

COOKING QUALITIES OF SEVERAL
CONCENTRATIONS OF VARIOUS TYPES
OF NONFAT DRIED MILK SOLIDS

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This is to certify that the
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VARIOUS TYPES OF NONFAT DRIED MILK SOLIDS

By

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INTRODUCTION

During the past few years there has been a tremendous growth in the use of nonfat dried milk solids in commercial food products, in large quantity cooking and home cooking. Dried milk solids are easily stored and cost much less than fluid skim milk.

Three methods are used in manufacturing nonfat dried milk solids: atmospheric roller or drum drying, vacuum drum drying and spray drying. The latter process may be carried out at low, intermediate or high temperatures and such powders are called dairy, intermediate and oven dried milk solids. The different temperatures to which these milks are subjected during the drying process cause the dried milk solids to have certain characteristics which are desirable for some special uses in cooking.

This study was initiated to obtain information concerning the merits of the various processed nonfat dried milk solids at different concentrations in baked custards. Custards were selected because they have a high degree of sensitivity to slight changes in egg-milk-sugar mixtures as demonstrated by Carr and Trout (3) and in Logue's study (22).

REVIEW OF LITERATURE

Nonfat Dry Milk Solids

Definition

The Federal Food, Drug and Cosmetic Act of March 2, 1944 has defined defatted milk solids as follows (34):

"That for the purposes of the Federal, Drug and Cosmetic Act of June 26, 1938 (ct. 675, Sec. 152, Sta. 1040) nonfat dry milk solids or defatted milk solids is the product resulting from the removal of fat and water from milk, and contains the lactose, milk proteins and milk minerals in the same relative proportions as in the fresh milk from which made. It contains not over 5 percentum by weight of moisture. The fat content is not over $1\frac{1}{2}$ percentum by weight unless otherwise specified. The term milk when used herein, means sweet milk of cows."

Methods of Manufacture

Dried milks consumed in the United States are manufactured by three principal processes: spray, atmospheric roller or drum and vacuum drum. The milk is pasteurized before or during the drying procedure in all three processes.

In some drying procedures the milk is partially concentrated first to increase the drying speed. This is done by the application of heat. The concentration varies with the method but it may be as great as 40 percent. This heat treatment sometimes has an effect on the cooking quality of the milk. Holm (17) stated that skim milk is usually preheated to 185° F since the milk treated in this manner has better baking qualities than skim milk which has received only pasteurization treatment.

Spray Dried Process: In the spray drying method the partially concentrated milk is sprayed by pressure or centrifugal means into a chamber through which a current of heated air is directed. The milk droplets dry instantly to a fine powder. The force of gravity or cyclonic motion removes the milk powder from the air. Three different types of spray dried powder are produced. They differ only in the temperature used during the process (17).

Atmospheric Drum Process or Roller Process: In this method revolving metal rollers or drums are coated with a thin film of milk which dries by steam heat as the rollers revolve. A steel blade, which is placed parallel to the surface of the roller or drum, removes the film of dry milk in one complete revolution. The milk product is

then reduced to a powder by a grinding device. Wright (36) states that atmospheric roller drying causes quite extensive heat damage.

Vacuum Drum Process: This process is the same as the atmospheric drum process except that the drum or roller is enclosed in a chamber which is maintained under a partial vacuum during the drying period. Vacuum drum processed milk is expensive to produce and thus is manufactured only in very small quantities (20).

Characteristics of Nonfat Dried Milk Solids

Nonfat dried milk solids have many characteristics which affect their cooking properties. Hunziker (20) states that the particles in spray dried milks are minute spherical grains, each grain has one or more air cores and consequently is susceptible to oxidative deterioration. The lactose is present in a noncrystalline form as a very concentrated solution or glass (33). Since lactose constitutes the continuous phase it may diminish the permeability of the milk powder particles to gases. The lactose glass is very hygroscopic and can take up water until it is diluted to such an extent that the molecules attain sufficient mobility to become oriented in crystals. Dried

milk powders manufactured by the spray and vacuum drum processes are 99 percent soluble and retain many of the properties of fluid milk (20). Maximum protein solubility in water occurs at 50° C (18). Choi and coworkers (8) pointed out that lactose was nonhygroscopic in fresh non-fat dried milk solids of low moisture content. As the powder absorbed moisture, the lactose changed to α -lactose hydrate which was much less soluble. The critical moisture level was 7.5-8 percent. This moisture content was accompanied by loss of solubility, caking, browning and development of undesirable odors and flavors (29).

Atmospheric roller processed dried milk powders are composed of flakes which are irregular in size and shape (20). No air cells are present. These powders are partially non-hygroscopic. Due to the high drum temperature necessary for drying there is a slight discoloration of the product and partial coagulation of the protein. This coagulation is a result of the denaturation of the protein constituents, casein and lactalbumen, which makes them insoluble. Therefore these powders are difficult to dissolve in water.

