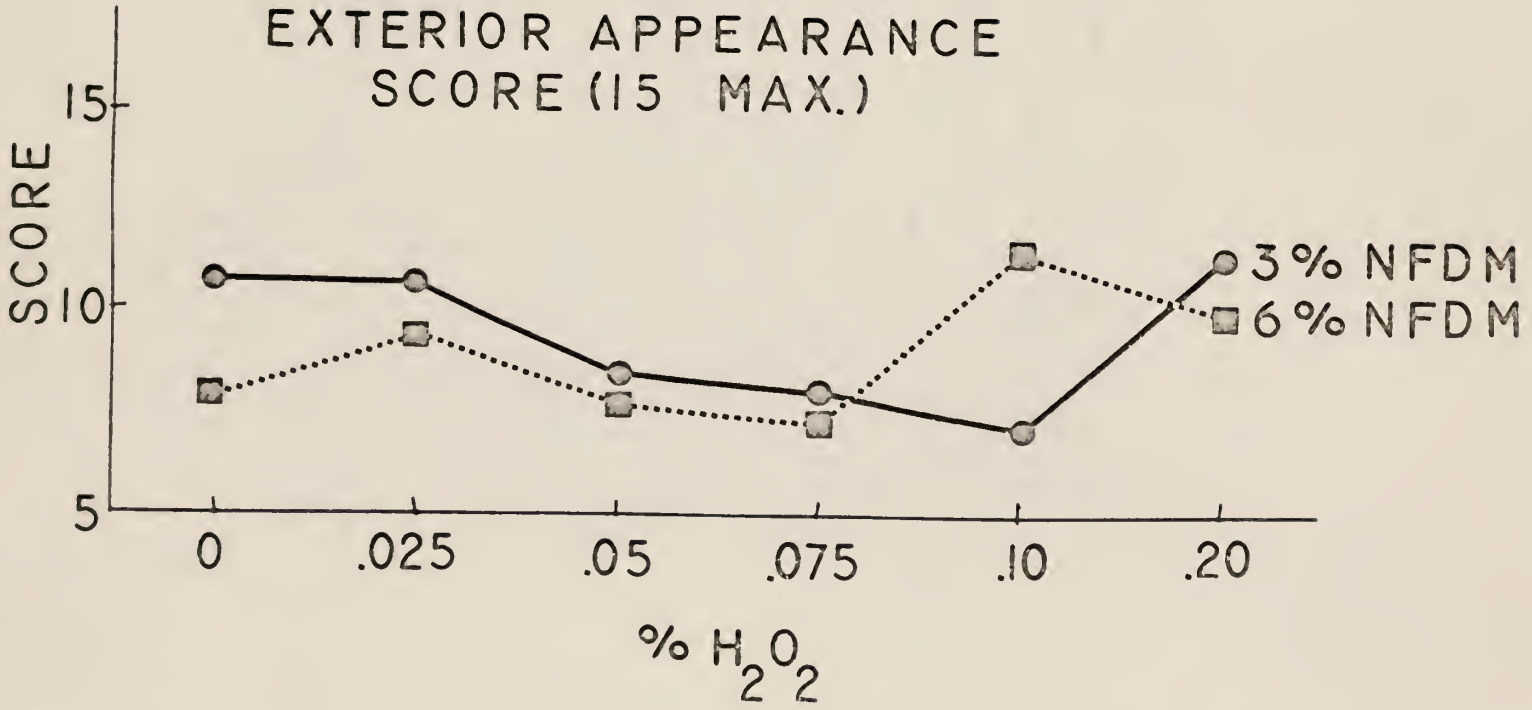

Fig. 3. The Effect on H_2O_2 Treatment of NDM on Exterior Appearance Score

Exterior appearance score was significantly increased at 60 p.p.m. dough oxidant over 30 p.p.m. dough oxidant at both 3 and 6 percent levels of NDM (Appendix, Table 15). This score also was increased significantly at 90 p.p.m. dough oxidant compared to 60 p.p.m. dough oxidant with 3 percent NDM. Apparently, higher dough oxidation improved exterior appearance score.

Exterior appearance score was decreased significantly at 171 r.p.m. mixing speed compared to 147 r.p.m. with the control and the three lower levels of H_2O_2 treatment (Appendix, Table 16). The overmixing of these doughs had a drastic effect on loaf appearance. The higher levels of H_2O_2 treatment, 0.10 and 0.20 percent, apparently counteracted the adverse effects of the higher mixing speed on exterior appearance score. Exterior appearance score was increased significantly with 6 percent NDM compared to 3 percent NDM at 125 r.p.m. mixing speed; however, at the two higher mixing speeds exterior appearance score was decreased significantly with 6 percent NDM compared to 3 percent NDM (Appendix, Table 17).

The combined effect of milk treatment, dough oxidant and the amount of milk on exterior appearance score is summarized in Table 18 of the Appendix. A similar comparison involving milk treatment, dough oxidant and mixing speed on exterior appearance score is summarized in Table 19 of the Appendix.

Grain Score

Grain score (30 points maximum) is summarized in Fig. 4. Grain score was increased significantly at levels of 0.10 and 0.20 percent H_2O_2 treatment at both the 3 and 6 percent levels of NDM. The general trend was a greater grain score at the 3 percent level of NDM than with 6

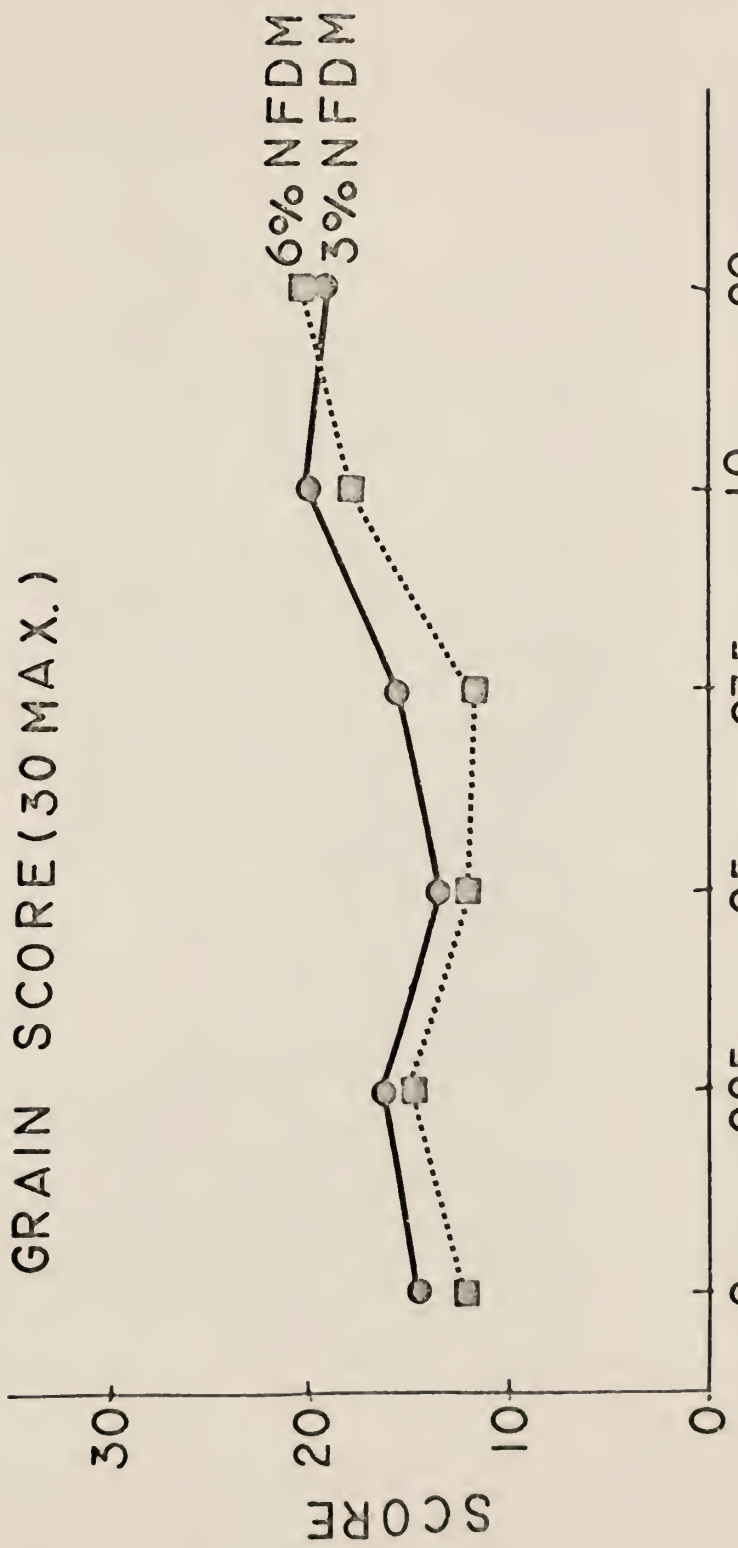

Fig. 4. The Effect of H_2O_2 Treatment of NDM on Grain Score

percent. Grain scores were decreased significantly with the use of 6 percent NDM compared to 3 percent with all H_2O_2 treatments except the 0.20 percent (Appendix, Table 20).

There was a general improvement in grain score with increases in the amount of dough oxidant (Appendix, Table 21). Apparently, the higher oxidation levels were necessary for the development of desirable grain. Grain score was decreased significantly with the use of 6 percent NDM compared to 3 percent NDM (Appendix, Table 22) with 60 and 90 p.p.m. dough oxidant.

Grain score was decreased significantly at mixing speeds of 147 r.p.m. and 171 r.p.m. with the 6 percent level of NDM compared to 3 percent NDM. At the lower mixing speed, 125 r.p.m. grain score was slightly increased with 6 percent NDM (Appendix. Table 23). Grain scores were decreased significantly at both the 3 and 6 percent levels of NDM at 171 r.p.m. mixing speed compared to 147 r.p.m. (Appendix, Table 23). Doughs apparently were overmixed at the highest mixing speed resulting in a very definite effect on grain score.

The combined effect of milk treatment, dough oxidant and the amount of milk on grain score is summarized in the Appendix, Table 24. Likewise the combined effect of milk treatment, the amount of milk and mixing speed on grain score is summarized in the Appendix, Table 25.

Texture Score

Texture score (30 points maximum) is summarized in Fig. 5. The most desirable texture scores were obtained at levels of 0.10 and 0.20 percent H_2O_2 treatment at both the 3 and 6 percent levels of NDM. With the 3 percent level of NDM the texture score was greater

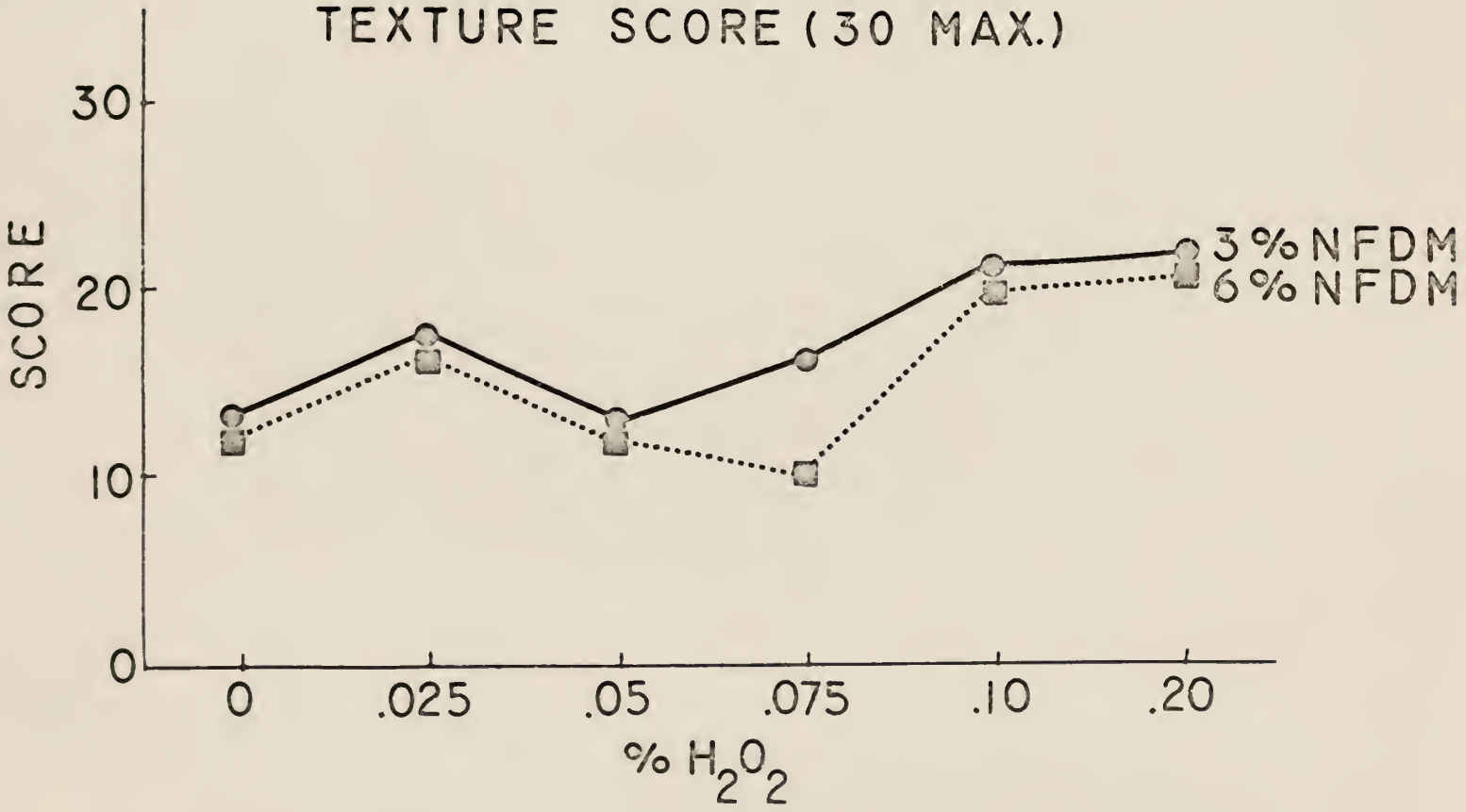

Fig. 5. The Effect of H_2O_2 Treatment of NDM on Texture Score

than with the use of 6 percent NDM. With the control, 0.075 percent H_2O_2 and 0.20 percent H_2O_2 the texture score was significantly greater with 3 percent NDM than with the use of 6 percent NDM (Appendix, Table 26).

Texture score was increased significantly at all levels of H_2O_2 treatment except 0.05 percent H_2O_2 with 60 p.p.m. dough oxidant compared to 30 p.p.m. dough oxidant (Appendix, Table 27). Texture score was increased significantly with the control and 0.025 percent H_2O_2 with the use of 90 p.p.m. dough oxidant compared to 60 p.p.m. dough oxidant. Texture scores were increased at the other levels of H_2O_2 with 90 p.p.m. dough oxidant but not to a significant degree. With the use of 6 percent NDM compared to 3 percent NDM, texture score was decreased significantly only with 90 p.p.m. dough oxidant (Appendix, Table 28).

