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THE EFFECT OF MILK AND MILK REPLACERS ON CAKE PROPERTIES

by

DALE EUGENE SIGSWORTH

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Approved by:

Joseph G Ponte Jr

Major Professor

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INTRODUCTION

The structure of cakes is highly dependent on the gel forming properties of the starch contained in the flour. Starch has been used to replace flour in high ratio cakes with satisfactory results (Cauwain and Gough 1975). Howard (1972) has suggested that the gelation stage is the most important stage in baking. During this stage, the batter changes from a fluid, aerated emulsion to a solid, porous cake structure which will not shrink after removing from the oven. If the cake batter has not reached the gelation temperature of the starch during baking the structure will not hold and the cake will collapse. Miller and Trimbo (1965) stated that any changes in the batter which allow earlier gelatinization and the associated increase in batter consistency improve the quality of the resulting cake. It is therefore of prime interest to study the effect of various cake ingredients on the gel forming properties of cakes.

For many years nonfat dry milk (NFDM) has played a prominent role in cake baking because of its desirable functional and nutritional properties. Because of higher prices, lower availability and production decreases, bakers have been searching for products which are available and economical to use and still have properties similar to NFDM. As a result the present day market offers a vast number of all-dairy and cereal-dairy blends which act as substitutes for NFDM. The effects of those replacers on cake crumb characteristics have not been thoroughly investigated.

The purpose of this study was to determine the effects of milk and milk replacers on the gel forming properties of starch in cakes. The study was designed to show if milk replacers affected the gelation properties of cakes in the same manner as NFDM.

REVIEW OF THE LITERATURE

Functions of NFDM in Baking

Before a discussion of previous work on milk replacers in cakes, the functions of nonfat dry milk in cake baking will be reviewed. Most of what will be covered here is based on a review by Kirk (1971) and Craig and Colmey (1971).

NFDM increases batter absorption and helps to retain its moisture during baking and during storage. The lactose contained in NFDM participates in the browning reaction with proteins to produce a uniform crust color during baking. Both the lactose and serum protein components produce a tenderizing effect on the crumb structure. About 75% to 80% of milk protein consists of casein which acts to impart body and resilience to the crumb. Casein is a near perfect protein from the standpoint of amino acid balance and therefore will contribute significantly to the nutritional make up of baked goods. Milk has a relatively high lysine content which when used with cereal products adds greatly to the nutritional value.

The effects of NFDM on the rheology of batters and dough has not been extensively studied. D'Appolonia (1972) reported that the addition of NFDM to starch slurries lowered the amylograph pasting temperature, raised the peak viscosity and did not affect the peak temperature.

Utilization of Milk Replacers

Of all milk replacer ingredients whey is probably more widely used and has been in use longer in cake products than other ingredients. This is due, in part, to the economical factors and partly to the functionality of whey which so readily fits into cake systems.

Hanning and DeGoumois (1952) have described various functions of whey in cake baking. Cakes made with whey at a 35% level (flour basis) with a reduction of 33% sugar and decreases in shortening and eggs compared favorably with the control cakes. A sensory score nearly as high as the control cakes was achieved when eggs and shortening were reduced. When all three variables were reduced by 33% the whey cakes scored less by a statistically significant amount.

In a second series of tests, Hanning and DeGoumois (1952) reported that whey cakes showed an advantage over cakes made with NFDM and fluid milk when tested twenty-four hours after baking. No detrimental effects of whey were noted on flavor in the cakes after forty-eight hours. Cakes made with 15% whey ranked better for moistness than cakes made with either 15% NFDM or 7.5% whey.

In a third series of tests, Hanning and DeGoumois (1952) reported increase in batter viscosities with additional whey or fat. Volume and compressibility were improved when the whey content was increased in cakes containing 40% fat.

Compressibility and texture were significantly improved when more whey was added.

The same researchers found that increasing whey levels resulted in a uniform batter viscosity when adjustments were made for water level. Whey improved texture and compressibility and did not signficantly reduce cake volume.

Best (1967) found that cakes made with 10% whey, 2% NFDM and 30% fat produced the highest volume of all treatments at each sugar level (100% to 130%). The control cakes, made with 12.5% NFDM and 50% fat, showed the highest batter viscosity and the lowest specific gravity. Although the specific gravity data would imply that this cake should have the best volume it was inferior to the cakes made with 10% whey and 2% NFDM. The cakes made with 10% whey, 2% NFDM and 30% fat were also more tender than the control cakes which contained 50% fat.

Soy flour has been used in economy grade cakes to improve moisture retention and shelf-life of the cakes. Turro and Sipos (1970) studied a special process soy flour in four different cake systems. Special process soy flour is higher in protein and fiber and lower in fat than regular soy flour, and has a greater water binding capacity, improved flavor and higher protein content. They found that use of special process soy flour in pound cakes at 50%, 75%, and 100% replacement for NFDM resulted in cakes having very little difference in quality. Adjustments in the formula were small--a slight increase in water and the addition of dextrose to replace the reducing sugar of NFDM at over 50% replacement level was necessary.

In sponge cake, Turro and Sipos (1970) found an increase in volume at both the 50% and 75% level of replacement. At the 100% level of replacement 17% more baking powder was needed to achieve the same volume.

Special-process soy flour at 75% replacement level was the best for devil's food cake. Although the volume at 75% level replacement was the same as the control, the grain and texture received much better sensory scores. The 100% level of replacement resulted in lower volumes.

The yellow layer cakes showed good results in 50% and 75% levels of replacement. At 100% replacement dextrose was added at 2% of sugar weight for color and a 75% increase in baking powder was needed to obtain the desired volume.

MATERIALS AND METHODS

Materials

The two cake systems utilized were yellow sponge cake and yellow layer cake. The formulas and ingredients used in both cakes are given in Table I.

Low-heat NFDM was used in the control cake. Typical analyses for most of the replacers is given in Table II. An all-dairy blend milk replacer was used. The milk replacer is made by Kraftco Corporation and marketed as Cake Classic. The analysis was not available; however, the ingredient listing is as follows: sweet whey solids, sodium caseinate, nonfat dry milk, lecithin, calcium phosphate, and calcium oxide.

Methods

Sponge Cake Mixing Method. The N-50 Hobart Mixer with 5-quart bowl and wire whip was used to mix the sponge cakes. All of the dry ingredients with 56% of the water were added to the mixing bowl and mixed for one minute at low speed. The bowl was scraped and the ingredients were mixed an additional two minutes at second speed. The remaining water was added and the bowl was scraped. The batter was then mixed for one minute at low speed. The bowl was scraped and the batter mixed one minute at high speed.

Layer Cake Mixing Method. The N-50 Hobart Mixer with 5-quart bowl and two wing paddle were used to mix the layer cakes. All of the dry ingredients and 64% of the water were added to the mixing bowl and mixed one minute at low speed. The bowl was scraped and the ingredients were mixed for three minutes at speed 2. The remaining water was added after which the bowl was scraped, followed by a final mixing period of three minutes at low speed.

The treatments for the layer and sponge cake are given in Table III. Treatments 2 through 6 represent an effort to study the effect of 100% replacement of NFDM by the replacers with no other formula changes made. In treatments 7 through 9 the water level was optimized. The water level at which the cake volume was highest was determined to be optimum. The level of calcium caseinate and whey were determined by the percentage which they represent as components of NFDM. The level of soy flour was determined by the level of soy flour used in many commercial replacers.

Baking Method. A description of the baking method for yellow sponge cake and yellow layer cake follows. The batter (340 g) was weighed into an 8-inch tin-plated steel cake pan with a paper circle at the bottom. The sponge cakes were baked in a Reed Reel Oven at 365°F for twenty-seven minutes. The layer cakes were baked at 375°F for twenty-five minutes. After removal from the oven the cakes were allowed to cool on a metal rack for one-half hour before being taken from the pan. After depanning, the cakes were allowed to cool another one-half hour

TABLE I

INGREDIENTS UTILIZED IN THE YELLOW LAYER CAKE AND THE YELLOW SPONGE CAKE SYSTEMS

Ingredient	Yellow Sponge Cake	Yellow Layer Cake
Cake Flour	100.0[a]	100.0[a]
Granulated Sugar	106.1[b]	120.0[b]
Salt	2.5	3.0
NFDM (milk replacer)	10.0[c]	10.0[c]
Whole egg solids	10.3[d]	11.7[d]
Double-acting Baking Powder	5.0[e]	6.0[e]
Soy Flour	1.7[f]	--
Cake Emulsifier	1.04[g]	1.47[g]
Shortening (emulsified)	--	23.3[h]
Water	98.6	130.0

[a] Lite Maid Cake Flour obtained from International Multifoods.