Theory of Heat Coagulation

Custards thicken and attain a serving consistency due to the formation of a gel. This is formed by the

coagulation of protein which holds the liquid within its meshes. In custards egg furnishes the larger percentage of heat-coagulable protein, since only 0.75 percent of the protein of cow's milk is heat-coagulable. However this small amount has a decided effect on coagulation of custards (23). According to Gortner (12), heat denaturation or coagulation of proteins takes place in three steps: (a) the denaturation proper which is the intra-molecular rearrangement of the molecules, (b) the flocculation of the denatured protein and (c) the coagulation or setting. This coagulation occurs because of polymerization of the denatured protein molecules. Chick and Martin (4) thought that coagulation occurred in two stages only: denaturation and coagulation. In the language of colloid chemistry denaturation is the change in the protein from the hydrophilic to the hydrophobic state (24). When a protein has reached the denatured state it is insoluble. This occurs most readily at its isoelectric point and thus proteins are least soluble at this pH.

Coagulation of protein may be brought about by a variety of ways. One of the principal means is heat. Acids, alkalis, salts and sugar play an important role in coagulation. A brief discussion of the role played by these factors in the coagulation of custards follows.

Effect of Temperature

One of the most common ways that proteins are denatured in food preparation is by heat. Chick and Martin (5) state that heat coagulation is a reaction between protein and water. The effect of temperature is merely to accelerate the reaction (4). Davies (11) indicates that the degree of denaturation of the protein in milk depends upon the time and temperature of heating. The rate of heating plays an important role in the temperature at which coagulation takes place (23).

Effect of Acid

The clotting of the denatured protein by small amounts of acid or alkali is due to the electric charge given to the particle (5). Addition of an acid solution speeds the second part of the heat coagulation process but not the denaturation process itself. For every solution containing denatured protein there is a critical temperature, depending on the reaction, below which coagulation does not take place. In general the coagulation temperature is higher with an increase in acidity.

Effect of Alkali

Alkali also has a definite effect on protein coagulation. According to Chick and Martin (6), in alkaline solution the

second part of the coagulation process does not occur. If after heating, the alkali is neutralized with acid then coagulation occurs.

Effect of Salts

Chick and Martin (7) indicate that coagulation is greatly influenced by the presence of neutral salts. Dispersion by salts appears to be caused by the adsorption of ions on the denatured particles of protein. The ion of the opposite charge to that of the protein is adsorbed. The coagulating power of the ion increases with increasing valence. In heat coagulation of milk, the milk salts play an important role. In general the citrates and phosphates appear to increase stability whereas calcium decreases the stability of milk to heat (23).

Effect of Sugar

An increased proportion of sugar elevates the gelation or coagulation temperature (23). This is due to the peptizing effect of the sugar on the protein.

Use of Baked Custards in Studying the Properties of Dried Milk Solids

Custards were selected for use in this study to show differences in cooking properties of various dry milk solids

because custards have a high degree of sensitivity to slight changes in egg-milk-sugar mixture. This sensitivity was demonstrated in Logue's study (22) on the cooking qualities of different grades of eggs and in the study by Carr and Trout (3) on the different cooking properties of whole and homogenized milks.

Whole milk custards should be baked to an internal temperature of 82° - 84° C (23). With normal baking conditions curdling generally occurs between 85° - 87° C. If the custards are heated rapidly they are too thin to serve even at 87° - 89° C, and frequently curdle before a serving consistency is reached. Carr and Trout (3) observed that heat penetration was slower in custards made with homogenized milk than those made with plain milk. Such custards could withstand higher baking temperatures without seriously affecting the stability of the gel.

Morse and Davies (25) reported that an increase in gel strength and gel stability occurred in baked custards fortified with nonfat dry milk solids. Carr and Trout (3) found that custards made from homogenized milk also had a more stable gel. The formation of egg gel, such as in baked custards, depends upon the coagulation of the protein and the ability of the precipitated protein to hold within

its meshes the solution from which it was precipitated (26). Thus it would seem that in nonfat dry milk solids and homogenized milk the protein has been changed somewhat in nature from that of whole milk, since custards made from dried milk solids coagulate at a different rate and the protein mesh retains the solution better. In Morse and Davies' experiment (25) as the concentration of dry milk solids was increased the strength of the gel improved.

The curd tension meter readings in Carr and Trout's experiment (3) indicated that homogenized milk had a firmer coagulum than nonhomogenized milk. Hollender and Weckel (16) found just the reverse results. In their study the serum protein separation was greater with homogenized milk. This separation increased when the cooking time was prolonged. Homogenized milk had a more critical cooking temperature than plain whole milk.