With the use of all three mixing speeds, texture score decreased significantly with the use of 6 percent NDM compared to 3 percent NDM (Appendix Table 29). Apparently this decrease in score was due to the higher percentage of milk, but the mixing speeds had very little effect. At both 3 and 6 percent levels of NDM the texture score decreased significantly at the mixing speed of 171 r.p.m. These doughs apparently were overmixed, greatly affecting the texture.

The combined effect of milk treatment, dough oxidant and the amount of milk on texture score is summarized in the Appendix, Table 30.

Total Loaf Score

Total loaf scores were obtained by compiling the scores of the various characteristics (loaf volume, exterior appearance, grain and

texture). Total loaf scores are summarized in Fig. 6. The highest total loaf scores were obtained with the use of 0.10 and 0.20 percent H_2O_2 treatment at both the 3 and 6 percent levels of NDM. However, total loaf scores were significantly lower with the use of 6 percent NDM compared to 3 percent NDM at all H_2O_2 treatments except 0.10 percent. (Appendix, Table 31)

Total loaf scores increased significantly with all H_2O_2 treatments with the use of 60 p.p.m. dough oxidant comapred to 30 p.p.m. dough oxidant (Appendix, Table 32). At 90 p.p.m. compared to 60 p.p.m. total loaf score was increased significantly at all levels of H_2O_2 treatment except 0.20 percent. Total loaf score decreased significantly at all levels of dough oxidant with the use of 6 percent NDM compared to 3 percent NDM (Appendix, Table 33).

Total loaf scores decreased significantly with all mixing speeds used at the 6 percent level of NDM compared to the use of 3 percent NDM (Appendix, Table 34). At the highest mixing speed (171 r.p.m.), total loaf score decreased significantly at both the 3 and 6 percent level of NDM. At this mixing speed, doughs were apparently overmixed.

The combined effect of milk treatment, dough oxidant and amount of milk on total loaf score is summarized in Appendix, Table 35.

The interaction of milk treatment, dough oxidant and mixing speed on total loaf score is summarized in Appendix, Table 36.

Crust Color

Crust color measurements are summarized in the Appendix, Tables 37 - 39. It would be expected that with the use of 6 percent NDM compared to 3 percent NDM, the crust color would be darker. Table 37

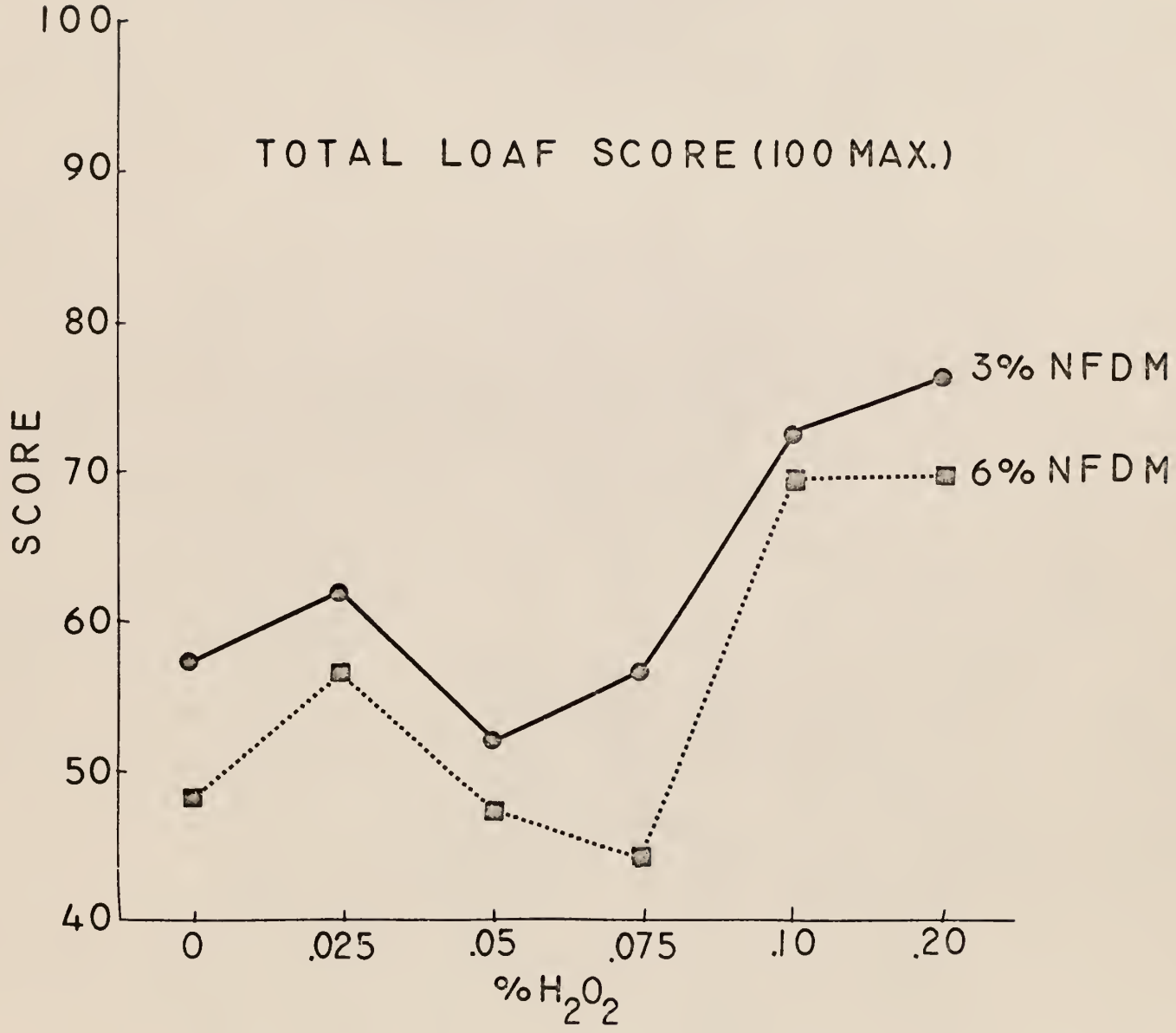

Fig. 6. The Effect of H_2O_2 Treatment of NDM on Total Loaf Score

of the Appendix does not show this to be so. This could probably be explained by slight variations in oven temperatures and time of baking. The oven temperatures was difficult to precisely control due to the oven door being opened periodically to insert and remove bread.

Power Requirements

Power requirements were calculated at the different mixing speeds, however, no statistical significance was shown.

SUMMARY

Part I

The following summarizes the findings from this study using H_2O_2 treated NDM in continuous mix bread:

1. Loaf volume increased significantly with 0.10 and 0.20 percent H_2O_2 treatment of NDM at both the 3 and 6 percent usage levels. A significant depression in loaf volume was observed with 0.05 and 0.075 percent H_2O_2 treatment of NDM.

2. Exterior appearance score increased significantly with 0.10 and 0.20 percent H_2O_2 treatment of NDM at the 6 percent level of NDM and with 0.20 percent H_2O_2 treatment of NDM at the 3 percent level. A depression in exterior appearance was observed with 0.05 and 0.075 percent H_2O_2 treatment of NDM at both levels of NDM.

3. Grain score increased significantly with 0.10 and 0.20 percent H_2O_2 treatment of NDM at both levels of NDM. A slight depression was observed at both levels of NDM with H_2O_2 treatment of 0.05 and 0.075 percent.

4. Texture score increased significantly with 0.10 and 0.20 percent H_2O_2 treatment of NDM at both levels. A depression in texture score was observed with H_2O_2 treatment of 0.05 and 0.075 percent at both levels of NDM.

5. Total loaf score increased significantly at both levels of NDM with the use of 0.10 and 0.20 percent H_2O_2 treatment of the NDM. A severe depression in total loaf score was observed with 0.05 and 0.075 percent H_2O_2 treatment at both levels.

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APPENDIX

PART I

Table 1. Effect of milk treatment and amount of milk on bread loaf volume (c.c./lb)

Milk Treatment	Amount of Milk		
	3% Milk		6% Milk
Heated 185°F/30 min.	2556	*	2362
Heated 185°F/30 min. 0.025% H_2O_2	2555	*	2306
	*		
Heated 185°F/30 min. 0.05% H_2O_2	2405	*	2295
Heated 185°F/30 min. 0.075% H_2O_2	2400	*	2273
	*		
Heated 185°F/ 30 min. 0.10% H_2O_2	3081	*	2708
Heated 185°F/30 min. 0.20% H_2O_2	3036	*	2678

LSD = 61.23 5% level of significance

* Significantly different from adjacent values

Table 2. Effect of milk treatment and dough oxidant on bread loaf volume (c.c./lb.)

Milk Treatment	Dough Oxidant (p.p.m.) 30		60		90
Heated 185°F/30 min.	2366	*	2481		2529
Heated 185°F/30 min. 0.025% H_2O_2	2327	*	2434	*	2530
			*		*
Heated 185°F/30 min. 0.05% H_2O_2	2266	*	2343	*	2441
Heated 185°F/30 min. 0.075% H_2O_2	2260	*	2337		2411
	*		*		*
Heated 185°F/30 min. 0.10% H_2O_2	2830	*	2912		2942
					*
Heated 185°F/30 min. 0.20% H_2O_2	2892		2895	*	2785

LSD = 75.03 5% level of significance

* Significantly different from adjacent values

Table 3. Effect of dough oxidant and amount of milk on bread loaf volume (c.c./lb.)

Dough Oxidant (p.p.m.)	Amount of Milk		
	3% Milk		6% Milk
30	2594	*	2387
	*		*
60	2671	*	2463
	*		
90	2751	*	2461

LSD = 43.47 5% level of significance

* Significantly different from adjacent values

Table 4. Effect of milk treatment and mixing speed on bread loaf volume. (c.c./lb.)

Milk Treatment	Mixing Speed (r.p.m.) 125		147		171
Heated 185°F/30 min.	2518	*	2442		2416
Heated 185°F/30 min. 0.025% H_2O_2	2494		2422		2375
	*				*
Heated 185°F/30 min. 0.05% H_2O_2	2418		2388	*	2244
Heated 185°F/30 min. 0.075% H_2O_2	2402		2366	*	2241
	*		*		*
Heated 185°F/30 min. 0.10% H_2O_2	2900		2870		2913
					*
Heated 185°F/30 min. 0.20% H_2O_2	2850		2895		2828

LSD = 75.05 5% level of significance

* Significantly different from adjacent values

Table 5. Effect of amount of milk and mixing speed on bread loaf volume (c.c./lb.)

	Amount of Milk		
Mixing Speed	3% Milk		6% Milk
125	2680	*	2513
			*
147	2711	*	2417
	*		
171	2625	*	2381

LSD = 43.47 5% level of significance

* Significantly different from adjacent values

Table 6. Effect of milk treatment, dough oxidant and amount of milk on bread loaf volume (c.c./lb.)

	Dough Oxidant (p.p.m.)					
	30		60		90	
Milk Treatment	3% Milk	6% Milk	3% Milk	6% Milk	3% Milk	6% Milk
Heated 185°F/30 min.	2335	2397	* 2609	* 2353	* 2722	* 2335
	*	*	*			
Heated 185°F/30 min. 0.025% H_2O_2	2530	* 2123	* 2498	* 2368	* 2634	* 2426
	*		*		*	
Heated 185°F/30 min. 0.05% H_2O_2	2335	* 2197	* 2337	2307	* 2503	* 2379
Heated 185°F/30 min. 0.075% H_2O_2	2343	* 2178	* 2341	2333	* 2515	* 2306
	*	*	*	*	*	*
Heated 185°F/30 min. 0.10% H_2O_2	2978	* 2682	* 3076	* 2746	* 3187	* 2696
					*	
Heated 185°F/30 min. 0.20% H_2O_2	3042	* 2742	* 3122	* 2668	* 2945	* 2624

LSD = 106.38 5% level of significance

* Significantly different from adjacent values

Table 7. Effect of milk treatment and amount of milk on loaf volume score (25 max.)

	Amount of Milk		
Milk Treatment	3% Milk		6% Milk
Heated 185°F/30 min.	18.166	*	16.055
Heated 185°F/30 min. 0.025% H_2O_2	18.222	*	15.500
	*		
Heated 185°F/30 min. 0.05% H_2O_2	16.500	*	15.277
Heated 185°F/30 min. 0.075% H_2O_2	16.388	*	15.000
	*		*
Heated 185°F/30 min. 0.10% H_2O_2	23.722	*	19.888
Heated 185°F/30 min. 0.20% H_2O_2	23.388	*	19.500

LSD = .647 5% level of significance

* Significantly different fram adjacent values

Table 8. Effect of milk treatment and dough oxidant on loaf volume score (25 max.)

Milk Treatment	Dough Oxidant (p.p.m.) 30		60		90
Heated 185°F30 min.	16.166	*	17.250		17.916
Heated 185°F/30 min. 0.025% H_2O_2	15.750	*	16.916	*	17.916
			*		*
Heated 185°F/30 min. 0.05% H_2O_2	15.083		15.750	*	16.833
Heated 185°F/30 min. 0.075% H_2O_2	14.916		15.666	*	16.500
	*		*		*
Heated 185°F/30 min. 0.10% H_2O_2	21.166	*	22.083		22.166
					*
Heated 185°F/30 min. 0.20% H_2O_2	21.750		21.833	*	20.750

LSD = .794 5% level of significance

* Significantly different from adjacent values

Table 9. Effect of dough oxidant and amount of milk on loaf volume score (25 max.)

Dough Oxidant (p.p.m.)	Amount of Milk		
	3% Milk		6% Milk
30	18.611	*	16.333
	*		*
60	19.388	*	17.111
	*		*
90	20.194	*	17.166

LSD = .459 5% level of significance

* Significantly different from adjacent values

Table 10. Effect of milk treatment and mixing speed on loaf volume score (25 max.)

Milk Treatment	Mixing Speed (r.p.m.) 125		147		171
Heated 185°F/30 min.	17.750	*	16.916		16.666
Heated 185°F/30 min. 0.025% H_2O_2	17.500		16.750		16.333
	*				*
Heated 185°F/30 min. 0.05% H_2O_2	16.666		16.250	*	14.750
Heated 185°F/30 min. 0.075% H_2O_2	16.416		16.000	*	14.666
	*		*		*
Heated 185°F/30 min. 0.10% H_2O_2	21.916		21.500		22.000
Heated 185°F/30 min. 0.20% H_2O_2	21.416		21.750		21.666

LSD = .794 5% level of significance

* Significantly different from adjacent values

Table 11. Effect of amount of milk and mixing speed on loaf volume score (25 max.)

Mixing Speed	Amount of Milk		
(r.p.m.)	3% Milk		6% Milk
125	19.527	*	17.694
			*
147	19.750	*	16.638
	*		
171	18.916	*	16.277

LSD = .459 5% level of significance

* Significantly different from adjacent values

Table 12. Effect of milk treatment, dough oxidant and amount of milk on loaf volume score (25 max.)