[b] Domino Extra Fine Granulated Sugar obtained from Amstar Corp.

[c] Low-heat NFDM obtained from Land O' Lakes, Inc.

[d] Whole egg solids obtained from Monark Egg Corp.

[e] Red Star Baking Powder obtained from Universal Foods Corp.

[f] High fat soy flour (12% fat) obtained from Archer Daniels Midland Co.

[g] Atmos 2462 Cake Emulsifier obtained from ICI America, Inc.

[h] Atmos 729 Cake Emulsifier obtained from ICI America, Inc.

[i] Quick Blend Emulsified Cake Shortening obtained from Hunt-Wesson Foods, Inc.

TABLE II

TYPICAL ANALYSES OF MILK/REPLACERS

Milk/Replacer	Protein	Moisture	Carbohydrate	Fat	Ash
NFDM[1]	35.0	3.5	51.0	0.8	8.6
Soy-whey[2]	35.5	5.0	51.0	0.9	6.5
Whey[3]	12.5	4.5	72.0	1.2	8.2
Soy Flour (defatted)[4]	47.0	8.0	36.6	0.9	6.0
Calcium Caseinate[5]	90.0	3.0	--	0.7	6.0

1 Land O' Lakes, Inc.: Low-heat Nonfat Dry Milk - Land O' Lakes Food Processing Bulletin No. 101a.

2 Land O' Lakes, Inc.: Airlac 550 - Land O' Lakes Food Processing Bulletin No. 124b.

3 Land O' Lakes, Inc.: Low-heat Whey - Land O' Lakes Foods Processing Bulletin No. 117a.

4 Watt, Bernice K. and Merrill, Annabel L. 1963. Composition of Foods Agriculture Handbook No. 8, USDA.

5 Dairy Research Inc. Dairy Based Ingredients for Food Products.

before the volumes were measured. The cakes were then wrapped in heat sealable plastic and stored in the freezer for future tests.

Physical Tests. The batter temperature was measured immediately after mixing with a dial thermometer. Batter temperatures were maintained between 66°F and 70°F. Batter specific gravity was determined by pouring the batter from the mixing bowl into an aluminum measuring cup. Specific gravity was calculated by dividing the weight of the batter by the weight of an equal volume of water and expressed as grams per milliliter.

The cake volume was determined by the rapeseed displacement method one hour after baking. A cross-sectional slice 1 inch wide and 5.5 inches long was then taken 3 inches from the edge of each cake and compressibility was measured using a Bloom Gelometer. The readings recorded by this method are the weights in grams required to deform the sample 4 mm by a 1-inch diameter flat bottomed plunger.

Starch Gelatinization. Starch was isolated from cake samples prior to analysis. Crusts were removed from the cakes and the cakes were placed in 600 ml of water in a liter beaker. The beaker with cake was placed on a magnetic stirrer. A stirring bar was added. Water was added until all the cake particles were suspended while stirring. The stirrer was operated at a relatively low speed such that a vortex did not develop. The mixture was stirred for twenty minutes. The suspension was filtered through a 116 Nitex bolting cloth. The cloth was draped in a Buchner funnel for suction to aid

TABLE III

THE LEVELS OF NFDM AND MILK REPLACERS AND THE LEVELS OF WATER USED IN THE TREATMENTS DURING THIS INVESTIGATION

Treatment No.	Treatment	Milk/ Replacer (%)[1]	Sponge Cake Water Level (%)[1]	Water Level (%)[1]
1	NFDM (Control)	10	98.6	130
2	Whey[2]	10	98.6	130
3	Calcium Caseinate	10	98.6	130
4	Soy Flour	10	98.6	130
5	All-Dairy	10	98.6	130
6	Soy-Whey	10	98.6	130
7	Calcium Caseinate	3	97.3	126.7
8	Whey[2]	7	97.3	126.7
9	Soy Flour	5	98.6	130

[1] Percentage on flour basis

[2] Low-heat Whey

in the filtering of the cake suspension. The filtrate was poured into 250 ml centrifuge bottles and placed in a centrifuge. The samples were centrifuged at 2400 RPM for ten minutes. The samples were decanted, resuspended and poured into 50 ml centrifuge tubes. It is important to note that if any fat remained in the centrifuge bottles, it was carefully washed out before resuspending the starch. The 50 ml centrifuge tubes of resuspended starch was centrifuged ten minutes at 2400 RPM. The starch sample, after decanting the tube, was transferred to a 4-ounce glass bottle and frozen at 10°F. After freezing, the samples were freeze dried. Using the freeze dried starch sample, the percent of starch gelatinization was determined by Chiang and Johnson's (1977) glucoamylase method.

Cake Crumb Viscosity by the Amylograph. The following materials and equipment were used to measure cake crumb viscosity: a Brabender Visco-amylo-graph with 350 cm.-g. cartridge, a Waring blender--2 speed, a water bath, a 600 ml beaker, and 125 grams of cake crumb with the crust removed. The method used was a modification of the method used by Yasunaga (1968) for the determination of starch gelatinization in bread. The cakes were allowed to thaw one hour on the lab bench and the crust was removed. A 125 gram piece of cake was placed in the Waring blender with 300 ml of distilled water and blended fifteen seconds at low speed followed by forty-five seconds at high speed. The slurry was transferred to a 600 ml beaker with an additional 150 ml of water and placed in the water bath for one hour at 30°C before transferring to the amylograph bowl. The slurry was heated from 30°C to 95°C at the rate of 1.5°C per minute for fifty-two minutes.

<u>Amylograph Viscosity on Flour and NFDM/Replacer</u>. In this study 80 grams of flour were used with 460 ml of distilled water. The standard 700 cm.-g. cartridge and procedure was utilized. The treatment levels are given in Table IV. The same levels of milk and milk replacers were used in this study as in the cake studies. In addition, lactose was added to the treatments to obtain further information.

<u>Moisture</u>. The AACC method 44-15A was used on a uniform sample of cake crumb for the moisture determination.

<u>pH</u>. Preparation for the pH determination was made by stirring 15 grams of cake crumb with 100 ml of water in a 150 ml beaker for twenty minutes on a magnetic stirring apparatus. After stirring, the suspension was allowed to stand for five minutes. pH was determined with a Corning meter.

<u>Crust Color and Crumb Grain</u>. Color was determined subjectively by the experimenter. Ratings were either satisfactory or unsatisfactory. The cakes were also ranked according to color for comparison. The grain was also determined subjectively by the experimenter.

<u>Height of Cake during Baking</u>. It was observed that cakes baked with certain treatment seemed to shrink more while still in the oven than others. Thus the following experiment was prompted. Cakes were baked in 7.5-inch glass pans utilizing a batter weight of 320 grams. A cathetometer was used to measure the heights of cakes after fifteen, twenty, and twenty-five minutes of baking. The cathetometer used was obtained from the Department of Physics. The particular one used in

TABLE IV

TREATMENT LEVELS FOR AMYLOGRAPH FLOUR-NFDM/REPLACER VISCOSITY STUDY

Treatment	Treatment Level (%)[1]
Control	0
NFDM	10
Whey	10
Calcium Caseinate	10
Soy Flour	10
All-Dairy	10
Soy Whey	10
Calcium Caseinate	3
Whey	7
Soy Flour	5
Lactose	6

[1] Percentage on flour basis

this study measured vertical heights from 0 to 100 cm. The cakes were baked in a Despatch Reel Oven. The oven had a glass door which proved convenient because the oven door could be left shut while the measurements were being taken. The reel was not operated during the baking process to improve the accuracy of the measurements.