Custards made with plain whole milk have a soft crust which browns evenly. Custards made with homogenized milk and nonfat dried milk solids had a tough skin which did not brown except at the extreme edges (3, 25). A theory of browning is set forth by Ramsey and coworkers (31). When milk was heated for a sufficient length of time at high temperatures (90° - 120° C) the lactose was decomposed

and acid products formed. This increased acidity inverted some of the sucrose to dextrose. A brownish color developed as a result of the condensation product of the free aldehyde group on the dextrose molecule with the protein. They found that this did not occur when sucrose only was present because it contains no free aldehyde or ketone group.

Morse and Davies (25) showed that whole milk custards had a sweeter flavor. They suggested this might have been due to the fact that sugar concentrates in the liquid phase and since these custards showed greater syneresis they seemed sweeter.

In the work, mentioned above, by Morse and his coworkers the pH of the baked custards containing nonfat dried milk solids ranged from 6.9 to 7.3. The acidity of the custards increased with an increase in concentration of milk solids.

Nutritive Value and Uses of Nonfat Dried Milk Solids

In studying the properties of nonfat dried milk solids the nutritive value should be considered. Coulter (9) stated that the nutritive value of spray dried whole milk is not inferior to that of the milk from which it is prepared, unless oxidative deterioration or sugar protein interaction have occurred. Nonfat dried milk solids contain

only very small amounts of the fat soluble vitamins and only .9 percent fat.

The type of nonfat dried milk solids to be used in different products in cooking often presents a problem. The solubility of the different milk solids is important in food preparation, especially in products such as beverages, soups and sauces which have a high water concentration (28).

O'Malley (27) recommended the following uses for non-fat dried milk solids. Spray dried milk solids should be used in cakes and similar products. Either spray or roller nonfat dried milk solids should be used in yeast raised products. When these are used the milk must be heat treated before drying to inactivate the compounds in raw milk which interfere with the development of the dough. Milk solids for cottage cheese should be pasteurized only, since higher temperatures interfere with the curd formation.*

The fact that improvement in baking quality of nonfat dried milk solids appears to involve heat denaturation of milk serum proteins has prompted efforts to correlate baking

*In a private communication, Beach states that oven tested or high heat powder is used in the baking industry in dry mixes and sausage manufacture. The low heat powder, which usually is more expensive, is used for cultured butter milk, cottage cheese, ice cream and chocolate milk.

qualities with the extent of denaturation. Heat treatment (9) produces an effect similar to removal of a reducing group. This heat treatment decreases the reactivity of the majority of the -SH groups. Harland and Ashworth (14) devised a method for determining nondenatured serum protein by measuring the turbidity developed by acidification of the filtrate, which was obtained by salting out the casein with sodium chloride. From 18 samples of good quality baking nonfat dried milk solids, 15 had nondenatured serum protein nitrogen content ranging from .67 to 1.40 mg per gram. Fourteen out of 17 samples of poor baking quality dried solids had readings ranging from 1.86 to 6.59 mg per gram. Thus it appears that if denaturation is carried too far, a dried milk solid of poor baking quality results. Kitzes (21) indicated that spray drying has the distinct advantage over roller drying of minimizing heat damage.

Subjective and Objective Measurements of Baked Custards

Subjective Tests

The ultimate test for any product is its eating quality. The best flavor, texture or eating quality is that which people prefer in a given food. Organoleptic tests are conducted to decide how near the standard the unknown samples come.

The validity of organoleptic tests is based on several fundamental assumptions (30):

1. Reaction of the same judge to exactly the same food will continue to be the same throughout the period of the test.
2. Difference between two samples from two lots is greater than the difference between two samples from the same lot.
3. Preferences expressed represent reliable, reproducible decisions, not mere guesses which may easily be reversed.

Organoleptic tests are the only means of expressing many important qualities of food products. In the laboratory, eating quality or palatability of a product is divided into component parts. Trained judges are asked to discriminate between samples by rating large and small differences in the various characteristics. These differences are usually rated on the basis of their degree of acceptability. Written records of sensations and impressions are kept. An evaluation of these records is used as a basis for determining the relative quality of a sample.

Organoleptic tests are not sensitive enough for critical evaluation in some cases. In order to eliminate the personal factor, much time and thought has been spent on the development of objective means of testing the quality of foods.

The results of these tests are correlated with those obtained by organoleptic procedures.

Objective Tests

Several tests have been developed to measure some of the physical characteristics of baked custards by objective means. The main tests are the syneresis of the custard, the rate of heat penetration during baking and the gel strength.