	Dough Oxidant (p.p.m.)					
	30		64		90	
Milk Treatment	3% Milk	6% Milk	3% Milk	6% Milk	3% Milk	6% Milk
Heated 185°F/30 min.	15.833	16.500	* 18.666 *	15.833	* 20.000 *	15.833
	*	*				
Heated 185°F/30 min. 0.025% H_2O_2	18.000	* 13.500	* 17.666 *	16.166	* 19.000 *	16.833
	*		*		*	
Heated 185°F/30 min. 0.05% H_2O_2	15.833	* 14.333	* 16.166	15.333	* 17.500 *	16.166
Heated 185°F/30 min. 0.075% H_2O_2	15.833	* 14.000	* 15.666	15.666	* 17.666 *	15.333
	*	*	*	*	*	*
Heated 185°F/30 min. 0.10% H_2O_2	22.833	* 19.500	* 23.833 *	20.333	* 24.500 *	19.833
					*	
Heated 185°F/30 min. 0.20% H_2O_2	23.333	* 20.166	* 24.333 *	19.333	* 22.500 *	19.000

LSD = 1.128 5% level of significance

* Significantly different from adjacent values

Table 13. Effect of milk treatment and amount of milk on exterior appearance score (15 max.)

Milk Treatment	Amount of Milk: 3% Milk		6% Milk
Heated 185°F/30 min.	10.888	*	8.000
			*
Heated 185°F/e0 min. 0.025% H_2O_2	10.777	*	9.555
	*		*
Heated 185°F/30 min. 0.05% H_2O_2	8.555		7.777
Heated 185°F/30 min. 0.075% H_2O_2	8.222	*	7.333
	*		*
Heated 185°F/30 min. 0.10% H_2O_2	7.111	*	11.555
	*		*
Heated 185°F/30 min. 0.20% H_2O_2	11.333	*	10.333

LSD = .794 5% level of significance

* Significantly different from adjacent values

Table 14. Effect of milk treatment and dough oxidant on exterior appearance score (15 max.)

Milk Treatment	Dough Oxidant (p.p.m.) 30		60		90
Heated 185°F/30 min.	8.833	*	9.833		9.666
					*
Heated 185°F/30 min. 0.025% H_2O_2	9.166		10.000	*	11.333
	*		*		*
Heated 185°F/30 min. 0.05% H_2O_2	7.000		8.333		9.166
					*
Heated 185°F/30 min. 0.075% H_2O_2	7.166		8.000		8.166
	*				*
Heated 185°F/30 min. 0.10% H_2O_2	8.500		8.666		10.833
			*		
Heated 185°F/30 min. 0.20% H_2O_2	9.000	*	11.666		11.333

LSD = .961 5% level of significance

* Significantly different from adjacent values

Table 15. Effect of dough oxidant and amount of milk on exterior appearance score (15 max.)

Dough Oxidant	Amount of Milk		
(p.p.m.)	3% Milk		6% Milk
30	8.277		8.277
	*		*
60	9.500		9.333
	*		
90	10.666	*	9.500

LSD = .564 5% level of significance

* Significantly different from adjacent values

Table 16. Effect of milk treatment and mixing speed on exterior appearance score (15 max.)

Milk Treatment	Mixing Speed (r.p.m.) 125		147		171
Heated 185°F/30 min.	10.500		10.166	*	7.666
Heated 185°F/30 min. 0.025% H_2O_2	10.500	*	10.666	*	9.333
Heated 185°F/30 min. 0.05% H_2O_2	9.333	*	8.500	*	6.666
Heated 185°F/30 min. 0.075% H_2O_2	9.000	*	8.166	*	6.166
Heated 185°F/30 min. 0.10% H_2O_2	9.500	*	9.333	*	9.166
Heated 185°F/30 min. 0.20% H_2O_2	11.000		10.333		10.666

LSD = .961 5% level of significance

* Significantly different from adjacent values

Table 17. Effect of the amount of milk and mixing speed on exterior appearance score (15 max.)

Mixing Speed	Amount of Milk		
(r.p.m.)	3% Milk		6% Milk
125	9.666	*	10.277
			*
147	10.111	*	8.944
	*		*
171	8.666	*	7.888

LSD = .564 5% level of significance

* Significantly different from adjacent values

Table 18. Effect of milk treatment, dough oxidant and amount of milk on exterior appearance score (15 max.)

	Dough Oxidant (p.p.m.)					
	30		60		90	
Milk Treatment	3% Milk	6% Milk	3% Milk	6% Milk	3% Milk	6% Milk
Heated 185°F/30 min.	8.666	9.000	* 11.666 *	8.000	* 12.333 *	7.000
	*		*	*		*
Heated 185°F/30 min. 0.025% H_2O_2	10.333 *	8.000 *	9.666	10.333	* 12.333 *	10.333
	*			*	*	*
Heated 185°F/30 min. 0.05% H_2O_2	7.000	7.000 *	8.666	8.000	* 10.000 *	8.333
					*	
Heated 185°F/30 min. 0.075% H_2O_2	7.666	6.666 *	8.666	7.333	8.333	8.000
	*	*	*	*		*
Heated 185°F/30 min. 0.10% H_2O_2	6.000 *	11.000 *	6.000 *	11.333	* 9.333 *	12.333
	*	*	*		*	
Heated 185°F/30 min. 0.20% H_2O_2	10.000 *	8.000 *	12.333	11.000	12.333	11.000

LSD = 1.358 5% level of significance

* Significantly different from adjacent values

Table 19. Effect of milk treatment, dough oxidant and mixing speed on exterior appearance score (15 max.)

	Mixing Speed (r.p.m.)								
	125			147			171		
	Dough Oxidant (p.p.m.)								
Milk Treatment	30	60	90	30	60	90	30	60	90
Heated 185°F/30 min.	10.5	10.0	11.0 *	9.0	* 11.0	10.5 *	7.0	8.5	7.5
Heated 185°F/30 min. 0.025% H_2O_2	9.0	10.5 *	12.0 *	10.0 *	10.5	11.5 *	8.5 *	9.0 *	10.5 *
Heated 185°F/30 min. 0.05% H_2O_2	8.5	8.5	* 11.0 *	7.0	* 9.5	9.0 *	5.5	7.0	7.5
Heated 185°F/30 min. 0.075% H_2O_2	8.5	9.0	9.5 *	7.5	8.0	9.0 *	5.5	7.0	6.0
						*	*		*
Heated 185°F/30 min. 0.10% H_2O_2	9.0	9.0	10.5 *	8.5	8.5	* 11.0 *	8.0	8.5	* 11.0
	*	*		*	*			*	
Heated 185°F/30 min. 0.20% H_2O_2	11.0	11.5	10.5	9.0	* 11.0	11.0 *	7.0	*12.5	12.5

LSD = 1.672 5% level of significance

* Significantly different from adjacent values.

Table 20. Effect of milk treatment and amount of milk on grain score (30 max.)

Milk Treatment	Amount of Milk		
	3% Milk		6% Milk
Heated 185°F/30 min.	14.555	*	12.333
	*		*
Heated 185°F/30 min. 0.025% H_2O_2	16.444	*	15.000
	*		*
Heated 185°F/30 min. 0.05% H_2O_2	13.777	*	12.333
	*		
Heated 185°F/30 min. 0.075% H_2O_2	15.666	*	11.777
	*		*
Heated 185°F/30 min. 0.10% H_2O_2	20.222	*	18.000
			*
Heated 185°F/30 min. 0.20% H_2O_2	19.666		19.777

LSD = 1.212 5% level of significance

* Significantly different from adjacent values

Table 21. Effect of milk treatment and dough oxidant on grain score (30 max.)

Milk Treatment	Dough Oxidant (p.p.m.) 30		60		90
Heated 185°F/30 min.	9.166	*	13.666	*	17.500
	*		*		*
Heated 185°F/30 min. 0.025% H_2O_2	10.333	*	15.166	*	21.666
	*		*		*
Heated 185°F/30 min. 0.05% H_2O_2	9.666	*	12.666	*	16.833
			*		
Heated 185°F/30 min. 0.075% H_2O_2	9.500	*	14.333	*	17.333
	*		*		*
Heated 185°F/30 min. 0.10% H_2O_2	18.166		19.500		19.666
					*
Heated 185°F/30 min. 0.20% H_2O_2	18.000	*	20.000		21.166

LSD = 1.483 5% level of significance

* Significantly different from adjacent values

Table 22. Effect of dough oxidant and amount of milk on grain score (30 max.)

Dough Oxidant	Amount of Milk		
(p.p.m.)	3% Milk		6% Milk
30	12.444		12.500
	*		*
60	16.333	*	15.444
	*		*
90	21.388	*	16.666

LSD = .856 5% level of significance

* Significantly different from adjacent values

Table 23. Effect of amount of milk and mixing speed on grain score (30 max.)

Mixing Speed	Amount of Milk		
(r.p.m.)	3% Milk		6% Milk
125	17.666		17.722
			*
147	17.777	*	14.722
	*		*
171	14.723	*	12.166

LSD = .856 5% level of significance

* Significantly different from adjacent values

Table 24. Effect of milk treatment, dough oxidant and amount of milk on grain score (30 max.)

	Dough Oxidant (p.p.m.)					
	30		60		90	
Milk Treatment	3% Milk	6% Milk	3% Milk	6% Milk	3% Milk	6% Milk
Heated 185°F/30 min.	8.000 *	10.333 *	13.333	14.000 *	22.333 *	12.666
	*					*
Heated 185°F/30 min. 0.025% H_2O_2	10.333	10.333 *	14.666	15.666 *	24.333 *	19.000
				*	*	*
Heated 185°F/30 min. 0.05% H_2O_2	9.666	9.666 *	13.000	12.333 *	18.666 *	15.000
			*			
Heated 185°F/30 min. 0.075% H_2O_2	10.333	8.666 *	16.333 *	12.333 *	20.333 *	14.333
	*	*	*	*		*
Heated 185°F/30 min. 0.10% H_2O_2	18.333	18.000 *	21.000 *	18.000 *	21.333 *	18.000
				*		*
Heated 185°F/30 min. 0.20% H_2O_2	18.000	18.000	19.666	20.333	21.333	21.000

LSD = 2.09 5% level of significance

* Significantly different from adjacent values

Table 25. Effect of milk treatment, amount of milk and mixing speed on grain score (30 max.)

	Mixing Speed (r.p.m.)					
	125		147		171	
Milk Treatment	3% Milk	6% Milk	3% Milk	6% Milk	3% Milk	6% Milk
Heated 185°F/30 min.	15.000	14.666 *	16.333 *	12.333	12.333 *	10.000 *
Heated 185°F/30 min. 0.025% H_2O_2	16.666	18.333 *	17.666 *	14.333	15.000 *	12.333 *
Heated 185°F/30 min. 0.05% H_2O_2	16.000	15.000	14.000 *	12.333	11.333	9.666
Heated 185°F/30 min. 0.075% H_2O_2	18.000 *	14.333 *	17.000 *	11.666 *	12.000 *	9.333 *
Heated 185°F/30 min. 0.10% H_2O_2	21.000	20.000 *	20.666 *	18.000	19.000 *	16.000
Heated 185°F/30 min. 0.20% H_2O_2	19.333 *	24.000 *	21.000	19.666	18.666 *	15.666

LSD = 2.09 5% level of significance

* Significantly different from adjacent values

Table 26. Effect of milk treatment and amount of milk on texture score (30 max.)

Milk Treatment	Amount of Milk		
	3% Milk		6% Milk
Heated 185°F/30 min.	13.666	*	12.222
	*		*
Heated 185°F/30 min. 0.025% H_2O_2	17.333		16.444
	*		*
Heated 185°F/30 min. 0.05% H_2O_2	13.333		12.111
	*		*
Heated 185°F/30 min. 0.075% H_2O_2	16.444	*	10.000
	*		*
Heated 185°F/30 min. 0.10% H_2O_2	21.111		20.111
Heated 185°F/30 min. 0.20% H_2O_2	21.777	*	20.444

LSD = 1.274 5% level of significance

* Significantly different from adjacent values

Table 27. Effect of milk treatment and dough oxidant on texture score (30 max.)

Milk Treatment	Dough Oxidant 30		60		90
Heated 185°F/30 min.	9.666	*	12.000	*	17.166
			*		*
Heated 185°F/30 min. 0.025% H_2O_2	10.833	*	16.666	*	23.166
			*		*
Heated 185°F/30 min. 0.05% H_2O_2	10.666		11.833		15.666
			*		
Heated 185°F/30 min. 0.085% H_2O_2	10.333	*	14.166		15.166
	*		*		*
Heated 185°F/30 min. 0.10% H_2O_2	18.333	*	21.000		22.500
Heated 185°F/30 min. 0.20% H_2O_2	19.333	*	21.833		22.166

LSD = 1.567 5% level of significance

* Significantly different from adjacent values

Table 28. Effect of dough oxidant and amount of milk on texture score (30 max.)

Dough Oxidant (p.p.m.)	Amount of Milk		
	3% Milk		6% Milk
30	13.333		13.055
	*		*
60	16.444		16.055
	*		
90	22.055	*	16.555

LSD = .898 5% level of significance

* Significantly different from adjacent values

Table 29. Effect of amount of milk and mixing speed on texture score (30 max.)

Mixing Speed	Amount of Milk		
(r.p.m.)	3% Milk		6% Milk
125	18.611	*	17.666
147	18.500	*	15.222
	*		*
171	14.722	*	12.777

LSD = .898 5% level of significance

* Significantly different from adjacent values

Table 30. Effect of milk treatment, dough oxidant and amount of milk on texture score (30 max.)

	Dough Oxidant (p.p.m.)					
	30		60		90	
Milk Treatment	3% Milk	6% Milk	3% Milk	6% Milk	3% Milk	6% Milk
Heated 185°F/ 30 min.	7.000 *	12.333 *	10.000 *	14.000 *	24.000 *	10.333
	*	*	*	*		*
Heated 185°F/30 min. 0.025% H_2O_2	11.666	10.000	15.000 *	18.333 *	25.333 *	21.000
			*	*	*	*
Heated 185°F/30 min. 0.05% H_2O_2	11.333	10.000	11.333	12.333	17.333 *	14.000
			*	*		*
Heated 185°F/30 min. 0.075% H_2O_2	12.000 *	8.666 *	18.333 *	10.000 *	19.000 *	11.333
	*	*	*	*	*	*
Heated 185°F/30 min. 0.10% H_2O_2	18.000	18.666	21.666 *	20.333	23.666 *	21.333
Heated 185°F/30 min. 0.20% H_2O_2	20.000	18.666	22.333 *	21.333	23.000	21.333

LSD = 2.215 5% level of significance

* Significantly different from adjacent values

Table 31. Effect of milk treatment and amount of milk on total loaf score (100 max.)