Micrographs of Cake. Small centrally located cubes (0.25 inches^3) were mounted and frozen at -20°C for slicing by an American Optical microtome model Cryp-cut II apparatus. The cake slices were mounted on glass slides for observation on a light microscope. The slices were viewed at a magnification of 378 x.

RESULTS AND DISCUSSION

Amylograph Viscosity on Flour and NFDM/Replacer

The amylograph results for flour-NFDM and milk replacer studies are given in Table V. In all cases milk and milk replacers lowered the peak viscosity as well as the temperature at which the peak viscosity was attained. Conversely, lactose, as Hirai et al (1970) have shown, increased peak viscosity and delayed the attainment of peak viscosity until a higher temperature was reached. Both levels of whey yielded higher peak viscosities than NFDM whereas the other treatments yielded lower peak viscosities. Sugar concentrations, especially at high levels, decrease the available water of a given system. When sugar and starch are combined in a water system, a decrease in water availability due to the sugar, will increase the concentration of starch in the remaining water, thus increasing the viscosity. The high lactose content of whey which would reduce the available water without modifying the way the starch swells is the most probable reason for the higher viscosity. Soy flour was quite effective in lowering peak viscosity. Of all treatments at the 10% level, the soy flour treatment yielded the lowest viscosity.

FIGURE I

TYPICAL AMYLOGRAPH VISCOSITY CURVE INVOLVING FLOUR PLUS 10% CALCIUM CASEINATE

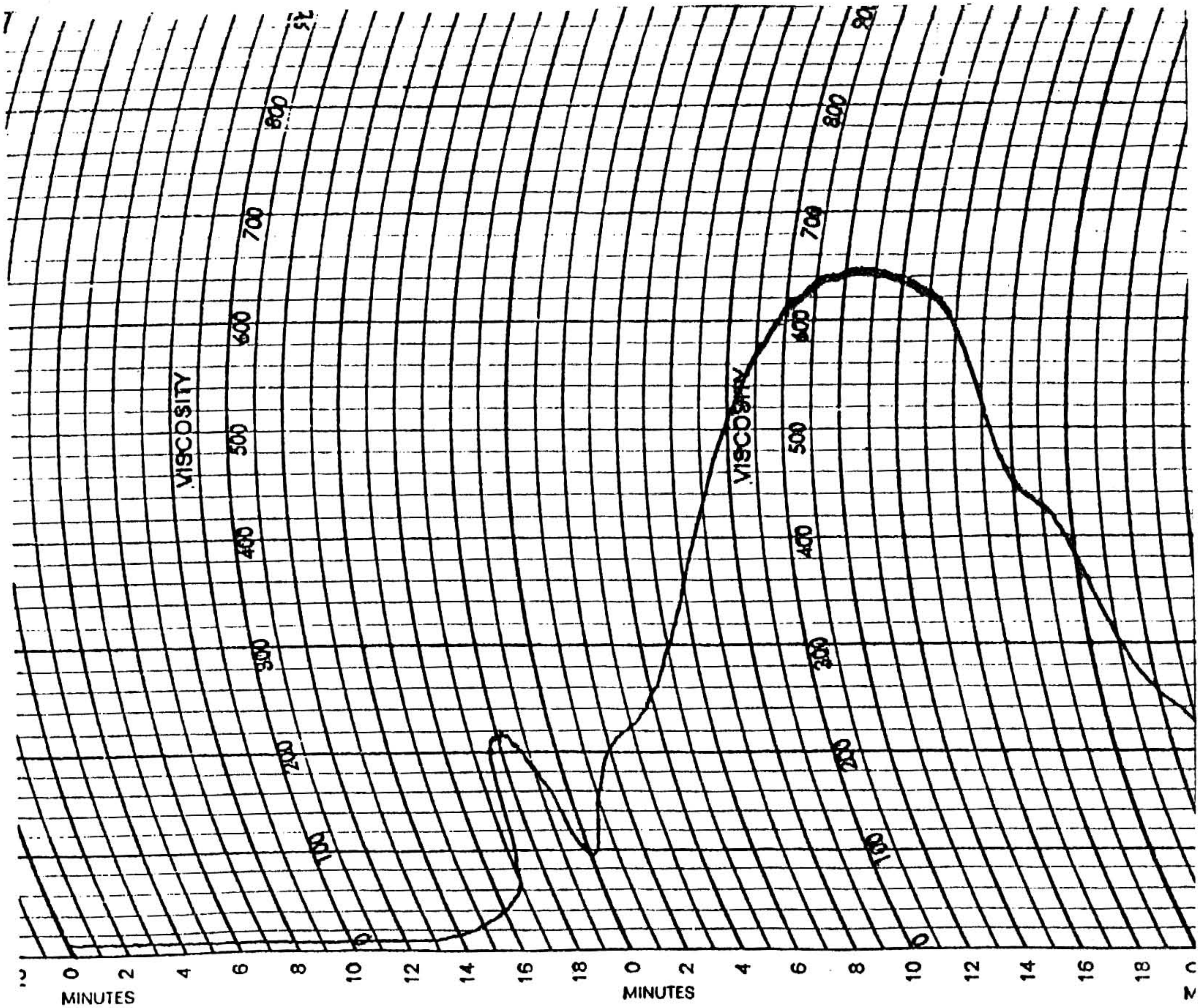


TABLE V

THE PEAK VISCOSITY IN BRABENDER UNITS AND THE TEMPERATURE OF THE PEAK VISCOSITY IN °C OF THE FLOUR-TREATMENT PASTES AS OBTAINED BY THE AMYLOGRAPH

Treatment (%)[1]		Peak Viscosity[2,3]	Temperature of Peak Viscosity[2,3]
Control	0	880 B	88.5 A
NFDM	10	600 D	73.5 D
Whey	10	690 C	79.5 C
Calcium Caseinate	10	530 E F	75.0 D
Soy Flour	10	490 F G	80.25 C
All-Dairy	10	525 F G	79.5 C
Soy-whey	10	515 F G	79.5 C
Calcium Caseinate	3	485 G	80.25 C
Whey	7	675 C	84.8 B
Soy flour	5	570 D E	81.4 C
Lactose	6	945 A	89.2 A

[1] Percentage of Flour basis

[2] Means followed by the same letter are not significantly different at the 0.05 level of probability as determined by Duncan's Multiple Range Test

[3] Mean of 2 replicate observations

The calcium caseinate treatments had some unusual effects on the amylograph viscosity curve. A reproduction of the curve is given in Figure I. An explanation for the minor peak in viscosity may possibly be found in the description of the following phenomena. Casein exists in micelles which tend to form aggregates when heated. This phenomenon was observed by the experimenter between 45°C and 56°C. At 45°C the aggregates were very small but continued to grow until the minor peak in viscosity began to register on the amylograph. From that point the aggregates rapidly disintegrated. By the time the starch pasting temperature was reached the aggrgates were no longer visible. The starch was rapidly absorbing water at the temperature in which the peak was formed. This effect, in combination with the aggregate formation by the casein, could possibly be enough to yield the minor peak shown in Figure I. It may also be theorized that the decrease of the viscosity is caused by shear thinning. It should also be noted that the peak resulting from the 3% calcium caseinate treatment does not show the minor peak and reduces the peak viscosity more than the 10% treatment. It is apparent that caseinate and perhaps the mineral ions contained in caseinate modify the starch such that the peak viscosity is greatly reduced. Howard (1972) reported a stabilization in batter viscosity during the initial stages in baking as the result of polyvalent cation salts, such as calcium chloride contained in the batter. A possible reason for higher viscosity with the 10% treatment is that the 10% treatment is providing a higher background viscosity by a reduction in the available water in the system.

NFDM and milk replacers lower the temperature of amylograph peak viscosity whereas lactose, a major component of whey and NFDM, acts to raise the temperature of amylograph peak viscosity. The amylograph curves for NFDM showed that a lower temperature was required to reach the peak viscosity than curves for milk replacers. It appears that both serum and casein proteins act to lower the temperature of the peak viscosity and when combined as in NFDM they act synergistically. Soy flour lowered the temperature of the peak viscosity to approximately the same level as the whey treatments. However, the whey treatments showed much more difference between treatment levels than did the curves for soy flour. Both of the commercial milk replacers lowered the peak viscosity temperature to about the same level as whey.