Syneresis: After the gels are allowed to stand, protected against evaporation, for a number of hours, there is a tendency for the gel to separate into 2 phases, liquid and solid. This is called syneresis. Various methods have been devised for measuring this weeping. Some employ the use of adsorbent paper while others use a fine mesh or screen through which the liquid drains. Then this liquid can be weighed. Unfortunately there is no standard method for measuring syneresis.

Gel Strength: The gel strength of a custard can be measured by various instruments. In this experiment three methods were used: the penetrometer which measures the consistency or breaking strength of the gel; the curd

tension meter which measures the cutting strength of the gel and the 'standing index' which measures the ability of a gel to hold its shape on standing.

Curd Tension Meter: The curd tension meter was first used by Hill (15) to estimate the degree of hardness of the curd in milk. This test was employed to find out the type of milk most suitable for infants. A milk with a soft curd was found to be the easiest to digest. The instrument measured the tension or force required to draw the curd knives through the curd. Carr and Trout (3) used a modification of the curd tension meter to measure the differences in gel strength in custards made from homogenized and non-homogenized milk. The curd tension meter measures the resistance of the custard to the cutting blades of the instrument. The reading is in grams and is called "the curd tension."

Penetrometer: Various elaborate instruments are available for determining the consistency of food products by measuring their penetrability. One of these instruments is called the penetrometer.* The instrument measures the depression in a sample caused by a force applied over an

*New York Testing Laboratory Penetrometer.

area for a given length of time. Hooke's law states that the strain produced is in proportion to the stress producing it and this is the basic principle of the penetrometer. The average readings of such tests in millimeters penetration is referred to as the index of "penetrability". The penetrometer was originally used for penetration tests of bituminous materials, asphalts, petrolatum and grease. A modification has been used to determine the moisture content of soils of which maximum density is produced by a specific amount of compacting. A penetration cone, needle or disc may be used, depending upon the type of material to be tested.

The penetrometer has been used successfully in testing the texture of various baked products such as cake and bread, vegetables, and the consistency of batters and cooked mixtures such as cornstarch puddings and applesauce.

Standing Index: A measure for the gel strength of a custard is the "standing index." This measurement, used by Carr and Trout (3), is the ratio of the height to the average diameter. After the custard has stood for sometime the standing index diminishes as a result of the decrease in height and increase in spread.

PROCEDURE

Design of Experiment

Baked custards prepared from drum dried and from spray dried nonfat dried milk solids were compared objectively and subjectively. The best proportions of nonfat dried milk solids to be used in the baked custards were determined.

The pattern selected for this experiment was the statistical plan known as the balanced incomplete block. In this design only a part of the total number of samples is judged at the same time. The distribution of the treatments is randomized throughout the tests.

Four variations were prepared each day. Each variation was baked 4 times during the experiment. Skim milk was used as the control. Seventeen custards of each replication were made at one time. One custard was used for the temperature reading, 11 for the objective tests and 5 for the subjective tests.

Ingredients

All the ingredients were obtained at the beginning of the study with the exception of the fresh skim milk which was purchased as needed.

Fresh eggs were obtained from the Foods and Nutrition storeroom. The eggs were mixed with a mechanical mixer* using the following proportions: .75 grams of salt, 75 grams of sugar, and 288 grams of eggs. This mixture was beaten 8 minutes at No. 1 speed. It was then strained into a large container and the procedure repeated until sufficient egg-sugar-salt mixture for the entire experiment had been obtained. This large quantity was thoroughly blended to insure a homogeneous mixture. Then the egg-sugar-salt mixture was weighed into 363.75 gram portions and placed in pint freezing containers, sealed, labeled and stored immediately in the deep freezer.

The three types of spray dried milk** used in this experiment are described by Beach (2) as:

1. Low heat or dairy type powder which is heated to 175° F and held at this temperature for five minutes or to 145° F and held for 30 minutes.

2. High heat or oven tested powder which may be heated to a minimum temperature of 175° F and held for 30 minutes or more often heated to 195° F and held for 30 minutes. Temperatures as high as 240° F may be used but the holding time is reduced.

*Kitchen Aid.

**Purchased from Michigan Producers Dairy Company.

3. Normal type or intermediate spray dried powder is heated to temperatures in between that used for oven or dairy types of dried milk.

These solids were obtained in polyethylene sacks which were tightly tied to keep out any moisture, and stored in cold storage.

The drum dried nonfat solids* used in this experiment were preheated to 180° F. The temperature of the roller was 320° F. Enough drum dried milk was purchased for the entire experiment and stored in cold storage in screw-top bottles.

The figures for the solubility index and moisture content of the dried milk solids at the beginning and end of the experimental period are listed in Table 1. The moisture content was determined according to the methods recommended by the Dry Milk Institute (1) and the solubility index by the method outlined by Howat and coworkers (19).