Milk Treatment	Amount of Milk		
	3% Milk		6% Milk
Heated 185°F/30 min.	57.277	*	48.611
	*		*
Heated 185°F/30 min. 0.025% H_2O_2	62.777	*	56.500
	*		*
Heated 185°F/30 min. 0.05% H_2O_2	52.166	*	47.500
	*		*
Heated 185°F/30 min. 0.075% H_2O_2	56.722	*	44.111
	*		*
Heated 185°F/30 min. 0.10% H_2O_2	72.166		69.555
	*		
Heated 185°F/30 min. 0.20% H_2O_2	76.166	*	69.722

LSD = 2.779 5% level of significance

* Significantly different from adjacent values

Table 32. Effect of milk treatment and dough oxidant on total loaf score (100 max.)

Milk Treatment	Dough Oxidant (p.p.m.) 30		60		90
Heated 185°F/30 min.	43.833	*	52.750	*	62.250
			*		*
Heated 185°F/30 min. 0.025% H_2O_2	46.083	*	58.750	*	74.083
	*		*		*
Heated 185°F/30 min. 0.05% H_2O_2	42.416	*	48.583	*	58.500
			*		
Heated 185°F/30 min. 0.075% H_2O_2	41.916	*	52.166	*	57.166
	*		*		*
Heated 185°F/30 min. 0.10% H_2O_2	66.166	*	71.250	*	75.166
			*		
Heated 185°F/30 min. 0.20% H_2O_2	68.083	*	75.333		75.416

LSD = 3.406 5% level of significance

* Significantly different from adjacent values

Table 33. Effect of dough oxidant and amount of milk on total loaf score (100 max.)

Dough Oxidant	Amount of Milk		
(p.p.m.)	3% Milk		6% Milk
30	52.666	*	50.166
	*		*
60	61.666	*	57.944
	*		
90	74.305	*	59.888

LSD = 1.964 5% level of significance

* Significantly different from adjacent values

Table 34. Effect of the amount of milk and mixing speed on total loaf score (100 max.)

Mixing Speed	Amount of Milk		
(r.p.m.)	3% Milk		6% Milk
125	65.472	*	63.361
			*
147	66.138	*	55.527
	*		*
171	57.027	*	49.111

LSD = 1.964 5% level of significance

* Significantly different from adjacent values

Table 35. Effect of milk treatment, dough oxidant and amount of milk on total loaf score (100 max.)

	Dough Oxidant (p.p.m.)					
	30		60		90	
Milk Treatment	3% Milk	6% Milk	3%Milk	6% Milk	3% Milk	6% Milk
Heated 185°F/30 min.	39.500 *	48.166 *	53.666	51.833 *	78.666 *	45.833
	*	*		*		*
Heated 185°F/30 min. 0.025% H_2O_2	50.333 *	41.833 *	57.000 *	60.500 *	81.000 *	67.166 *
	*		*	*	*	*
Heated 185°F/30 min. 0.05% H_2O_2	43.833	41.000	49.166 *	48.000	63.500 *	53.500
			*			
Heated 185°F/30 min. 0.075% H_2O_2	45.833 *	38.000 *	59.000 *	45.333 *	65.333 *	49.000
	*	*	*	*	*	*
Heated 185°F/30 min. 0.10% H_2O_2	65.166	67.166	72.500 *	70.000	78.833 *	71.500
	*		*			
Heated 185°F/30 min. 0.20% H_2O_2	71.333 *	64.833 *	78.666 *	72.000 *	78.500 *	72.333

LSD = 4.807 5% level of significance

* Significantly different from adjacent values

Table 36. Effect of milk treatment, dough oxidant and mixing speed on total loaf score (100 max.)

	Mixing Speed (r.p.m.)								
	125			147			171		
	Dough Oxidant (p.p.m.)								
Milk Treatment	30	60	90	30	60	90	30	60	90
Heated 185°F/30 min.	53.25	52.75 *	68.75 *	43.25 *	56.75 *	65.75 *	35.00 *	48.75 *	52.25
		*	*			*			*
Heated 185°F/30 min. 0.025% H_2O_2	48.75 *	64.50 *	78.75 *	49.00 *	57.75 *	75.50 *	40.50 *	54.00 *	68.00
		*	*		*	*		*	*
Heated 185°F/30 min. 0.05% H_2O_2	48.00	52.50 *	68.50 *	43.25 *	51.00 *	57.50 *	36.00 *	42.25 *	49.50
						*			*
Heated 185°F/30 min. 0.075% H_2O_2	48.25 *	57.75 *	63.75 *	41.00 *	52.25 *	65.75 *	36.50 *	46.50	42.00
	*	*	*	*	*	*	*	*	*
Heated 185°F/30 min. 0.10% H_2O_2	71.75	74.00	77.50 *	62.75 *	72.00	77.75 *	64.00	67.75	70.25
Heated 185°F/30 min. 0.20% H_2O_2	74.50	79.50	76.75 *	68.50 *	76.75	78.50 *	61.25 *	69.75	71.00

LSD = 5.893 5% level of significance

* Significanctly different from adjacent values

Table 37. Effect of milk treatment and amount of milk on crust color (% reflectance of magnesium oxide)

Milk Treatment	Amount of Milk		
	3% Milk		6% Milk
Heated 185°F/30 min.	9.111	*	11.333
	*		*
Heated 185°F/30 min. 0.025% H_2O_2	17.222	*	14.555
	*		*
Heated 185°F/30 min. 0.05% H_2O_2	12.111		11.333
			*
Heated 185°F/30 min. 0.075% H_2O_2	13.222		14.333
	*		
Heated 185°F/30 min. 0.10% H_2O_2	15.222		15.333
	*		*
Heated 185°F/30 min. 0.20% H_2O_2	12.222		11.333

LSD = 1.254 5% level of significance

* Significantly different from adjacent values

Table 38. Effect of milk treatment and dough oxidant on crust color (% reflectance of magnesium oxide)

Milk Treatment	Dough Oxidant (p.p.m.) 30		60		90
Heated 185°F/30 min.	11.833	*	10.000		8.833
	*		*		*
Heated 185°F/30 min. 0.025% H_2O_2	16.500		15.833		15.333
	*		*		*
Heated 185°F/30 min. 0.05% H_2O_2	11.666		11.166		12.333
	*		*		
Heated 185°F/30 min. 0.075% H_2O_2	14.666	*	13.000		13.666
			*		*
Heated 185°F/30 min. 0.10% H_2O_2	14.166		14.833	*	16.833
	*		*		*
Heated 185°F/30 min. 0.20% H_2O_2	10.333		11.833		13.166

LSD = 1.54 5% level of significance

* Significantly different from adjacent values

Table 39. Effect of milk treatment, dough oxidant and amount of milk on crust color (% reflectance of magnesium oxide)

	Dough Oxidant (p.p.m.)					
	30		60		90	
Milk Treatment	3% Milk	6% Milk	3% Milk	6% Milk	3% Milk	6% Milk
Heated 185°F/30 min.	9.333 *	14.333 *	10.000	10.000	8.000	9.666
	*		*	*	*	*
Heated 185°F/30 min. 0.025% H_2O_2	17.000	16.000 *	18.333 *	13.333 *	16.333	14.333
	*	*	*	*	*	*
Heated 185°F/30 min. 0.05% H_2O_2	12.333	11.000	11.333	11.000	12.666	12.000
		*		*	*	
Heated 185°F/30 min. 0.075% H_2O_2	14.333	15.000 *	10.333 *	15.666	15.000 *	12.333
			*			*
Heated 185°F/30 min. 0.10% H_2O_2	15.000	13.333	14.000	15.666	16.666	17.000
	*	*		*	*	*
Heated 185°F/30 min. 0.20% H_2O_2	11.333	9.333 *	13.000 *	10.666	12.333	14.000

LSD = 2.152 5% level of significance

* Significantly different from adjacent values


NFDMS IN DOUGH 3%
MILK NO 1
MILK TREATMENT
HEATED 185 F/30 MIN.
MIXING SPEED
OXIDANT P P M
125 RPM
147 RPM
171 RPM
30
60
90


NFDMS IN DOUGH 3%
MILK TREATMENT
HEATED 185 F/30 MIN.
MILK NO 1
MIXING SPEED
125 RPM
147 RPM
171 RPM
OXIDANT P P M
30
60
90


NFDMS IN DOUGH 6%
MILK NO 1
MILK TREATMENT
HEATED 185 F/30 MIN.
MIXING SPEED
OXIDANT P P M
125 RPM
147 RPM
171 RPM
30
60
90


NFDMS IN DOUGH 6%
MILK TREATMENT
HEATED 185 F/30 MIN.
OXIDANT P P M
125 RPM
MILK NO 1
MIXING SPEED
147 RPM
171 RPM
30
60
90


NFDMS IN DOUGH 3%
MILK NO 1
MILK TREATMENT
HEATED 185 F/30 MIN.
.025% H. PEROXIDE
ANT P P M
MIXING SPEED
125 RPM
147 RPM
171 RPM
30
60
90


NFDMS IN DOUGH 3%
MILK TREATMENT
HEATED 185 F/30 MIN.
.025% H. PEROXIDE
MILK NO 1
MIXING SPEED
OXIDANT P P M
125 RPM
147 RPM
171 RPM
30
60
90


NFDMS IN DOUGH 6%
MILK NO 1
MILK TREATMENT
HEATED 185 F/30 MIN.
.025% H. PEROXIDE
MIXING SPEED
OXIDANT P P M
125 RPM
147 RPM
171 RPM
30
60
90


NFDMS IN DOUGH 6%
MILK TREATMENT
HEATED 185 F/30 MIN.
.025% H. PEROXIDE
MILK NO 1
MIXING SPEED
OXIDANT P P M
125 RPM
147 RPM
171 RPM
30
60
90


NFDMS IN DOUGH 3%
MILK TREATMENT
HEATED 185 F/30 MIN.
.050% H. PEROXIDE
MILK NO 1
MIXING SPEED
OXIDANT P P M
125 RPM
147 RPM
171 RPM
30
60
90

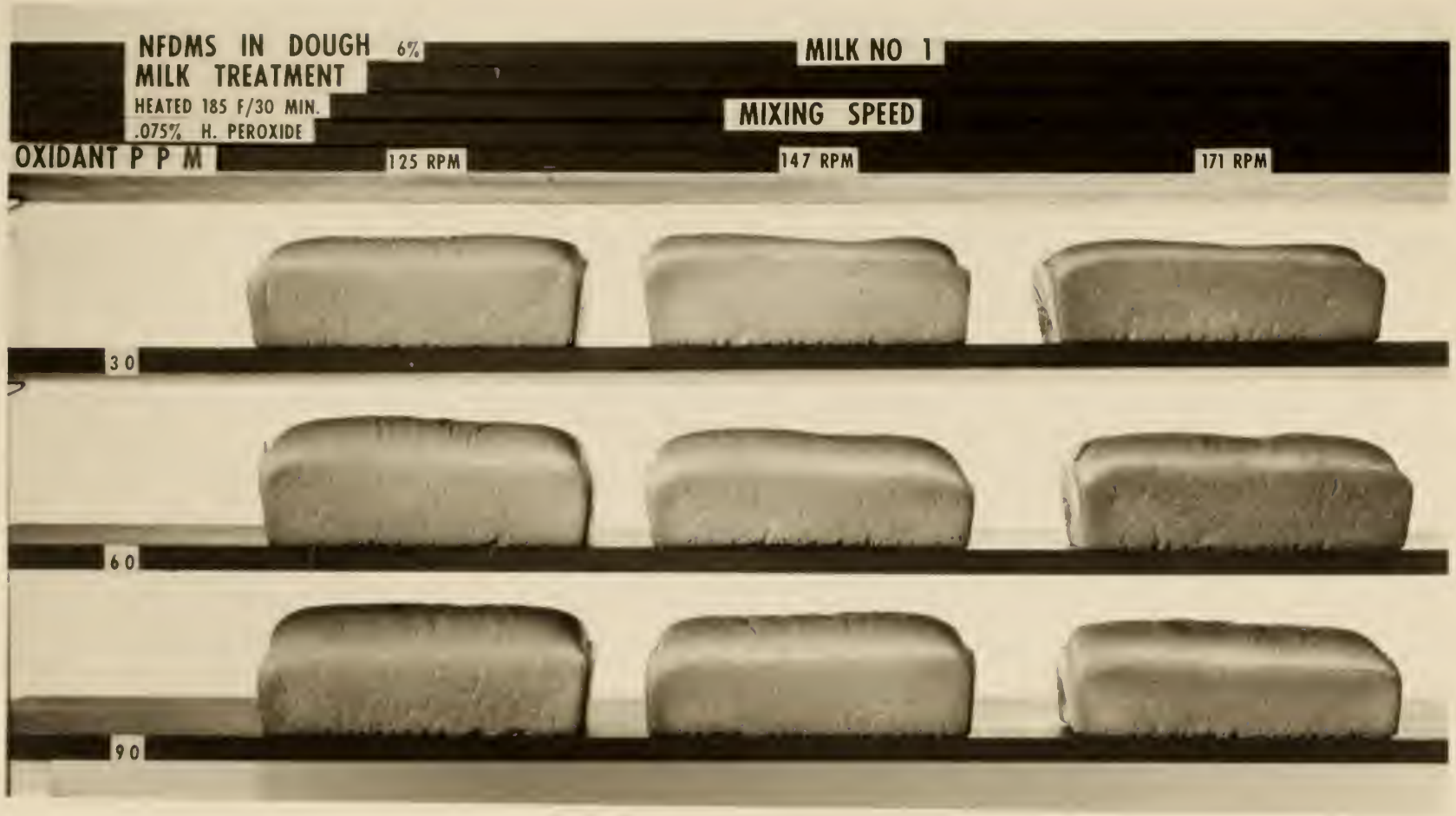

NFDMS IN DOUGH 3%
MILK TREATMENT
HEATED 185 F/30 MIN.
.050% H. PEROXIDE
OXIDANT P P M
MILK NO 1
MIXING SPEED
125 RPM
147 RPM
171 RPM
30
60
90


NFDMS IN DOUGH 6%
MILK TREATMENT
HEATED 185 F/30 MIN.
.050% H. PEROXIDE
OXIDANT P P M
125 RPM
MIXING SPEED
147 RPM
171 RPM
MILK NO 1
30
60
90


NFDMS IN DOUGH 6%
MILK TREATMENT
HEATED 185 F/30 MIN.
.050% H. PEROXIDE
MILK NO 1
MIXING SPEED
OXIDANT P P M
125 RPM
147 RPM
171 RPM
30
60
90


NFDMS IN DOUGH 3%
MILK TREATMENT
HEATED 185 F/30 MIN.
.075% H. PEROXIDE
MILK NO 1
MIXING SPEED
171 RPM
147 RPM
125 RPM
OXIDANT P P M
30
60
90


NFDMS IN DOUGH 3%
MILK TREATMENT
HEATED 185 F/30 MIN.
.075% H. PEROXIDE
OXIDANT P P M
MILK NO 1
MIXING SPEED
125 RPM
147 RPM
171 RPM
30
60


NFDMS IN DOUGH 6%
MILK TREATMENT
HEATED 185 F/30 MIN.
.075% H. PEROXIDE
MILK NO 1
MIXING SPEED
OXIDANT P P M
125 RPM
147 RPM
171 RPM
30
60
90