Effect of Milk Replacers on Yellow Layer Cake

The results of the yellow layer cake study are given in Table VI. There was no significant differences among data for specific gravity or cake volume (Table VI) indicating that the type of milk or milk replacer had no effect on those factors in the layer cakes which contained 23% fat (flour basis). For specific volume, only the highest and lowest means were significantly different according to Duncan's Multiple Range Test.

The analysis of variance showed that milk replacers did not significantly affect the starch gelatinization in layer

TABLE VI

MEANS OF STATISTICALLY ANALYZED PARAMETERS FOR THE YELLOW LAYER CAKE SYSTEM

Measured Parameters		Specific Gravity[1,2] (g/cc)	Cake Volume[1,2] (cc)	Starch Gelatinization Percentage[1,2]	Cake Compression[1,2] (g)	Cake Crumb Viscosity by Amylograph[1,3] (BU)
Significance of the F Statistic		0.17	0.39	0.08	0.34	0.34
Treatment (%)[4]						
NFDM	10	0.847 AB	1079 A	83.06 ABC	155 AB	382 A
Whey	10	0.853 A	1032 A	80.82 C	150 AB	338 A
Calcium Caseinate	10	0.833 AB	1039 A	83.70 ABC	179 A	340 A
Soy Flour	10	0.853 A	1067 A	85.68 A	146 AB	400 A
All-Dairy	10	0.843 AB	1089 A	82.95 ABC	154 AB	340 A
Soy-Whey	10	0.863 A	1062 A	84.13 ABC	136 B	370 A
Calcium Caseinate	3	0.820 B	1054 A	81.59 BC	149 AB	385 A
Whey	7	0.840 AB	1069 A	81.95 BC	162 AB	358 A
Soy Flour	5	0.847 AB	1078 A	84.80 AB	140 B	382 A

[1]Means followed by the same letter are not significantly different at the 0.05 level of probability as determined by Duncan's Multiple Range Test
[2]Mean of three replicate observations
[3]Mean of two replicate observations
[4]Percentage of flour basis

cakes and that the test for compressibility failed to show significant differences between treatments, although it was noticeable to the experimenter that the cakes made with 10% calcium caseinate were less tender than cakes made with other treatments. However, the cakes made with 10% soy flour and 10% whey were significantly different in percent gelatinization at the 0.05 level of probability.

The milk or milk replacers had no significant effect on amylograph viscosity of the cake crumb. Because of the greater concentrations of other ingredients involved in crumb viscosity, i. e., sugar, fat, and eggs, the effect of milk or milk replacers was small. It was expected that the relationship between crumb viscosity and percent of starch gelatinized would be related linearly and inversely because starch that is gelatinized to a greater degree will have less swelling power and thus yield lower amylograph viscosities. Although not significant, this relationship was observed ($r=-0.52$). The effect of the other major ingredients on crumb viscosity by the amylograph plus the large change in available water to the crumb tended to mask the effects of the NFDM and milk replacers.

Calcium caseinate tends to lower cake moisture levels in layer cakes (Table VII). Evidently casein does not have the humectant properties that serum milk proteins, soy proteins or lactose had during the baking process, thus allowing more moisture loss during the baking process. No trends were noted in the pH data.

TABLE VII

MOISTURE AND pH RESULTS FOR THE YELLOW LAYER CAKE SYSTEM

Treatment (%)[1]		Moisture (%)	pH
NFDM	10	28.3	8.00
Whey	10	29.9	7.85
Calcium Caseinate	10	26.5	8.05
Soy Flour	10	29.3	7.90
All-Dairy	10	29.4	8.05
Soy-Whey	10	28.4	7.95
Calcium Caseinate	3	27.8	7.85
Whey	7	28.4	7.94
Soy Flour	5	29.2	8.20

[1] Percentage of flour basis

TABLE VIII

HEIGHTS IN CENTIMETERS OF YELLOW LAYER CAKE DURING BAKING

Treatment (%)[1]		15 minutes	20 minutes	25 minutes
NFDM	10	5.54	7.02	6.80
Whey	10	5.31	6.70	6.52
Calcium Caseinate	10	4.70	5.92	6.35
Soy Flour	10	5.28	6.97	6.66
All-Dairy	10	5.68	7.08	6.66
Soy-Whey	10	5.02	6.48	6.26
Calcium Caseinate	3	4.65	7.13	7.05
Whey	7	5.36	7.08	6.76
Soy Flour	5	5.50	7.00	7.09

[1] Percentage of flour basis

Crust color was satisfactory for cakes made with NFDM, whey and the all-dairy replacer. The cakes made with the soy-whey blend were too pale to be grouped with the satisfactory cakes but were far better than the cakes made with calcium caseinate and soy flour which were unsatisfactory.

A study of the cake crumb grain resulted in a classification of the cakes into groups as follows:

Fine:	7% whey
	10% all-dairy
Medium:	10% NFDM
	10% soy-dairy
	10% whey
Coarse:	10% and 5% soy flour
	10% and 3% calcium caseinate

Height of the cakes at different intervals while baking is given in Table VIII. At the fifteen minute reading it was readily apparent that the amylograms obtained on calcium caseinate was affecting the height. A comparison of the flour and NFDM/replacer systems shows pasting temperatures (the temperatures of initial visible viscosity) of 60°C, 58.5°C and 51°C for the control, flour-NFDM and flour-10% calcium caseinate respectively. On this basis it appears that caseinate increases the viscosity of the batter during the early part of the bake cycle which would tend to keep the height of the cake low. The treatments containing caseinate including NFDM or soy flour at the 5% level maintained the height of the cake very well from the twenty minute reading until the twenty-five minute reading. With the all-dairy replacer and the whey treatment there was a considerable amount of shrinking during this period of the bake cycle.

Effect of Milk Replacers on Yellow Sponge Cake

The results of the yellow sponge cake study are given in Table IX and shown in Figure IIa. The analysis of various procedures and Duncan's Multiple Range Test for specific gravity showed levels of significance. The batter containing NFDM had the lowest specific gravity whereas the batters containing soy flour and 10% caseinate had the highest specific gravity. NFDM and whey contain serum proteins wheich have foaming properties that aid in the incorporation of air into the foam batters, such as sponge cakes.

Although the analysis of variance F-statistic for cake volume was not significant for effects of milk on volume it can be noted from Duncan's Test that cakes made with NFDM were significantly higher in volume than all but two of the other treatments. All other cakes were statistically the same at alpha level equal to 0.05.

In yellow sponge cake the effect of milk or milk replacer on the percentage of starch gelatinization was highly significant. The cakes made with 10% whey, 10% calcium caseinate and 10% soy flour resulted in a significantly lower percentage of starch gelatinization compared to the control NFDM cake. A study of the amylograph results for flour-whey and flour-soy

TABLE IX

MEANS OF STATISTICALLY ANALYZED PARAMETERS FOR THE YELLOW SPONGE CAKE SYSTEM

Measured Parameters		Specific Gravity[1,2] (g/cc)	Cake Volume[1,2] (cc)	Starch Gelatinization Percentage[1,2]	Cake Compression[1,2] (g)	Cake Crumb Viscosity by Amylograph[1,3] (BU)
Significance of the F Statistic / Treatment (%)[4]		0.0003	0.08	0.0001	0.80	0.53
NFDM	10	0.790 C	1206 A	86.95 A	154 A	587 A
Whey	10	0.810 C	1136 AB	75.85 D	153 A	665 A
Calcium Caseinate	10	0.880 A	1139 AB	76.13 D	197 A	558 A
Soy Flour	10	0.887 A	1084 B	80.87 C	179 A	655 A
All-Dairy	10	0.860 AB	1117 B	83.65 B	144 A	618 A
Soy-Whey	10	0.850 AB	1120 B	85.79 AB	162 A	565 A
Calcium Caseinate	3	0.850 AB	1131 B	84.64 AB	154 A	600 A
Whey	7	0.827 BC	1114 B	85.33 AB	151 A	603 A
Soy Flour	5	0.863 AB	1106 B	83.77 B	159 A	618 A

[1] Means followed by the same letter are not significantly different at the 0.05 level of probability as determined by Duncan's Multiple Range Test