The figures for the solubility index and moisture content of the spray dried milk solids fell within the normal range cited in the literature and thus it was assumed that normal samples of spray dried milk were used

*Lansing Dairy Company.

TABLE 1

Solubility Index and Moisture Content of Dried Milks

Type of Milk	Solubility Index		Moisture Content	
	Beginning of Experiment percent	End of Experiment percent	Beginning of Experiment percent	End of Experiment percent
Spray, oven	100.7	98.0	3.51	4.06
Spray, dairy	94.9	97.2	2.67	2.88
Spray, inter- mediate	99.6	96.3	4.10	3.85
Drum	55.8	56.7	3.18	4.20

in the experiment. The first lot of drum dried milk solids obtained had a very low solubility index and therefore a second lot was purchased which was definitely known to be fresh. This lot also had a low solubility index indicating that this was characteristic for drum dried milk solids.

General Procedure

The basic custard described in Lowe (23) was used in this experiment. The recipe was as follows:

Milk (skim)	6 cups	1464 grams
Sugar	3/4 cup	150 grams
Egg	6	288 grams
Salt		.75 grams

The nonfat dried milk solids were substituted for skim milk into the recipe on the basis of skim milk containing 9-1/2 percent solids and 90-1/2 percent water. The solids were used in a:

1:1 ratio = 140.25 grams solids + 1323.75 grams water =
6 cups skim milk

1:1.5 ratio = 210.38 grams dry milk solids + 1323.75
grams water

1:2.0 ratio = 280.5 grams dry milk solids + 1323.75
grams water

Preliminary Preparation

Four cartons of the egg-salt-sugar mixture were removed from the deep freeze and placed in the refrigerator to thaw.

The nonfat dried milk solids were weighed on cellophane paper on a torsion balance. To these solids was added half of the total sugar in the recipe - the remainder being already in the frozen egg mixture. The milk solids and sugar were blended with a metal tablespoon using 20 strokes. The required amount of water was heated in an enamel pan to 50° C. This was transferred to the large size bowl of an electric mixer.* The electric beater was operated at No. 2 speed and the dried milk solids were sprinkled into the water in 4 portions as indicated below:

	Time	Speed
1st portion	0 minutes	No. 2
2nd portion	3/4 minutes	No. 2
3rd portion	1½ minutes	No. 2
4th portion	2¼ minutes	No. 2

After the last addition of milk the mixture was beaten an additional 1-3/4 minutes at No. 2 speed and then 1/2 minute at No. 5 speed. A rubber spatula was used to clean

*Hamilton Beach, Model G

off the sides of the bowl during the mixing process. The milk was transferred to a Pyrex bowl, covered and stored in the refrigerator over night.

Preparation of Custard Mix

The egg mixture was blended with the milk for 1/2 minute using the electric beaters at No. 2 speed. Any froth was removed.

Custard Cups

The custards were baked in 5 oz. Pyrex custard cups. The cup was filled with custard mix to within 1/2 inch of the top. This distance was measured with a depth gauge. All the cups contained 101 ± 3 grams of custard. The cups were numbered according to subjective and objective tests for which they would be used. They were placed in the baking pan in a definite pattern. This pattern varied according to the oven in which the custards were to be baked.

Baking

Water at 35° C was poured into the baking pan filling it half full. The custards were placed in the oven and more water was added to the baking pan until it came up

to the designated mark. (This mark had been previously established so that the water reached the exact height of the custard in the cup.) They were baked at 325° F in gas ovens. The oven temperatures were checked each day with an oven thermometer. A thermometer was placed in the custard dish designated in the plan and a second thermometer in the water bath. The custards were baked to an internal temperature of 92° C. This temperature was determined by preliminary experiments, as follows. Custards made from all the different types and concentrations of dried milk solids were removed from the oven at internal temperatures ranging from 84° C to 95° C. At 84° C the gel of the custards had not formed and at 95° C the custards appeared slightly curdled. Custards baked to an internal temperature of 92° C gave the most acceptable custard for all the types of dried milk solids at the various concentrations.

Cooling

The custards were removed from the water bath and placed on a wire rack. They were allowed to cool until they reached room temperature (2 to 2½ hours).

Subjective Tests

The custards were scored for flavor, sweetness, smoothness, appearance, color inside, firmness, crust,

and general acceptability, by 5 judges from the Foods and Nutrition Department of Michigan State College. The judges were requested to record comments concerning any outstanding features noted. A sample of the score sheet used is shown on page 85 of the appendix.

Objective Tests

The room temperature and humidity were taken and recorded at the beginning and end of each test period.

pH Readings

The pH was taken on the fluid mixture before baking. In order to determine the pH of the baked custard, 2 grams of custard were mixed thoroughly with 10 ml. of distilled water. The pH was measured by using a Beckman pH meter.