NFDMS IN DOUGH 3%
MILK TREATMENT
HEATED 185 F/30 MIN.
.100% H. PEROXIDE
MILK NO 1
MIXING SPEED
OXIDANT P P M
125 RPM
147 RPM
171 RPM
30
60
90


NFDMS IN DOUGH 6%
MILK TREATMENT
HEATED 185 F/30 MIN.
.075% H. PEROXIDE
MILK NO 1
MIXING SPEED
OXIDANT P P M
125 RPM
147 RPM
171 RPM
30
60
90


NFDMS IN DOUGH 3%
MILK TREATMENT
HEATED 185 F/30 MIN.
.100% H. PEROXIDE
MILK NO 1
MIXING SPEED
OXIDANT P P M
125 RPM
147 RPM
171 RPM
30
60
90


NFDMS IN DOUGH 6%
MILK TREATMENT
HEATED 185 F/30 MIN.
.100% H. PEROXIDE
MILK NO 1
MIXING SPEED
OXIDANT P P M
125 RPM
147 RPM
171 RPM
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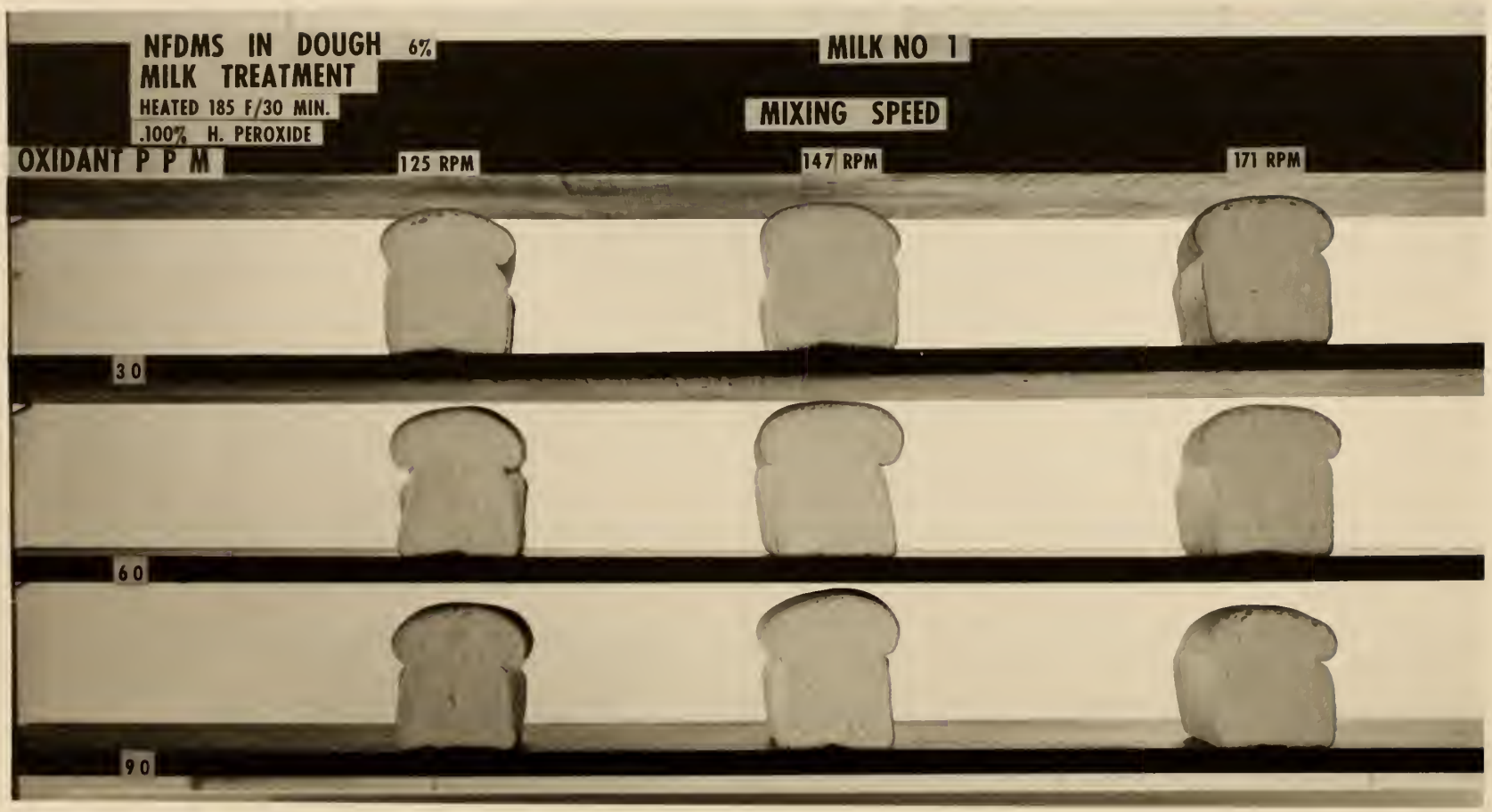
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.100% H. PEROXIDE
MILK NO 1
MIXING SPEED
OXIDANT P P M
125 RPM
147 RPM
171 RPM
30
60
90


NFDMS IN DOUGH 3%
MILK TREATMENT
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147 RPM
125 RPM
OXIDANT P P M
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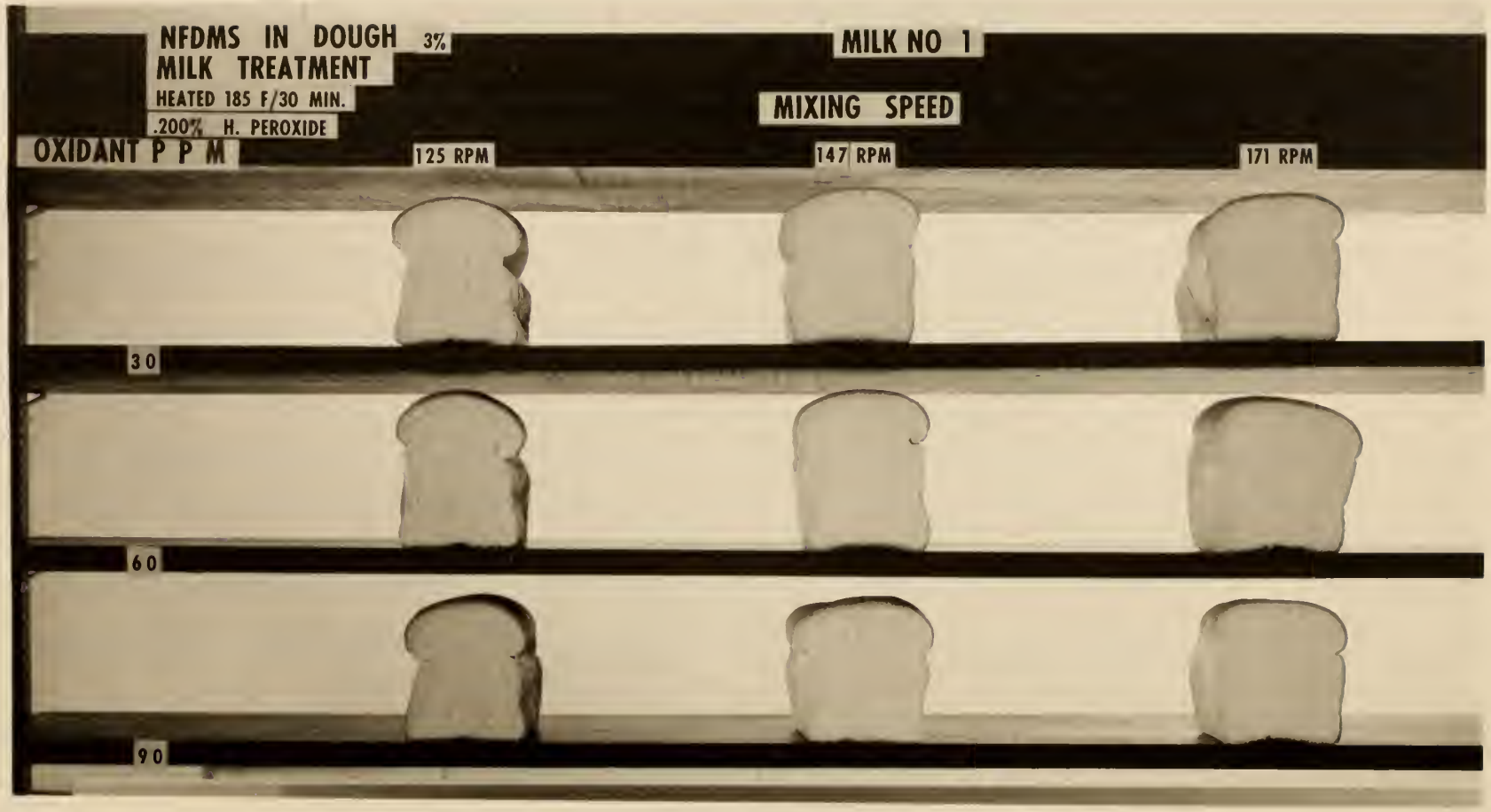
NFDMS IN DOUGH 3%
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OXIDANT P P M
30
60
90

PART II

The Use of Dried Cottage Cheese Whey as a Non-Meat Binder in an Emulsion-Type Sausage

INTRODUCTION

The disposal of whey has become a major problem for cheese manufacturers in recent years. In 1966, the United States produced 23 billion pounds of fluid sweet and acid whey (27). Traditionally whey has been disposed of by dumping into streams or rivers or by pumping it into sewage systems. Dumping whey into streams and rivers causes pollution resulting in destruction of fish and aquatic plants. One volume of whey in 25 volumes of water has been found to be toxic to fish (45). The main disadvantage in using sewer systems as a means of whey disposal is the tremendous cost involved due to the high biological oxygen demand (BOD) required for decomposition of whey. BOD is defined as the quantity of oxygen utilized in the biochemical oxidation of organic matter in a specific time at a specified temperature (45). The theoretical BOD of undiluted whey is about 40-60 thousand p.p.m. This value is at least 100 times as great in polluting characteristics as an equal volume of crude domestic sewage (45). Another problem with disposing of whey in sewage disposal plants is the high lactose content compared to nitrogenous materials (6). This can upset the nutrient balance of the microflora in sewage treatment plants causing destruction or a reduced activity of the microflora which are needed for sewage breakdown.

Since acid whey is such a problem to dispose of as a waste product, it is logical to try to develop satisfactory food uses for this by-product of the cottage cheese industry. Much work has been done on this problem in recent years. In fact, acid cottage cheese whey probably should not be considered a waste product because of

the high nutritive value that it possesses. Dried cottage cheese whey contains approximately 12 percent protein, 65 percent lactose, 6 percent lactic acid, 2.5 percent moisture, B-complex vitamins, vitamin C and large quantities of calcium (practically all that originally existed in the milk).

The principle proteins in whey are lactalbumin and lactoglobulin. It has been calculated that 73 percent of the nutrients of NDM used for cottage cheese are lost in the whey. If all the acid whey in the United States in 1966 had been dried, this would have amounted to 500 million pounds of acid whey powder (27). As a food source for human consumption, cottage cheese whey is less acceptable than sweet whey because of its higher lactic acid content. Sweet whey may contain as low as 0.1 percent lactic acid compared to 6 percent lactic acid in acid cottage cheese whey. Neutralization of acid whey has been considered but it has been found to add to the expense and change the whey characteristics (27). Acid whey, however, has been used with satisfactory results in sherbets (5).

This object of this study was to investigate the use of dried cottage cheese whey as a non-meat binder in emulsion-type sausages.

REVIEW OF LITERATURE

Cottage Cheese Whey Drying

The two major problems encountered by the cottage cheese manufacturer in disposing of or utilizing whey are, first, condensing and drying cottage cheese whey into a satisfactory product and, secondly, selling the product at a price at or above the cost of condensing and drying.

Hanrahan and Webb (20) successfully foam spray dried cottage cheese whey by injecting nitrogen gas at 2,000 p.s.i. into condensed whey of 45 percent total solids. Injection of gas into the concentrate to be spray dried increased the surface area and lowered the density of the drying particle which increased the effectiveness of moisture removal. Previously cottage cheese whey had been found to be somewhat difficult to dry and this problem was thought to be primarily due to the state of the lactose present.

Normal spray dried cottage cheese whey was found to be extremely hygroscopic. Lactose can exist in three different stages, in solution, in the crystalline or in the amorphous state (26). The amorphous state is very hygroscopic as opposed to the crystalline state which is thought to be less hygroscopic. If spray dried cottage cheese whey can be produced with the lactose present in the crystalline state it will be less hygroscopic and give fewer problems in drying as well as in subsequent storage and use of the product.

Food Uses of Dried Sweet and Acid Whey

Webb and Whittier (44) mentioned several food uses for dried sweet whey (whey from rennet clotted cheese). It has been used as a

foaming agent, and emulsifier, in highly flavored fruit-whey drinks, soups, cheese and cheese foods, baking products, candies, and as a food acidulant for use in sherberts and bottled beverages.

Wix and Woodbine (45) stated that there seems to be a lack of interest in whey as a human food due to poor flavor and saltiness. They stated that sweet whey could be used for making Scandinavian whey cheeses, Mysost and Primost. In addition, these authors stated that plain condensed or dried sweet whey solids could be added in the production of process cheese, and dried sweet whey may be used to replace flour in bread to the extent of 5-10 percent. Confectionary items such as fudge, caramel, and toffee have been produced with a sweet whey solids content of 14-40 percent. Also, an edible pudding containing 22-55 percent sweet whey solids was produced.

Alesch (1) stated that dried sweet whey had been used in baking as an additional ingredient or in a blend with other dairy products. He found that ice cream, containing 25 percent serum solids from sweet whey, produced an improved body, excellent flavor, and texture. In soft-serve ice cream, sweet whey replaced 50 percent solids-not-fat and in sherbets sweet whey improved flavor, protein stability and palatability when used at a 100 percent level of solids-not-fat. Blakely and Stine (5) found that substitution of acid cottage cheese whey powder in the formula gave a fine quality sherbet with no flavor criticism.

Henika et al. (24) and Singleton and Roberts (37) found that bakery products were improved in flavor, crust color, and tenderness with the use of dried cottage cheese whey. Guy et al. (18) found that some breads, cakes, and citrus flavored pie fillings were improved

by the inclusion of foam spray dried cottage cheese whey.

Henika et al. (25) reported that dough development with the continuous dough mixing unit was improved by the use of a whey/cysteine product in the formula. The product reduced the amount of developer required 40 percent which increased the production rate 5-30 percent and resulted in less bake out loss.

Guy et al. (19) found that the substitution of one-third of the usual NDM with cottage cheese whey solids in a 6 percent milk bread resulted in increased grain score, improved keeping quality, maintained equal or better volumes, and produced bread of good taste acceptability.

Kosikowski (27) reported that acid whey powder was used as an inexpensive, natural acidulant for replacing lactic starter cultures for coagulating milk for the production of Ricotta cheese. This product was found to be excellent in flavor and texture and produced greater yields.