[2] Mean of three replicate observations

[3] Mean of two replicate observations

[4] Percentage of flour basis

Figure IIa

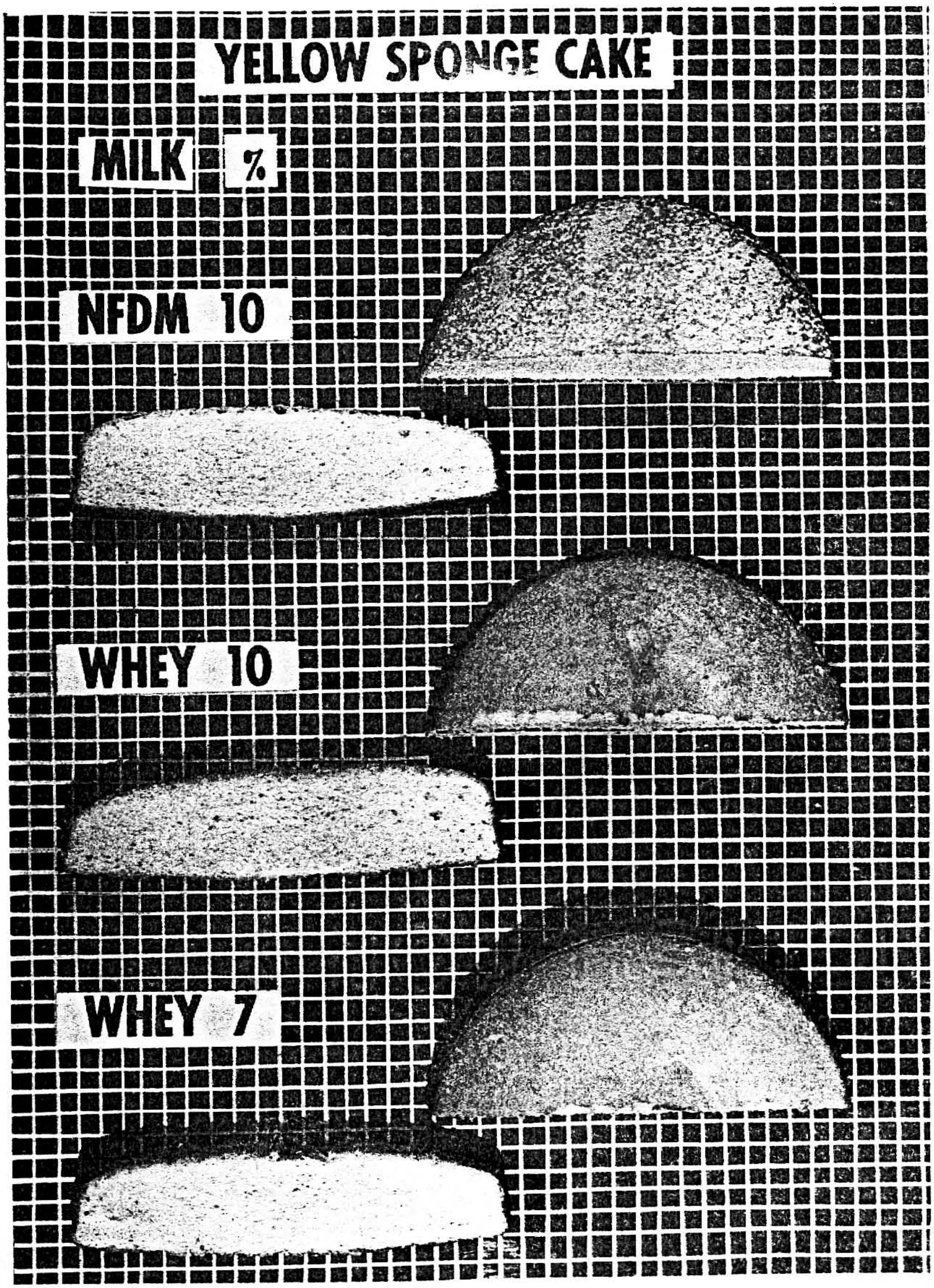
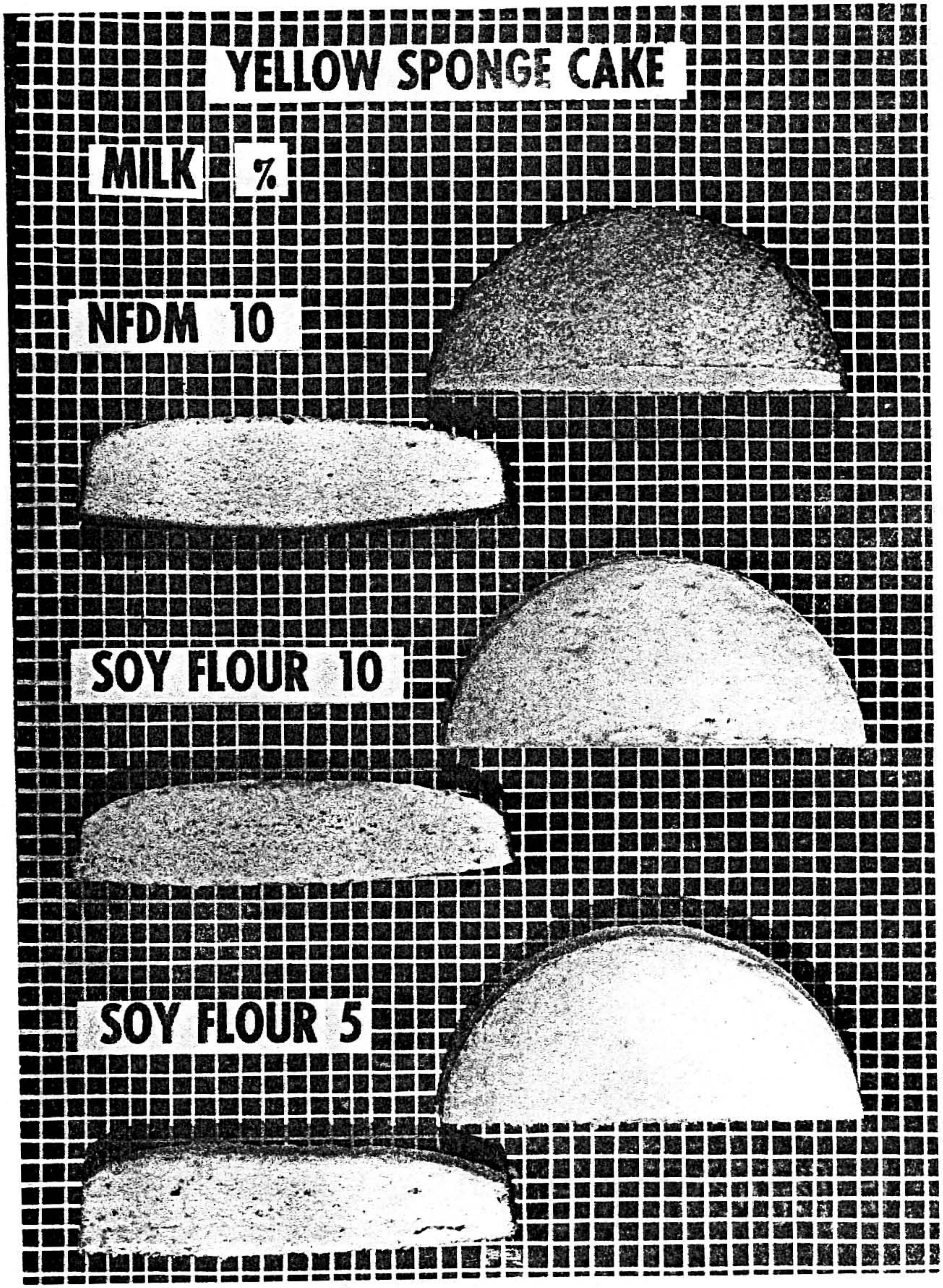
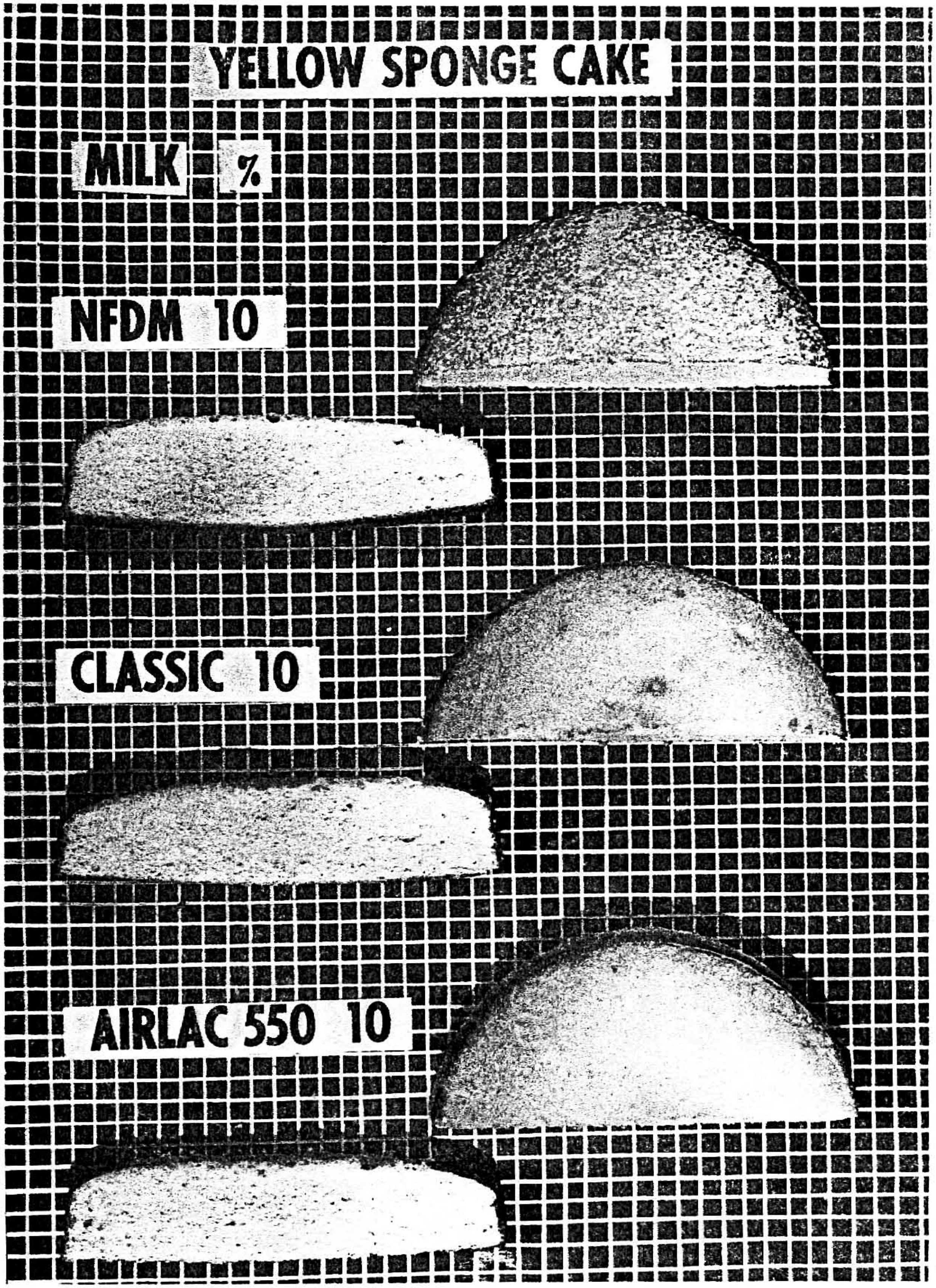
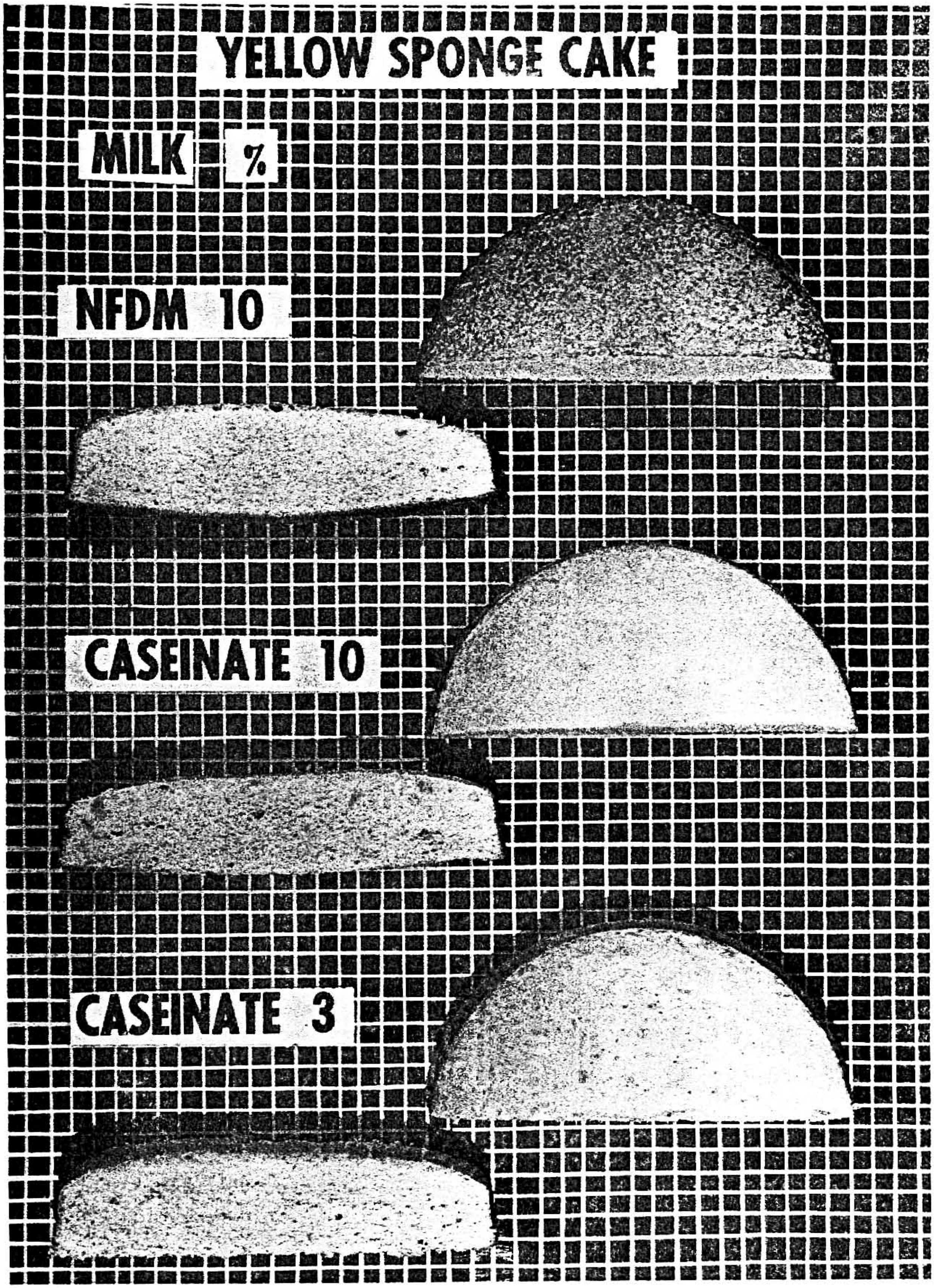