Time-Temperature Curves

The temperature of the uncooked custard mixture was taken before placing in oven. A second temperature reading was taken 10 minutes after the custard had been placed in the oven. Temperature readings were taken every 5 minutes thereafter until the internal temperature of the custard reached 92° C. The time-temperature curves for the 4 replications of each variable were plotted as a graph.

Syneresis

The rubbery crust was removed from the top of the custard with a knife. The custard was then inverted on a very fine screen under which a weighed petri glass was placed. The weight of the petri dish was recorded every hour for five hours. The amount of syneresis each hour was obtained by taking the difference in weight. This procedure was carried out on 2 samples for each type of custard. The samples were covered between readings to prevent evaporation.

Curd Tension Meter

The firmness of the custard was measured by the curd tension meter. The meter consists of a cutter and a float assembly which floats freely in a pool of mercury. The custard was placed in the path of the downward moving cutter. The blade was brought into contact with the custard and the amount by which the float was raised out of the mercury was a measure of the resistance offered to the passage of the cutter through the custard. This provided a measurement of the gel strength. Three types of readings were taken: one with the crust on the custard, one with the crust removed and a third on the inverted

custard. Two samples of each type of custard were used. The knives of the curd tension meter were unable to cut through some of the crusts. Therefore the data collected from the custards with the crust on were not used.

Penetrometer

The penetrometer readings give the depth of penetration within a certain time period caused by a total weight of 73.5 grams for disc and needle bar. The cup of custard was placed on the level platform and centered under the disc, which was in contact with the top of the custard. The spring was released for 2 seconds allowing the disc to penetrate the custard, giving the depth of penetration. A 2 second period was used instead of the usual 5 second period of penetration because with the longer period the disc passed directly through some of the custards to the glass plate. The strength of the crust, the strength of the gel at the top of the custard when the crust had been removed and a third reading on the gel strength of the inverted custard were made on each type of custard. The penetrometer readings reported are the average of duplicate readings for the above tests.

Standing Index

The standing index was determined by removing the rubbery crust and inverting the custard onto a flat square glass plate. This glass was placed over a paper which had concentric circles* drawn thereon. Quadrant readings were taken. The height in inches was measured with a depth gauge. The spread and height of each custard was taken at the beginning of the test period and every hour for the 5 following hours. This test was carried out on 2 samples of each type of custard. The custards were kept covered between readings to prevent evaporation.

Statistical Methods

It is well known that large day-to-day variations may occur in studies involving food preparation, even though the same procedures are being repeated each day. In addition, it is often impossible to handle many variations in a single day because the procedures are time consuming, and judging panels usually cannot handle more than 6 to 8 samples at one time. Since 13 variations were employed in this experiment, the balanced incomplete block given by Cochran and Cox (10) was used. This design permits adjustment of the data to allow for the fact that not all

*As in Grawemeyer and Pfund's experiment (15).

the samples were done on the same day. The corrected mean factors are indicated as adjusted mean scores. The complete calculation for one scoring item (flavor) is given in the appendix.

The least significant difference was calculated using the corrected skim milk custard scores as a standard. Calculation of the least significant difference designates a range around the standard. Any score falling outside this range is said to differ significantly from the standard. The least significant differences were computed for probabilities of 1 in 20 and 1 in 100. In this experiment all the dried milk custard scores were lower than the scores for the standard (skim milk), so only the negative half of the least significant difference range was used.

Correlations were calculated between the following pairs of items: crust score versus penetrometer reading (crust on); crust score versus difference between penetrometer reading for crust on and off; firmness score versus penetrometer reading (crust on); firmness score versus penetrometer reading (crust off); firmness score versus penetrometer reading (custard upside down); firmness score versus curd tension meter readings (crust off); firmness score versus curd tension meter readings (custard upside down). The method of calculation given by Snedecor (32) was employed.

DISCUSSION OF RESULTS

The quality of baked custards containing drum dried and spray dried milk solids at three different concentrations were evaluated. Hereafter, nonfat dried milk solids will be abbreviated DMS. The levels of DMS will be designated as concentration No. 1, which is equal to the concentration of solids in fluid skim milk; concentration No. $1\frac{1}{2}$, being equal to one and a half times the concentration of solids in fluid skim milk and concentration No. 2, which is equal to twice the concentration of solids in fluid skim milk. Three types of spray DMS were used which differed only in the heat used during processing. The DMS treated at low temperatures is called dairy DMS; the one at intermediate temperatures, intermediate DMS and the milk processed at high temperatures, oven DMS.