Emulsion-Type Sausages

Meat Emulsions

In the formation of an emulsion type sausage, (wiener, frankfurter, bologna, etc.) a dispersion of fat globules is formed within the protein slurry of the comminuted sausage (21). The comparatively soft fat is broken up early in the process and the globule size is reduced as chopping is continued. Total chopping time must be sufficient to form a protein matrix enclosing the dispersed fat globules. Hansen (21) stated that the salt soluble proteins, myosin and actomyosin, appear to concentrate at the fat globule surfaces and form a stabilizing membrane. If excessive temperature rise

occurs during chopping, the protein matrix may be partially denatured and broken down, resulting in an unprotected fat dispersion which may permit fat separation during cooking and smoking. An emulsifying agent which will lower the interfacial tension and also form a strong protective membrane around the fat globules is regarded as an important factor in preparing a stable meat emulsion. Upon heat processing, the protein is coagulated and the fat and water should be retained within the protein matrix.

Swift et al. (40) studied the capacity of meats for emulsifying fat. They found that meat comminuted to an optimum extent was increased in emulsifying capacity by increasing the proportion of the saline phase, increasing the rate of addition of fat, and decreasing the rate of mixing and the temperature. Swift and Sulzbacker (41) observed that the emulsifying capacity of water soluble proteins increased with increasing concentrations of NaCl and their capacity for fat emulsification was maximum at pH 5.2. At pH values approaching the isoelectric point of the salt soluble proteins, the emulsifying capacity of the water soluble proteins increased as the concentration of the NaCl was increased. An increase in the emulsifying capacity of meat by increasing the pH from 7 to 8 was thought to be due to an increased extraction of proteins with the high concentration of salt present. Eliminating or restricting added water in salted meat reduced the effectiveness of the treatment with salt and the emulsifying capacity of the meat.

Helmer and Saffle (23) stated that sausage emulsions were stable to chopping temperatures of 16°C and also were stable when the

emulsion was chopped to 32°C, chilled with dry ice to 4°C re-chopped to 16°C. Emulsion breakdown occurred each time the emulsion was chopped at 32°C. Paper chromatography, electrophoresis and extractable protein have shown that the breakdown of sausage emulsions was not due to denaturation of soluble protein.

Hegarty et al. (22) ranked proteins of beef muscle from those with the greatest emulsifying properties to the least as follows: 1) actin in the absence of salt, 2) myosin, 3) actomyosin, 4) sarcoplasmic proteins and 5) actin in 0.3 M salt. Myosin and actomyosin produced emulsions with superior stability, however, at the pH of meat (5.6-5.8), the sarcoplasmic fraction produced the most stable emulsions. Actin was found to produce very stable emulsions under all conditions. The amount of protein which was utilized in the formation of the interface of the emulsion appeared to be related to the stability of the emulsion.

Carpenter and Saffle (9) observed that several variables influenced the amount of oil that could be emulsified by the soluble protein present in various sausage raw materials. The amount of oil emulsified was found to depend upon the amount of soluble protein present in the meat, the speed of mixing, the final temperature of the emulsion, and the amount of oil initially added.

Meyer et al. (30) prepared frankfurter emulsions of varying composition with the addition of eight commercial emulsifiers, lecithin and oleic acid at 0.1, 1.0 and 3.0 percent. The emulsions were stuffed in fibrous casings and processed

following normal packing plant procedures. The amount of fat which rendered from the emulsifier treated samples upon heating was compared to a control. Higher concentrations of emulsifiers resulted in more rendering. Lecithin did not improve emulsion stability and imparted an off flavor to the finished product. None of the emulsifiers used was effective except oleic acid. It was noted that the type of fat (beef or pork) markedly affected the response of specific emulsifiers.

Trautman (43) studied the relative emulsifying capacity of ham muscle proteins and found that the salt soluble proteins were the major emulsifying components in ham muscle and were greatly influenced by the time post mortem. The water-soluble proteins and the salt insoluble residue were found to possess very little emulsifying capacity.

Carpenter and Saffle (10) stated that the ability of mean proteins to emulsify fat appears to depend, in part, upon the shape and the charges on the protein molecule. The water soluble proteins were found to have a greater emulsifying capacity than previously reported by Trautman (43). This conclusion was based on electrophoretic mobility and viscosity data.

Christian and Saffle (11) used 26 fat and oil samples from various sources to determine the amount of each which could be emulsified with salt soluble protein. Iodine numbers, acid values and specific gravities were determined and correlated with the amount of fat and oil emulsified. These factors resulted in little correlation with the amounts of fats and oils emulsified. A greater amount of saturated fatty acids also was

emulsified by a given amount of salt soluble protein.

Borton et al. (7) evaluated the emulsifying capacity of 13 commercial meat trimmings. Leaner products, with a higher percentage of protein, had higher fat emulsifying capacities per unit weight of sample. The fatter products indicated a more efficient emulsification by the protein because these materials had higher emulsifying capacities per unit of protein.

Water Binding in Sausages

Water binding in sausage products has been considered important to the sausage manufacturer from the profit standpoint. If a large percentage of water can be retained after heat processing of sausage products, more pounds of the finished product can be sold. Ten percent added water is allowed by law in finished cooked sausage products. The percentage moisture in the finished product must not be greater than four times the percent protein plus ten percent.

Sherman (35), investigated the influence of sodium chloride, pyrophosphate and polyphosphate on the water binding capacity of fresh pork. The addition of sodium chloride, tetrasodium pyrophosphate or alkaline polyphosphate was found to improve fluid retention. The phosphates were particularly effective in improving water binding capacity. With phosphate solutions, fluid retention at 0 C showed a significant correlation with pH of the meat mixtures. To some extent pH influenced the degree of solubilization of actomyosin from meat proteins. Fluid retention at 100 C, in the presence of phosphates, appears to be related to the concentration of actomyosin that goes into

solution during aging of the soluble meat mixture. The greater the concentration of actomyosin, the stronger the gel of denatured protein formed upon heat coagulation. This gel extends throughout the meat mass and retains moisture.

Fukazawa et al. (15) observed that water soluble proteins did not affect appreciably the binding quality of sausage.

Assaf and Bratzler (4) determined the concentration of 12 mineral elements in beef muscle and their relative degree of binding to meat extracts was evaluated from analysis of the concentration of each in dialyzed and undialyzed meat extracts and their dialyzates. The relative degree of binding was found to be Fe> Al> Ca> Cu> Mn> Mo> Mg> B> P> Na> K.

Non-Meat Sausage Binders

The Federal Meat Inspection Bureau has ruled that the total cereal, starches and nonfat dry milk (NDM) cannot exceed 3.5 percent of the finished sausage product. NDM has been used extensively by sausage manufacturers as a non-meat binder. Its advantages are that it has nutritional value, it binds the meat particles together, it improves ease of slicing, and it holds moisture and thus prevents shrinkage (2).

Soy protein has been used as a non-meat binder in emulsion-type sausage products, and as the only source of protein for imitation sausages. Frank and Circle (14) developed a process for using edible isolated soy protein as the only source of protein in all vegetable products closely simulating cooked sausage of the frankfurter and bologna types. These products were similar to emulsion-type sausages in appearance, flavor, texture, color

and nutritional value.

Gordon and Taylor (17) studied the effects of full fat soya flour in fresh sausage. As to water losses, there was no significant effect due to the presence of soya flour either alone or with added water. Incorporation of soya flour in the sausages consistently reduced the fat losses during cooking. There was a small but consistent amount of shrinkage associated with the incorporation of soya flour. Soya flour used in fresh sausage reduced the extent of water loss during cooking.

Pearson et al. (31) studied the effect of soy sodium proteinate, potassium caseinate and NDM on emulsifying capacity and the stability of the emulsions. These measures were taken at ionic strengths of 0.05 and 0.3, and at pH values of 5.4, 6.8, and 10.5 in H_2O solutions. Soy sodium proteinate and potassium caseinate were most effective as emulsifiers at the high pH (10.5) and had the greatest emulsifying capacity at the lower ionic strength (0.05). Potassium caseinate was a more effective emulsifier than soy sodium proteinate over the entire range of pH values and ionic strengths. At the lower concentrations, NDM had the greatest emulsifying capacity of any of the protein additions in the approximate pH range of meat (5.4) independent of ionic strength. Soy sodium proteinate emulsions were extremely unstable at the pH of meat (5.3-5.6). NDM was quite stable at the pH of meat, but potassium caseinate was quite stable at all pH values. These results indicate that both potassium caseinate and NDM would likely produce stable emulsions in sausage products.

Rongey and Bratzler (32) observed that the use of 3.5, 10, 15 and 20 percent high heat processed NDM produced very little change in percent moisture, percent protein and seven day storage shrink compared to an all meat control. Bologna containing 3.5 percent NDM resulted in a higher yield than the control product. The two highest levels of NDM produced a much lighter colored product. The flavor preference was the same for the all meat control, 3.5 and 10 percent NDM. Bologna containing added phosphate resulted in the greatest yield.

Peelability of Emulsion-Type Sausages

During heat processing of emulsion-type sausages both protein and fat migrate to the surface and are important factors in the ease of peeling.

Saffle et al. (33) investigated the effects of chemical composition, heat, collagen and the type of fat on the peeling ease of frankfurters. Low initial smokehouse temperature (54 C) resulted in easier peeling than those which received a high initial smokehouse temperature of 77 C, when 20 mm casing was used. When 30 mm casing was used, the high initial smokehouse temperature (77 C) resulted in better peeling than with 20 mm casing at the lower initial temperature. The addition of collagen in the form of pork skins, and processing with low initial smokehouse temperature resulted in the poorest peeling, but those processed at the highest temperature resulted in good peeling. Frankfurters containing pork fat gave better peeling scores than those containing beef fat and the amount of fat mi-

grating to the surface was greater for pork fat.

Saffle et al. (33) found an improvement in peeling ease at higher relative humidities of 74 and 88 percent as opposed to lower humidities. Frankfurters peeled significantly better at 16 C than at 4 or 10 C. The use of 52 dextrose equivalent (DE) syrup in the formula resulted in peeling characteristics superior to those in which 30.2 or 71 DE syrup was used.

Simon et al. (36) observed that frankfurter toughness and firmness increased as the meat protein content increased. Raising the relative humidity in the smokehouse during processing reduced toughness and firmness in the finished product.

Cured Meat Color

The red color of cured meat is essentially that of nitrosomyglobin. To form this pigment, nitrite reacts with oxymyoglobin (i.e. myoglobin in the presence of oxygen) to form metmyoglobin.

$$NO^- + 2MygO_2 \longrightarrow NO_3^- + Myg_2O + O_2$$

(Nitrite) (Oxymyoglobin) (Nitrate) (Metmyoglobin)

In the absence of oxygen, nitrite reacts with myoglobin to form equimolor quantities of metmyoglobin and nitrosomyoglobin (29).

A major problem with ready-to-eat cured meat products is fading of the surface color while on display in lighted showcases. This color loss is thought to be due to oxidation of the cured meat pigment, nitrosomyoglobin, from the ferrous to the ferric state (13). This is accelerated by light which brings about dissociation of nitric oxide from the myoglobin.

Tappel (42), Snyder (38), Stewart et al. (39) and Bowen (8) used reflectance spectrophotometry to study changes in meat color and found this technique to be satisfactory.

Erdman and Watts (13) found that extinction ratios of cured meat surfaced at 570/650 and 540/500 m provided sufficient information to determine the extent of cured meat color development in freshly exposed cured meat surfaces. Ratios of these wavelengths also can be used to determine the degree of color fade in cured meats by comparing the ratios before and after exposure to light.

Giddey (16) stated that accurate and consistent control of the different stages of processing, curing, and smoking can greatly affect color of cured meats.

MATERIALS AND METHODS

Manufacture of Spray Dried Cottage Cheese Whey

Two lots of fresh, acid cottage cheese whey were obtained from a commercial cottage cheese plant near the University. The first lot of whey (Lot A) was preheated to 77C for 30 min., cooled to 21 C and transferred to a Mojonnier Lo-Temp evaporator and condensed to 40 percent total solids at 21-24 C. The second lot of whey (Lot B) was preheated to 85 C for 30 min., and condensed to 45 percent total solids under the same conditions as Lot A. Both lots of whey were spray dried at 1,000 P.S.I. using a 0.699 mm diameter nozzle.

The third lot of dried cottage cheese whey (Lot C) was supplied by Dean Foods Company, Rockford, Illinois and was obtained from a batch of cottage cheese made by the direct acidification process.

Analyses of Dried Whey

The three lots of dried whey were analyzed by the following procedures:

(1) Whey protein nitrogen (WPN) was determined by the method of Harland and Ashworth as modified to Kuromoto et al. (28).

(2) Solubility index was measured by the standard method of the American Dry Milk Institute (3).

(3) Packing density was measured by the method of Sanderson (34) in which 50 g of dried cottage cheese whey were placed in a 250 ml graduated cylinder. The dried whey was packed by tapping the cylinder on a laboratory bench until no further reduction in volume was evident. The volume of packed dried whey in milliliters was measured and recorded. Packing density was expressed as grams per cubic centimeter.

(4) Total lactose was determined by the phenol-sulphuric acid method of Dubois et al. (12).

(5) Protein was determined by the A.O.A.C. macro-Kjeldahl method.

(6) Atomic absorption spectroscopy at 4227 Å using strontium to suppress phosphate interference, was used to determine calcium content of the samples.

(7) Moisture content was determined by use of an Ohaus moisture determination balance (Model No. 6,000).

(8) PH and titratable acidity were measured on six percent reconstituted whey samples.

Pilot Emulsion Test

The three lots of dried cottage cheese whey, (Lots A, B, and C), low heat NDM, high heat NDM, dried buttermilk, soy protein, a commercial Ca^{++} reduced NDM were analyzed for fat emulsification properties by use of the pilot emulsion test of

Swift et al. (40). Each of the above non-meat binders was used at the rate of 3.5 percent of the meat weight and was compared to an all meat control. Lean pork, ground through a 1/8 inch plate, was used as the base meat.

Procedure: Fifty g of raw material, meat plus additive, were placed in a Waring blender with 200 ml of 4 C 1M NaCl solution. The blend was mixed at 13,000 rpm for two minutes. The comminuted mixture was kept in an ice bath until the determinations were made. Twelve and one-half g of the prepared comminuted mixture were weighed into a pint jar and 37.5 ml of cold 1M NaCl were added. Fifty ml of vegetable oil were added to the mixture and the lid was attached to the jar and connected to a Virtis mixer. The cutting and mixing action was begun at 13,000 r.p.m. Immediately, more vegetable oil was added at the rate of 48 ml per minute and mixing and chopping were continued until the end point was reached. During mixing the emulsion formed, persisted and finally collapsed. The end point was detected when the emulsion collapsed resulting in a sudden increase in speed of the Virtis mixer. At the end point, the addition of fat was immediately discontinued and the amount of fat emulsified was recorded. This was reported as volume of oil emulsified per 50 g of raw material (meat plus additive).