Figure IIa




YELLOW SPONGE CAKE
MILK
%
NFDM 10
CLASSIC 10
AIRLAC 550 10


YELLOW SPONGE CAKE
MILK %
NFDM 10
CASEINATE 10
CASEINATE 3

reveals that these treatments caused the temperature of the peak viscosity to be significantly higher than that of flour-NFDM. This phenomenon may partially explain the lower percentage of starch gelatinization in sponge cakes. Calcium caseinate, in the amylograph study, showed indications of being a strong competitor for water at gelatinization temperatures. Because water is needed for gelatinization the percentage of gelatinization would be expected to be lower in sponge cakes made with calcium caseinate.

No significant differences among the cake crumb compression data were noted in the statistical analysis. However, the cakes made with 10% calcium caseinate were noticeably tougher. Likewise, the cakes containing soy flour were slightly tougher and easier to handle than the control cake, whereas those made with whey were very tender and easily broken.

An amylograph study on cake crumb is difficult since cake crumb represents a very complex system. Theoretically, it would be expected that the treatments resulting in higher starch gelatinization percentage would yield lower amylograph viscosity on their respective cake crumb. This relationship was observed when comparing all of the treatments with the exception of the 10% calcium caseinate treatment. The relationship shows a negative correlation of 0.90 (Figure II) when the data points from the calcium caseinate treatment are excluded. This means that the theory mentioned above was substantiated very well in the sponge cake system.

At this point, it seems worthwhile to discuss the substantial differences in results obtained on the two cake

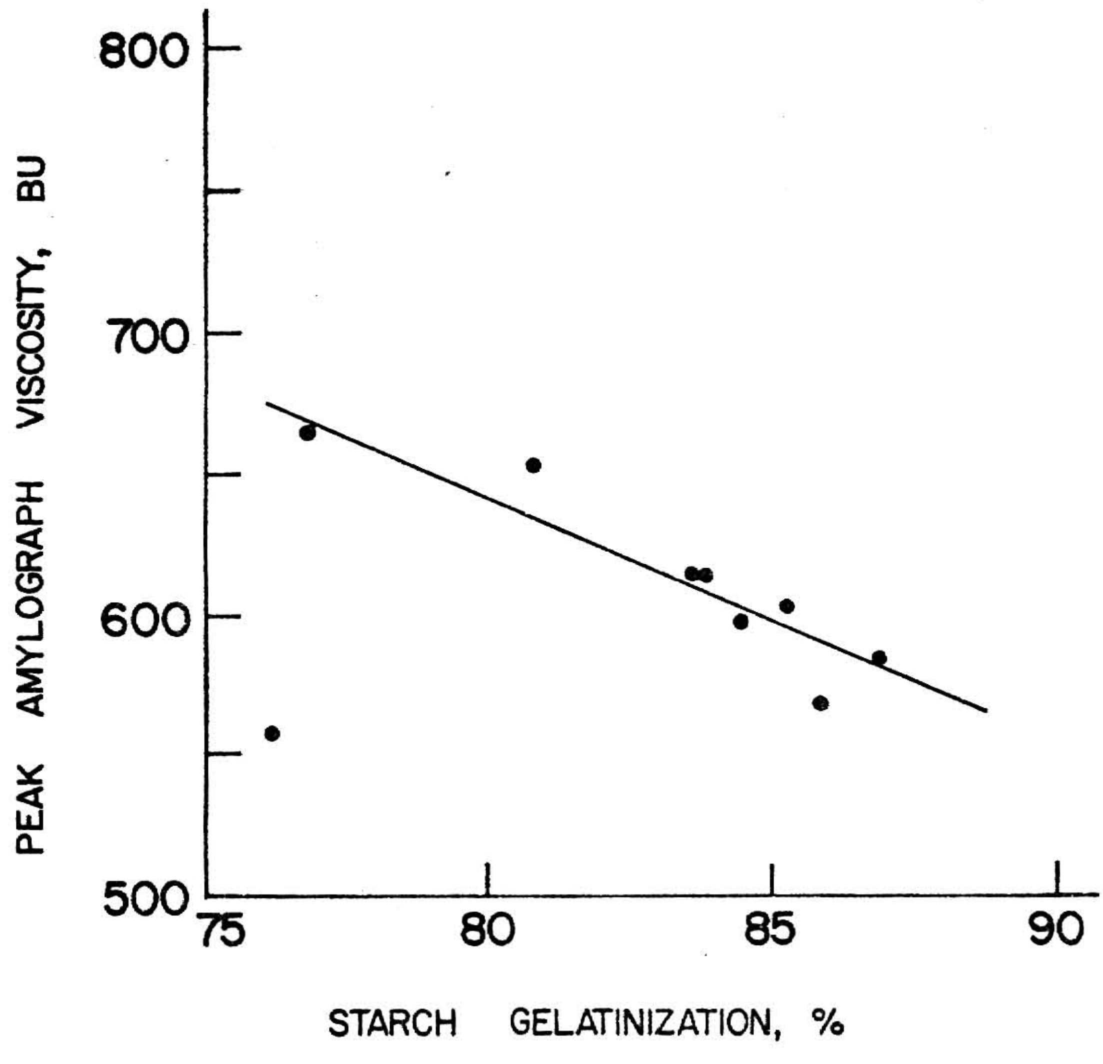


Figure II. The Relationship Between Starch Gelatinization and Cake Crumb Viscosity in the Sponge Cake System. r = 0.90

systems studied in this investigation. With the sponge cake system and the study involving the amylograph viscosity of flour-NFDM/replacers, the effects of NFDM and milk replacers on starch swelling were effectively demonstrated. However, in the layer cake system levels of significance relating these ingredients to starch swelling were not shown. Personal observation of cake quality did not reveal large differences among treatment effects in layer cakes, whereas in the sponge cake system differences as a function of treatment were very noticeable. In layer cakes, which are relatively rich, the necessity for milk or milk replacers are probably minimal due to the high tolerance built in the formula. It is apparent from the present work that the presence of fat and/or increased water level (23% fat and 130% water for layer cakes and no fat and 98.6% water for sponge cakes) may mask the effects of milk replacers on starch gelatinization, and related factors measured in the layer cake system.

Moisture and pH. The results of moisture on pH are given in Table X. The cakes made with 10% whey were the most moist. Those made with 5% soy flour showed an increase in moisture level over those containing 10% soy flour. No large differences were noted, however. The cakes made with the whey and calcium caseinate treatments had the lowest pH, whereas those made with the commercial blends of milk replacers were the highest. It should be noted, however, that these differences in pH have very minor, if any, effect at all on the cake system.

TABLE X

MOISTURE AND pH RESULTS FOR THE YELLOW SPONGE CAKE SYSTEM

NFDM/Milk Replacer	(%)[1]	Moisture (%)	pH
NFDM	10	25.9	7.80
Whey	10	27.4	7.70
Calcium Caseinate	10	25.0	7.75
Soy Flour	10	24.4	7.80
All-Dairy	10	24.5	7.90
Soy-Whey	10	24.4	7.90
Calcium Caseinate	3	24.8	7.75
Whey	7	26.0	7.70
Soy Flour	5	27.0	7.80

[1] Percentage of flour basis

Crust Color. Among the sponge cakes only those made with soy flour and calcium caseinate were too light in crust color. The remaining cakes were satisfactory ranging in color from NFDM (the darkest) to those made with the soy-whey blend. The importance of having a reducing sugar was demonstrated very well by the results of this test.

Cake Crumb Grain. The ratings as perceived by this experimenter for grain are as follows:

Medium:	10% NFDM
	10% Whey
Semi-coarse:	10% All-Dairy
	3% Calcium Caseinate
	7% Whey
Coarse:	10% Calcium Caseinate
	10% and 5% Soy Flour
	10% Soy-Whey

The cakes made with soy flour, 10% calcium caseinate or the replacer containing soy flour resulted in an unsatisfactory crumb grain.