The results of each subjective and objective test will be discussed in the following manner: the results of the analysis of variance will be given followed by an outline of the overall picture of the results dealing with all types of custards made; a paragraph dealing with the differences between custards containing the four types of DMS will follow and finally a discussion on the effect of concentration of DMS on the various custards.

Palatability Scores

A summary of the adjusted average scores and analysis of variance for each characteristic judged by the scoring panel is shown in the table following the discussion of that particular characteristic. Hereafter, the least significant difference, from scores of skim milk custard (standard), will be designated as LSD. The average judging scores for each replication are given on page 77 of the appendix. The highest rating a custard might receive for a given characteristic was seven, the lowest, one. A rating of seven would indicate an excellent product in that characteristic, a rating of one a very poor product.

Appearance

The average scores and analysis of variance for appearance are shown in Table 2. Analysis of variance for these scores indicates that the chief source of variation among the scores was the difference between custards made from the various types and concentrations of DMS.

Skim milk had the highest score for appearance. The scores for oven DMS concentration No. 2 fell within the least significant difference at the 5 percent level.

TABLE 2

Adjusted¹ Average Scores and Analysis
of Variance for Appearance Scores

Type of Milk	Ratio (Amounts)		
	Concentration No. 1	Concentration No. 1½	Concentration No. 2
Skim	5.7		
Dairy Spray	4.6	4.8	5.0
Intermediate Spray	5.0	5.0	5.0
Oven Spray	4.7	4.9	5.1
Drum	4.0	2.7	2.5
Skim - LSD ₀₁	5.0		
Skim - LSD ₀₅	5.1		

Analysis of Variance

<u>Source</u>	<u>Degrees of Freedom</u>	<u>Mean Square</u>	<u>F</u>
Total	51	-	-
Adjusted ¹ Treatment	12	.422567	3.40*
Error for Adjusted ¹ Treatment	27	.124463	
Adjusted ¹ Blocks	12	.127658	<1
Intra Block Error	27	.141504	

*Significant at 5% level

¹Adjusted according to method given by Cochran and Cox (10).

Custards of intermediate DMS at the three concentrations and dairy DMS at concentration No. 2 had equal scores, and were just at the limit of the 1 percent LSD. All the other custards received scores less than these. In some instances the reason for the low score was a cracking or wrinkling of the crust.

Of all the DMS, the intermediate gave the custard of best appearance. Custards of oven DMS had a slightly better appearance than those made from dairy DMS. The custards of poorest appearance were made from the drum DMS. This may have been due to the fact that the protein of the drum DMS was nearly insoluble. The custards appeared granular and bubbly.

An increase in concentration of dairy and oven DMS improved the appearance of the custards. There was no difference in the judges' scores for appearance when the concentration of intermediate DMS was increased in the custards. With drum DMS, as the concentration was increased the appearance scores were poorer.

Crust

The adjusted average scores and analysis of variance for the crusts are shown in Table 3. The chief source of

TABLE 3

Adjusted Average Scores and Analysis
of Variance for Crust Scores

Type of Milk	Ratio (Amounts)		
	Concentration No. 1	Concentration No. 1½	Concentration No. 2
Skim	5.2		
Dairy Spray	4.7	4.4	4.2
Intermediate Spray	4.7	4.3	4.2
Oven Spray	4.9	4.4	4.1
Drum	5.5	5.8	4.8
Skim - LSD ₀₁	4.4		
Skim - LSD ₀₅	4.5		
Analysis of Variance			
<u>Source</u>	<u>Degrees of Freedom</u>	<u>Mean Square</u>	<u>F</u>
Total	51	-	-
Adjusted Treatment	12	1.103333	6.26**
Error for Adjusted Treatment	27	.176290	-
Adjusted Blocks	12	.197992	1.04
Intra Block Error	27	.190152	

**Significant at 1% level

variation between scores would appear to be a consequence of the concentrations and kinds of DMS used. No significant variance between replications appeared in these data.

The crusts were scored only for toughness or tenderness. The crusts on the custards from drum DMS at concentration No. $1\frac{1}{2}$ received the highest score. The crust on the drum DMS at concentration No. 1 scored second highest and then the score for the crust on the control custard was next. The average score on the crusts of oven and dairy DMS at concentration No. $1\frac{1}{2}$ were equal. Scores for crusts from the three spray DMS at concentration No. 2 and intermediate DMS concentration No. $1\frac{1}{2}$ were highly significantly lower than that of the control.

Drum DMS gave the most tender crust of all the milks used. The judges indicated that, though tender, the crusts did not have a desirable consistency. They were mealy and spongy. The crust on the control custard was the next most tender and had a desirable consistency. Oven DMS gave the most tender crust of the spray DMS custards. The toughness of the crusts varied little between custards made with intermediate and dairy DMS.