Sausage Experiments

Sausage Production

Twenty-two, 6,810 g (15 lbs.) batches of wieners were prepared using the following meat blend:

3,064.5 g	(6.75 lbs.)	Pork trim 50-50 (approximately 50% lean, 50% fat)
1,589.0 g	(3.50 lbs.)	Lean pork 80%
1,816.0 g	(4.00 lbs.)	Veal trim
340.5 g	(.75 lbs.)	Pork hearts
6,810.0 g	(15.00 lbs.)	

Each ingredient was ground through a 1/8 inch plate and thoroughly mixed. Non-meat binders were added to the meat blends at 3.5 percent of the meat blend weight. The non-meat binders studied were spray dried cottage cheese whey, Lots A, B and C, spray dried cottage cheese whey Lot C in which the pH of the emulsion was raised

from 5.68 to 5.84 by the addition of phosphate buffer in place of tap water, low heat NDM (10.2 mg serum protein per g), high heat NDM (3.6 mg serum protein per g), dried buttermilk, soy protein and a commercial Ca^{++} reduced NDM. For each non-meat binder used, ice water was added at 10 and 15 percent of the batch weight.

The buffered emulsions, when the pH was adjusted, were prepared by dissolving 28.39 g of Na_2HPO_4 to 2 l of distilled water and 13.7 g of $NaH_2PO_4.H_2O$ to 1 l of distilled water. A 12.6:1 mixture of the Na_2HPO_4 solution and NaH_2PO_4 solution was prepared to give a total volume of 681 ml. This buffer was chilled and added in place of ice water to the emulsions. For the batch containing 15 percent added water, 340 ml of additional ice water was added to the phosphate buffer solution to make the final volume equal to 15 percent added water.

Seasoning was added to each 15 pound batch in the following amounts:

159.0 g	NaCl
31.8 g	sugar
7.8 g	nitrate
1.0 g	nitrite
3.0 g	ascorbate
7.2 g	coriander
3.9 g	mace
21.0 g	white pepper

The 80 percent lean pork, veal trim, pork hearts, and seasoning were placed in a sausage chopper and chopped for 1.5-2 minutes after which the non-meat binder was added. The ice water (or buffered ice water) was added immediately following the addition of the non-meat binder and chopping was continued for 1.5-2 minutes. Then the 50-50 pork trim was added to the emulsion, and each batch was chopped until an emulsion temperature of 15.5 C was reached. The emulsions were removed from the chopper and placed in a compressed air stuffer and

stuffed in 21 mm cellulose casings. The wieners were linked by hand. Each batch was allowed to remain at room temperature for onehour after chopping was initiated and then placed in a dark 4 C cooler until all batches were ready for heat processing.

The smokehouse was preheated to 82-93 C and the smoke generator turned on one hour after the wieners were placed in the house. The wieners were heated to an internal temperature of 67 C and then removed from the house and showered with cold tap water for seven minutes. Following the cold shower they were allowed to stand at room temperature for 30 min. before being placed in a dark 4 C chill room. The wieners were placed in the dark so that the color would not be affected by light.

After chilling overnight, the weiners were weighed for determination of weight loss after being chilled and peeled. Peelability, visual color, and fat separation scores were given to each batch after peeling. The wieners were packaged and frozen for color and flavor evaluation.

Physical Evaluation of Product

For each batch of wieners produced, three 12 wiener links were weighed so that product yield could be determined after heat treatment and smoking, and after being chilled.

Cellulose casings were peeled off and the peelability scores determined according to the following criterion:

Peelability Score

1	Very damaged surface = Poor peelability
2	
3	Slight surface scarring = Fair peelability
4	
5	Hard, smooth surface = Good peelability

Each batch of wieners was evaluated for fat separation after peeling according to the following score guide:

Fat Separation Score	Degree of Fat Separation
1	Extensive
2	Moderate +
3	Moderate
4	Slight +
5	Slight
6	Very Slight
7	None

Visual color evaluations were made by three experienced judges on each batch of wieners after peeling according to the following score guide:

Visual Color Score	Degree of Color Fade
1	Complete Fade
2	Moderate Fade
3	Slightly Pink
4	Pink
5	Dark Pink
6	Red
7	Dark Red

Color studies were made by determining percent reflectance at wavelengths of 500, 540, 570, 600 and 650 mμ on a Bausch and Lomb Spectronic 600. Two samples of each batch were wrapped in cellophane for the determinations. Color reflectance readings were made at these wavelengths at 0 time, 2 hours and 24 hours after exposure to 100 foot candles of flourescent lighting and compared to wieners receiving the same intensity of incandescent lighting. A ratio of percent reflectance $\frac{570}{650}$ mμ was chosen as a good measure of cured meat color as shown by Erdman and Watts (13). Visual color scores also were recorded at each time interval of exposure so that comparisons could be made between visual scores and spectrophotometric determinations.

Moisture, fat and protein determinations were made on emulsion samples of each batch collected prior to stuffing and on the final

wieners. Standard A.O.A.C. methods were used for these determinations.

All data obtained from the wiener experiments were subjected to statistical analysis.

Flavor Analysis

The taste panel consisted of eight members who were trained together several weeks on the flavor sensing technique known as descriptive flavor analysis. The technique involved examination of both the aroma and flavor of the test product. This included tastes, feelings, and odors perceived when food is eaten in a standardized manner. The sensations perceived were written in descriptive terms (e.g., sweet, astringent, meaty) in the order in which they were perceived. The intensity to which each sensation was perceived was indicated as: just recognizable, slight, moderate, or strong. Each panel member recorded his own findings independently. Afterwards the panel convened as a group in order to develop a common language for their descriptive terms.

Flavor trends were developed for wieners containing three conventional non-meat binders; low heat NDM, high heat NDM, and soy protein. In addition, flavor trends were developed for wieners containing the commercial lot of dried cottage cheese whey (Lot C) and Lot C in which the pH had been adjusted with phosphate. Flavor trends of wieners containing these two binders were compared to those containing conventional non-meat binders.

Panel Procedure

Two sets of coded test samples representing two variables were cooked for each tasting session. Each set of four frozen wieners was thawed by cooking for five min. in a round, covered aluminum roaster

containing 3.8 cm of boiling distilled water. The cooking pan was removed from the electric burner and the wieners were warmed further by standing for seven min. in the hot water bath. The wieners were placed in a warmed pottery casserole and cut cross sectionally in half.

Each panelist served his own sample and cut the wiener in half longitudinally and immediately the aroma evaluation was recorded on the response sheet. For flavor examination, a 0.6 cm portion was cut from a longitudinal half. As the panelist chewed and swallowed the bite, flavor impressions were recorded. Panelists who had received halves of the same wiener conferred to compare findings and later all panelists reported their agreed and disagreed findings. The interpretation of their findings was accomplished afterwards by the panel leader from a composite of the data.

RESULTS AND DISCUSSION

Analyses of Dried Whey

The results of the analyses of the three lots of dried cottage cheese whey involved in the experiment, are summarized in Table 1. It is noted in Table 1 that Lot C, which was a sample of spray dried cottage cheese whey from directly acidified cottage cheese, was lower in protein, calcium and WPN. This sample was higher in lactose, moisture and had a higher solubility index. Lots A and B were comparable in composition. Lot A, however, had a much lower solubility index than did lot B.

Pilot Emulsion Test

The results of the pilot emulsion test on all of the non-meat binders used in this experiment are summarized in Table 2. The values are arranged in order from the smallest emulsification to the largest.

Table 2. Pilot emulsion test

Additive	Ml. of oil emulsified per 50 g of raw material
Whey (lot B)	120.5^{a*}
Low heat NDM	128.5^{ab}
High heat NDM	132.5^{b}
Whey (lot A)	134.5^{bc}
Whey (lot C)	143.5^{cd}
Control	146.0^{de}
Ca++ reduced NDM	151.5^{de}
Soy protein	156.0^{ef}
Dried buttermilk	166.0^{f}

LSD = 10.6 5% level of significance

* Like superscripts are not significantly different

Table 1. Analyses of dried whey *

Dried Whey	WPN (mg serum protein/g)	Solubility index (ml)	Packing density (g/cc)	% Lactose	% Protein	% Calcium	% Moisture	pH of 6% reconstituted	T.A. of 6% reconstituted
Lot A	3.80	0.20	68.5	63.0	11.93	1.82	2.9	4.25	0.48
Lot B	3.53	0.65	62.5	64.0	12.02	1.86	2.7	4.45	0.44
Lot C	2.78	1.55	63.0	67.0	9.40	1.72	4.15	4.25	0.37

* Average of duplicate analysis

T.A. = Titratable Acidity

The most superior emulsifying properties were observed with the use of dried buttermilk and soy protein as non-meat binders. The use of Ca^{++} reduced NDM, soy protein and dried buttermilk exhibited better emulsifying properties than the all meat control. Dried whey Lot C, possessed emulsifying properties which were not significantly different from the all meat control. Dried whey Lots A and B, low heat NDM, and high heat NDM emulsified significantly less oil than the all meat control. From the standpoint of emulsification, results of this experiment indicated that dried whey Lot C could be used as a non-meat binder in emulsion type sausages.

Sausage Experiment

PH of Emulsions

The pH of each batch of sausage taken after the emulsion was fully chopped and before stuffing is summarized in Table 3. The pH values are arranged in order of the lowest to the highest.

Table 3. The effect of non-meat additive on the pH of the emulsion

Additive	pH (duplicate determinations)
Whey (lot A)	5.56^{a*}
Whey (lot B)	5.56^{a}
Whey (lot C)	5.68^{b}
Control A	5.79^{c}
Control B	5.80^{c}
Whey (lot C-buffered)	5.84^{cd}
Ca++ reduced NDM	5.88^{d}
Dried buttermilk	5.89^{d}
Soy protein	5.90^{de}
Low heat NDM	5.96^{ef}
High heat NDM	5.97^{f}

LSD = 0.065 5% level of significance

* Like superscripts are not significantly different

The lowest emulsion pH's were obtained with the use of the three lots of dried whey. These pH's were all significantly lower than the two all meat controls, as shown in Table 3. Buffering the emulsion containing dried whey Lot C resulted in a pH greater but not significantly greater than the two all meat controls. The objective of buffering the emulsion containing dried whey Lot C was to adjust the pH to a level equal to the all meat controls. With the use of the buffered-whey emulsion, the pH was not significantly different from the pH with the use of Ca^{++} reduced NDM, dried buttermilk, or soy protein. The use of both low heat and high heat NDM resulted in significantly higher emulsion pH's than all other emulsions.

Peelability Score

Peelability scores are summarized in Table 4 and are arranged in order from the lowest to the highest.

Table 4. The effect of non-meat additive on peelability score.

Additive	Peelability score
High heat NDM	3.00^{a*}
Whey (lot A)	3.25^{ab}
Whey (lot C)	3.25^{ab}
Control B	3.50^{abc}
Whey (lot B)	3.50^{abc}
Dried buttermilk	3.50^{abc}
Whey (lot C-buffered)	3.75^{bcd}
Control A	3.75^{bcd}
Low heat NDM	4.00^{cd}
Ca++ reduced NDM	4.00^{cd}
Soy protein	4.25^{d}

LSD = 0.59 5% level of significance

* Like superscripts are not significantly different

With the use of the three lots of whey there was not a significant difference in peelability score. However, with the use of dried whey Lot C-buffered, peelability score was increased compared to dried whey alone. Dried whey Lot C-buffered produced a peelability score not significantly different than low heat NDM, Ca^{++} reduced NDM and soy protein. Buffering of the emulsion to which dried whey had been added gave an improvement in peelability score compared to the use of dried whey alone. It is speculated that this change may be due to the pH increase of the buffered system.

Fat Separation Score

Fat separation scores, arranged in order of the lowest to the highest, are summarized in Table 5.

Table 5. The effect of non-meat additive on fat separation score.

Additive	Fat separation scores
Whey (lot A)	2.0^{a*}
Whey (lot B)	2.5^{a}
Whey (lot C)	3.0^{ab}
Dried buttermilk	3.0^{ab}
Control B	3.5^{abc}
High heat NDM	3.5^{abc}
Control A	4.5^{bcd}
Soy protein	5.0^{cd}
Ca++ reduced NDM	5.0^{cd}
Whey (lot C-buffered)	5.0^{cd}
Low heat NDM	5.5^{d}

LSD = 1.92 5% level of significance

* Like superscripts are not significantly different

The greatest fat separation resulting in the lowest score was obtained with the use of the three lots of dried whey. However, with the buffered

whey this score was significantly increased as shown in Table 5. This additive was comparable to the use of soy protein, Ca^{++} reduced NDM, and low heat NDM, which resulted in the highest fat separation scores that were not significantly different.

Visual Color Score

There was no significant difference in visual color scores of the wieners at the time of peeling.

Product Yield

Product yield is summarized in Tables 6 - 9 and is expressed as percentage weight loss. Table 6 shows the percentage weight loss after heat and smoke treatment and the weights are arranged in order of the smallest to the highest weight loss.

Table 6. The effect of non-meat additive on weight loss after heat processing and smoke treatment.

Additive	Percent weight loss (6 determinations)
Whey (lot C)	7.44^{a*}
Whey (lot C-buffered)	7.44^{a}
High heat NDM	8.23^{ab}
Control B	9.99^{bc}
Ca++ reduced NDM	10.00^{bc}
Soy protein	10.27^{c}
Control A	10.80^{c}
Low heat NDM	10.92^{c}
Dried buttermilk	11.83^{c}
Whey (lot A)	14.44^{d}
Whey (lot B)	15.64^{d}

LSD = 1.94 5% level of significance

* Like superscripts are not significantly different

Weight loss after heat and smoke treatment was significantly less with

the use of dried whey Lot C, dried whey Lot C-buffered and high heat NDM compared to all other additives. Wheys Lots A and B as additives resulted in significantly greater weight loss than the other additives.

Table 7 compares weight loss after heat and smoke processing for the two added water levels of 10 and 15 percent.

Table 7. The effect of non-meat additive and percent added H_2O on percentage weight loss after heat processing and smoke.

Additive	Percent weight loss after heat processing and smoke: 10% added H_2O		15% added H_2O
Control A	10.66		10.95
Whey (lot A)	15.85	*	13.03
Whey (lot B)	19.23	*	12.05
Low heat NDM	10.12		11.72
Soy protein	10.53		10.01
Dried buttermilk	9.97	*	13.69
Ca++ reduced NDM	10.47		9.54
Whey (lot C)	9.55	*	5.33
High heat NDM	9.59		6.87
Whey (lot C-buffered)	7.32		7.55
Control B	10.71		9.26

LSD = 2.77 5% level of significance

* Significantly different from adjacent values

As shown in Table 7, with the use of all three lots of whey (A, B and C) the wieners had significantly less percentage weight loss after heat processing with the 15 percent level of added water compared to the 10 percent level of added water. Apparently, an optimum level of water is necessary to minimize weight loss. With the use of dried buttermilk as the additive, percentage weight loss in the wieners was

significantly greater with the higher level (15 percent) of added water. In all other cases there was no significant difference in weight loss between the two levels of added water.

The percentage weight loss of the wieners after heat processing, smoking and chilling is summarized in Table 8 and are arranged in order of the smallest to the largest weight loss.