Cake Height during Baking. The results in Table XI show the heights of sponge cake during baking. The cakes made with 5% soy flour and the 10% soy-whey blend treatment tended to be smaller after fifteen minutes of baking than the other treatments. Conversely, the cakes made with 7% whey and 10% all-dairy replacer were the largest after fifteen minutes of baking. The sponge cakes did not shrink as much after twenty minutes of baking as did the layer cakes. Sponge cakes have a more rigid and resilient structure than

TABLE XI

HEIGHTS IN CENTIMETERS OF YELLOW SPONGE CAKE DURING BAKING

Treatment (%)[1]		15 minutes	20 minutes	25 minutes
NFDM	10	5.08	6.29	6.38
Whey	10	5.28	5.84	5.82
Calcium Caseinate	10	5.23	5.89	5.79
Soy Flour	10	5.42	5.71	5.32
All-Dairy	10	5.87	6.44	6.19
Soy-Whey	10	4.96	6.04	5.90
Calcium Caseinate	3	5.17	6.28	6.22
Whey	7	5.85	6.10	5.90
Soy Flour	5	4.90	5.94	6.04

[1] Percentage of flour basis

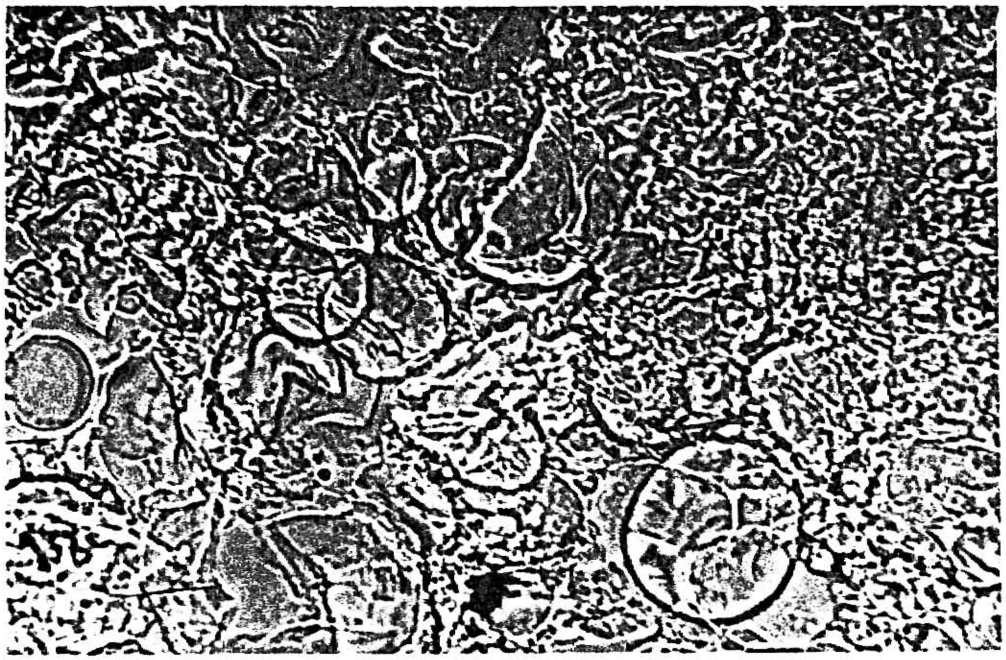
layer cakes.

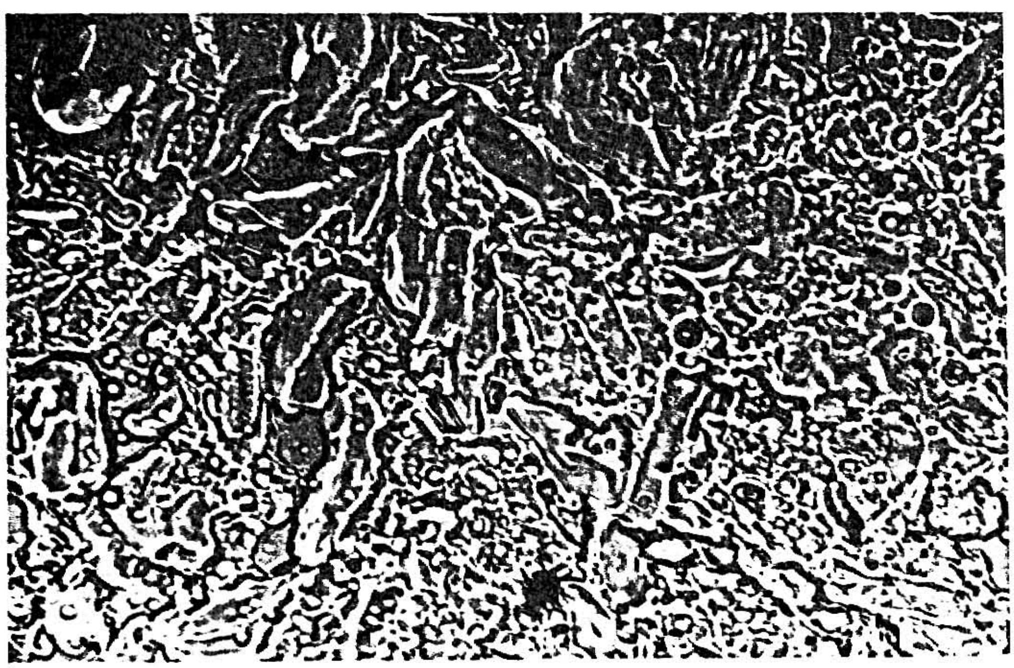
The peak viscosities of the flour-NFDM/replacer amylograph studies may be related to this shrinkage phenomenon. It appears, with the possible exception of the whey treatments, that the highest peak viscosities correspond with less shrinkage during the last five minutes of the baking period. Whey contains a high percentage of lactose which will decrease the water availability but not alter the way in which starch swells, thus higher viscosities in comparison to the other treatments were noted in the whey amylograms.

Micrographs of Cake. A study of the starch granules using the light microscope showed no noticeable differences. However, two pictures showing the swollen, intact starch granules and folded starch granules, both of which were seen in all treatments, are shown in Figure III.

FIGURE III

TYPICAL STARCH GRANULES





CONCLUSION

NFDM or an effective milk replacer is an essential part of cake systems. Crust color, grain and texture are strongly influenced by the type of milk powder or milk replacer used in the cake formulation. In layer cakes, the attributes just mentioned are the only ones which varying the milk treatment seems to affect significantly.

During this investigation levels of statistical significance were found only in the sponge cake data. Milk replacers did affect the specific gravity of the cake batter in the sponge cake system. Cake batters made with milk replacers were more dense than those made with NFDM. Cakes made with a milk replacer resulted in cakes having lower volumes than those made with NFDM. The percentage of starch gelatinized in the cakes varied greatly depending on the milk replacer used. In the sponge cake system cakes made with NFDM resulted in the highest percent of starch gelatinization. The cakes made with 10% milk replacing ingredients (whey, calcium caseinate and soy flour) resulted in low starch gelatinization whereas the other treatments were intermediate. The layer cake system was too complex to show significant differences.

Important areas of cake baking which were not analyzed statistically but in which general trends or differences were noted during this investigation. The cakes made with milk and milk replacers containing the reducing sugar lactose has a very satisfactory crust color. It would be necessary, for example, if one chose to use soy flour to replace NFDM to include a reducing sugar in the formulation to achieve a satisfactory crust color. The grain of cakes made with replacers lacking tenderizing agents such as lactose and serum milk proteins was coarse and therefore unsatisfactory. Various properties of the milk replacers seemed to be a factor in the height that the cakes achieved at different baking intervals.

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THE EFFECT OF MILK AND MILK REPLACERS ON CAKE PROPERTIES

by

DALE EUGENE SIGSWORTH

B.A., Southern Missionary College, 1976

AN ABSTRACT OF A THESIS

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DEPARTMENT OF GRAIN SCIENCE

KANSAS STATE UNIVERSITY
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ABSTRACT

Nonfat dry milk (NFDM) is an important component in making many cakes. In recent years, milk replacers have been utilized in cake production, to some extent, as a cost-saving measure. Milk replacers have had varying degrees of success depending on the types of cake systems involved. The present study was aimed at determining the effects of milk replacers and their components on cake properties. The materials utilized in this study were as follows: NFDM, whey, calcium caseinate, soy flour, a commercial all-dairy replacer and a commercial soy-whey replacer. Yellow sponge cake and yellow layer cake were the two systems of cake employed. Among the cake properties measured were volume, texture and several indices related to the condition of the starch in the cakes. The data indicate that NFDM and milk replacers alter cake properties very little in the layer cake system whereas in the sponge cake system milk replacers and their components are associated with a lower percentage of starch gelatinization, lower volume and higher batter specific gravity than NFDM.

Viscosity of flour suspensions with added NFDM and milk replacers was studied by the amylograph method. The data indicate that NFDM lowers the temperature of the peak

viscosity significantly more than the milk replacers. The viscosity of the suspensions with whey addition resulted in the highest viscosities among the materials utilized for the cake studies.