Table 8. The effect of non-meat additive on percentage weight loss after heat processing, smoking and chilling.

Additive	Percent weight loss
Whey (lot C-buffered)	11.74[a*]
High heat NDM	12.05[a]
Whey (lot C)	12.18[a]
Soy protein	13.26[ab]
Low heat NDM	13.45[ab]
Ca++ reduced NDM	13.66[ab]
Control A	14.20[b]
Control B	14.80[b]
Dried buttermilk	15.00[b]
Whey (lot A)	17.58[c]
Whey (lot B)	18.70[c]

LSD = 1.95 5% level of significance

* Like superscripts are not significantly different

As shown in Table 8, the smallest percentage weight loss after chilling was obtained with the use of dried whey Lot C-buffered. The use of dried whey Lot C-buffered and unbuffered, and high heat NDM resulted in significantly less weight loss than the two all meat controls. Dried wheys Lots A and B resulted in significantly greater weight loss than the all meat controls.

The effect of non-meat additive and level of added water (10 or

15 percent) on the percentage weight loss after smoke and chill is summarized in Table 9.

Table 9. The effect of non-meat additive and percent added H_2O on percentage weight loss after chill.

Additive	Percentage weight loss		
	10% Added H_2O		15% Added H_2O
Control A	14.33		14.08
Whey (lot A)	18.78		16.38
Whey (lot B)	22.05	*	15.34
Low heat NDM	12.43		14.47
Soy protein	13.57		12.95
Dried buttermilk	13.17	*	16.83
Ca++ reduced NDM	14.00		13.32
Whey (lot C)	14.65	*	9.70
High heat NDM	12.95		11.12
Whey (lot C-buffered)	11.64		11.83
Control B	15.19		14.42

LSD = 2.79 5% level of significance

* Significantly different from adjacent values

As shown in Table 9, weight loss was significantly less after heat processing, smoking and chilling with the use of dried whey Lots B and C at the 15 percent added water level compared to 10 percent added water. With the use of dried buttermilk weight loss was significantly greater at the higher water level (15 percent) compared to the lower water level (10 percent).

Composition of Emulsions and Wieners

The composition of the wiener emulsions and finished products is summarized in Table 10. The effect of non-meat additive and added water level (10 or 15 percent) on composition of the wieners is

Table 10. Composition summary of emulsions and wieners

Additive	EMULSIONS			WIENERS		
	Percent protein	Percent moisture	Percent ether extract	Percent protein	Percent moisture	Percent ether extract
Control A	13.72^{a*}	61.34^{ab}	20.04^{g}	15.68^{ab}	57.82^{d}	21.80^{e}
Whey (lot A)	13.92^{ab}	61.15^{ab}	19.16^{efg}	16.51^{c}	57.62^{d}	19.35^{b}
Whey (lot B)	13.95^{b}	60.69^{ab}	19.40^{fg}	16.61^{c}	56.28^{b}	19.92^{bc}
Low heat NDM	14.24^{cde}	60.21^{ab}	16.28^{a}	16.44^{c}	55.63^{a}	21.55^{e}
Soy protein	15.35^{h}	60.16^{ab}	18.86^{def}	17.25^{d}	55.71^{a}	21.17^{de}
Dried buttermilk	14.62^{fg}	61.20^{ab}	18.01^{cd}	16.38^{c}	56.89^{c}	20.64^{cd}
Ca++ reduced NDM	14.04^{bc}	60.62^{ab}	16.58^{ab}	16.53^{c}	56.43^{bc}	19.41^{b}
Whey (lot C)	14.35^{de}	61.42^{b}	18.45^{cdef}	15.92^{b}	59.62^{f}	18.22^{a}
High heat NDM	14.78^{g}	60.04^{a}	17.42^{bc}	16.43^{c}	57.99^{d}	19.25^{b}
Whey (lot C-buffered)	14.14^{bcd}	61.08^{ab}	15.78^{a}	15.42^{a}	59.04^{e}	18.19^{a}
Control B	14.45^{ef}	63.17^{c}	18.23^{cde}	15.85^{b}	59.86^{f}	19.59^{b}
LSD	0.22	1.36	1.14	0.37	0.49	0.76

5% level of significance

* Like superscripts are not significantly different

summarized in Table 11. Composition differences may be due to variations in processing losses and raw material composition differences.

Color Analysis

Table 12 shows the effect of additive on percent reflectance at 570 mμ, 650 mμ, the ratio of 570 to 650 mμ and visual color score. A lower reflectance ratio of 570/650 mμ indicated more color or less fade. As can be seen in this table, dried whey Lot C, high heat NDM and dried whey Lot C-buffered resulted in the lowest reflectance ratio at 570/650 mμ indicating better color. With the use of these additives, color held well throughout the time in which color was measured. The ratio of reflectance did not correlate well in all instances with visual color score, however, correlation coefficient of -0.92 was obtained between visual color score and the percent reflectance ratio of 570/650 mμ.

Table 13 contains a summary of the effect of added water on color by measurements of percent reflectance ratios at 570/650 mμ compared to visual color score. Visual color score was significantly lighter or paler with the use of 15 percent added water in the emulsion, compared to 10 percent added water. The ratio of reflectance readings was significantly greater with the use of 15 percent added water in the emulsion, indicating a paler color than with the 10 percent level of added water.

The combined effect of additive and water level on color is summarized in Table 14.

Table 11. The effect of non-meat additive and level of added water on the composition of the wieners.

Additive	% PROTEIN			% WATER			% ETHER EXTRACT		
	10% added H_2O		15% added H_2O	10% added H_2O		15% added H_2O	10% added H_2O		15% added H_2O
Control A	15.89		15.47	57.80		57.84	21.33		22.27
Whey (lot A)	17.70	*	15.32	57.37	*	58.88	19.46		19.25
Whey (lot B)	17.28	*	15.94	55.33	*	57.23	19.68		20.16
Low heat NDM	16.73	*	16.14	55.05	*	56.22	21.83		21.27
Soy protein	17.83	*	16.68	54.38	*	57.05	21.84	*	20.50
Dried buttermilk	16.72	*	16.05	56.49		57.30	21.09		20.20
Ca++ reduced NDM	16.91	*	16.15	56.18		56.68	18.93		19.89
Whey (lot C)	16.31	*	15.54	59.79		59.46	17.53	*	18.92
High heat NDM	16.56		16.30	57.51	*	58.48	19.78		18.73
Whey (lot C-buffered)	15.54		15.31	58.23	*	59.85	18.89	*	17.50
Control B	16.16	*	15.54	59.96		59.78	19.28		19.90
LSD =		.53			.70			1.07	

* Significantly different from adjacent values

Table 13. The effect of added water on percent reflectance at 570 mμ, 650 mμ, 570/650 mμ and visual color score.

Percent added water	% reflectance at 570 mμ	% reflectance at 650 mμ	Ratio 570/650 μ	Visual color score
10	24.71	48.84	.520	2.45
	*		*	*
15	25.39	48.29	.527	2.42
LSD =	0.46	.74	0.007	.03

5% level of significance

* Significantly different from adjacent values

Table 14. The effect of additive and water level on percent reflectance at 570, 650 and 570/650 mμ and visual color score.

Additive	570 μ		650 μ		570/650 μ		Visual Color Score	
	10% added H_2O	15% added H_2O	10% added H_2O	15% added H_2O	10% added H_2O	15% added H_2O	10%	15%
Control A	26.67 *	29.18	50.11	52.09	.541 *	.569	2.50 *	2.42
Whey (lot A)	26.70 *	30.02	49.93 *	55.96	.547	.539	2.46 *	2.38
Whey (lot B)	26.64	26.53	50.54	50.32	.532	.542	2.50	2.50
Low heat NDM	24.43 *	26.77	47.40 *	50.45	.528	.537	2.42	2.42
Soy protein	26.73	25.78	50.72 *	47.04	.537	.558	2.42 *	2.38
Dried buttermilk	27.52 *	24.47	50.82 *	48.08	.553 *	.521	2.46 *	2.54
Ca++ reduced NDM	23.12 *	20.08	45.76 *	50.37	.517 *	.568	2.54 *	2.46
Whey (lot C)	22.76	21.66	47.88	47.09	.484	.472	2.50 *	2.21
High heat NDM	21.19	21.26	44.93	44.48	.482	.486	2.42 *	2.50
Whey (lot C-buffered)	22.36	21.32	46.27	44.44	.493	.489	2.46 *	2.42
Control B	23.69	24.19	46.88	46.95	.513	.521	2.33 *	2.42
LSD	1.53		2.48		.023		.03	

* Significantly different from adjacent values

Flavor Analysis

The flavor trends for the wieners containing conventional non-meat binders; low heat NDM, high heat NDM, and soy protein are summarized below.

1) Low Heat NDM
   a) This binder per se was not detected
   b) Its effects were to reduce:
      1) aromatics of the spices
      2) duration of burn (pepper)

2) High Heat NDM
   a) This binder per se was not detected
   b) Its effects were to:
      1) make the meat character bland or flat
      2) reduce intensity of saltiness
      3) reduce intensity of bite (pepper) during chew and burn in the aftertaste

3) Soy Protein
   a) This binder was detected possibly
   b) Its effects were to:
      1) make the meat character flat or bland
      2) reduce intensity of saltiness
      3) reduce aromatics of the spices
      4) reduce duration and intensity of burn

All of the conventional binders affected the flavor to a degree. The low heat NDM had less flavor effect than the soy protein and possibly less than the high heat NDM.

The flavor trends for the wieners containing commercial dried cottage cheese whey (Lot C) from directly acidified cottage cheese and this whey buffered is summarized below.

1) Commercial cottage cheese whey (Lot C)
   a) This binder was detected possibly
   b) Its effects were similar to conventional binders; these were to:
      1) make the meat character flat
      2) reduce spice aromatics
      3) reduce bite
   c) Comparing it to high heat NDM, it:
      1) had dryer texture
      2) had less meat identity and a lag in flavor release
      3) had less spice aromatics and probably less pepper effect (bite, burn)

d) Comparing it to wiener containing (Lot C-buffered), it:
    1) had less flavor
    2) may have been detected per se

2) Commercial cottage cheese whey (Lot C-buffered)
    a) This binder was not detected per se
    b) Its effects were not similar to conventional binders
    c) Comparing it to high heat NDM, it:
        1) had better texture
        2) more meat identity
        3) more spice identity
        4) possibly less pepper burn

The criterion for evaluating binder performance should be how little the binder affects the flavor of the wiener. The binder can serve two purposes: 1) actual protein binder; 2) non-meat, and therefore a less expensive filler. If the binder can accomplish its purposes without adding an off-note or altering the flavor image of the fully seasoned meat blend, it has possibilities as an additive.

The flavor was affected by the addition of the commercial dried whey in the unbuffered system. The wiener containing dried cottage cheese whey (Lot C-buffered) had more meat and spice flavor. Comparing the results from different panel sessions, the wieners containing dried whey and buffer had no greater effects than did low heat NDM. Therefore, in this study, the wiener containing dried cottage cheese whey and buffer performed at least as well as those containing conventional NDM binders.

SUMMARY

Part II

The following summary was made form this study of the use of dried cottage cheese whey as a non-meat binder in an emulsion-type sausage.

1. Buffereing the emulsion with phosphate in which dried whey Lot C had been added resulted in a pH not significantly different from the pH of emulsions containing some conventional non-meat binders and the all-meat controls.

2. Peelability score was greater with the use of dried whey Lot C buffered compared to dried whey Lot C alone and was not significantly different from emulsions containing low heat NDM, Ca^{++} reduced NDM, and soy protein.

3. The use of dried whey Lot C-buffered resulted in significantly less fat separation than dried whey Lot C alone and resulted in fat separation scores comparable to conventional non-meat binders.

4. Dried whey Lot C-buffered resulted in the least percentage weight loss after processing of all non-meat binders studied.

5. More meat and spice flavor was detected in the flavor analysis with the use of dried whey Lot C-buffered than any of the other lots subjected to flavor analyses.

6. Dried whey Lot C, high heat NDM, and dried whey Lot C-buffered resulted in the lowest percent reflectance ratio at 570/650 m indicating a darker color.

7. It was found that dried cottage cheese whey could be used as a satisfactory non-meat binder by increasing the pH with phosphate buffer to a level comparable to the pH of an all-meat wiener.

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THE USE OF DRIED DAIRY PRODUCTS IN SOME MANUFACTURED FOODS

by

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Part I

A study was made on the effect of hydrogen peroxide (H_2O_2) treatment of nonfat dry milk (NDM) used in continuous mix bread on such characteristics as loaf volume, grain, texture, and exterior appearance. NDM treated with five levels of H_2O_2 (0.025%, 0.05%, 0.075%, 0.10%, and 0.20%) during manufacture was used in a factorially designed experiment with a continuous dough mixing unit. NDM was used at levels of 3 and 6 percent of the dough formula. Three levels of dough oxidant and three mixing speeds were involved in the experiment. The H_2O_2 treated samples of NDM were analyzed for whey protein nitrogen, sulfhydryl content, and residual H_2O_2. Physical dough characteristics of the H_2O_2 treated NDM samples were measured with the farinograph. Total loaf score, loaf volume, grain and textures scores were increased significantly at levels of 0.10% and 0.20% H_2O_2 compared to no H_2O_2 treatment. This occurred at both 3 and 6 percent levels of NDM. A significant depression in total loaf score resulted with H_2O_2 treatments of 0.05% and 0.075% compared to the control.

Part II

A study was made on the use of dried cottage cheese whey as a non-meat binder in an emulsion-type sausage and compared to other non-meat binders and an all-meat control. Non-meat additives were used at 3.5 percent of the meat weight. The additives consisted of 2 lots of dried cottage cheese whey (Lots A and B) prepared at the University Dairy Plant, one lot of dried cottage cheese whey obtained from cottage cheese made by the direct acidification process (Lot C), this whey in a pH adjusted

system (Lot C-buffered), low heat NDM, high heat NDM, Ca^{++} reduced NDM, dried buttermilk and soy protein. Two water levels were used at the rate of 10 and 15 percent of the meat blend weight. The sausages were evaluated for the following: emulsion pH, peelability, fat separation, color, flavor and percentage weight loss after processing.

Dried whey (Lots A and B) compared to the all-meat control and other additives did not produce satisfactory binding characteristics. Buffering the emulsion with phosphate in which dried whey (Lot C) had been added resulted in a pH not significantly different from the pH of emulsions containing conventional non-meat binders, soy protein and Ca^{++} reduced NDM. Peelability score was greater with the use of dried whey (Lot C-buffered) compared to dried whey (Lot C) alone and not significantly different from low heat NDM, Ca^{++} reduced NDM, and soy protein. The use of dried whey (Lot C-buffered) resulted in significantly less fat separation than dried whey (Lot C) alone and resulted in fat separation scores comparable to conventional non-meat binders. Dried whey (Lot C-buffered) resulted in the least percentage weight loss after processing of all non-meat binders studied. More meat and spice flavor were detected in the flavor analysis with the use of dried whey (Lot C-buffered).