All the crusts on the skim and spray DMS custards were rather tough. As the concentration of DMS was increased

the crusts became tougher. The toughness of the crusts appears to be caused by dry heat on the top of the custard, since dry heat toughens protein. Possibly the tenderness of the crusts on whole milk custards could be explained by the presence of fat which tends to collect at the surface of the custard. To test this hypothesis, a supplementary series was done, in which a small amount of melted butter was added to the DMS custard mix before baking. The crusts on these custards were more tender.

Color Inside

Analysis of variance on the average scores for the inside color of the custards, listed in Table 4, indicates that the main source of variation between the scores was due to the levels and types of DMS used. Variation due to replications was significant at the 5 percent level.

Skim milk custards had the highest score for color. The scores for intermediate and oven DMS custards at concentration No. 1 fell within the least significant difference at the 5 percent level. Custards of intermediate and oven DMS at concentration No. $1\frac{1}{2}$ had equal scores and were just at the limit of the 1 percent LSD. The scores would indicate that the color of all the other custards were highly significantly different from the control.

TABLE 4

Adjusted Average Scores and Analysis
of Variance for Inside Color Scores

Type of Milk	Ratio (Amounts)		
	Concentration No. 1	Concentration No. 1½	Concentration No. 2
Skim	6.2		
Dairy Spray	5.7	5.7	5.4
Intermediate Spray	6.1	5.8	5.5
Oven Spray	5.9	5.8	5.6
Drum	4.2	3.4	2.9
Skim - LSD ₀₁	5.8		
Skim - LSD ₀₅	5.9		
Analysis of Variance			
<u>Source</u>	<u>Degrees of Freedom</u>	<u>Mean Square</u>	<u>F</u>
Total	51	-	-
Adjusted Treatment	12	4.418331	115.35**
Error for Adjusted Treatment	27	.038304	
Adjusted Blocks	12	.070692	2.07*
Intra Block Error	27	.034230	

**Significant at 1% level

*Significant at 5% level

The color of intermediate DMS custards was the most acceptable to the judges of all the types of DMS custards. Custards of oven DMS had a better color than those made from dairy DMS. The color of custards from drum DMS had the lowest score of all. These custards were gray in color due to dark color of the milk solids. Probably the milk solids had been scorched in processing.

As the concentration of DMS was increased in all the custards the color became less desirable. The only exception to this was the dairy DMS, which had the same score for color at concentrations No. 1 and No. $1\frac{1}{2}$.

Flavor

The adjusted average scores and analysis of variance for flavor are given in Table 5. This indicates that the chief source of variation among scores was the different kinds and amounts of DMS. Variation due to replications was not significant.

The custards made with skim milk received the highest scores for flavor. Custards of oven and intermediate DMS at concentration No. 1 had equal scores and were second best. The average scores for custards of dairy DMS concentration No. 1 were just at the 5 percent limit of

TABLE 5

Adjusted Average Scores and Analysis
of Variance for Flavor Scores

Type of Milk	Ratio (Amounts)		
	Concentration No. 1	Concentration No. 1½	Concentration No. 2
Skim	6.0		
Dairy Spray	5.5	5.1	4.9
Intermediate Spray	5.7	5.2	5.1
Oven Spray	5.7	5.4	5.2
Drum	3.3	3.1	2.5
Skim - LSD ₀₁	5.4		
Skim - LSD ₀₅	5.5		
Analysis of Variance			
<u>Source</u>	<u>Degrees of Freedom</u>	<u>Mean Square</u>	<u>F</u>
Total	51	-	-
Adjusted Treatment	12	4.983818	53.22**
Error for Adjusted Treatment	27	.093648	
Adjusted Blocks	12	.06035	<1
Intra Block Error	27	.12327	

**Significant at 1% Level

the LSD while the flavor scores for oven DMS concentration No. 1½ fell just at the 1 percent limit. All other custards had scores below this level and were significantly different in flavor from the control.

Oven DMS custards had the best flavor of any of the DMS used. The flavor of custards from intermediate DMS were only slightly less acceptable. The scores for flavor of dairy DMS were considerably lower. Custards from drum DMS had a very poor flavor, tasting burnt. Probably this DMS had been scorched in manufacture.

As the concentration of DMS was increased in all of the custards the flavors were less acceptable. The judges described the flavor as being "too milky".

Firmness

Analysis of variance for the mean average scores, shown in Table 6, indicates that the main source of variation among these scores was due to the different amounts and kinds of DMS used in the custards. No significant differences due to replication were evident.

The control custard received the highest score for firmness. Oven and intermediate DMS custards at concentration No. 1 had equal scores, and were just at the limit

TABLE 6

Adjusted Average Scores and Analysis
of Variance for Firmness Scores

Type of Milk	Ratio (Amounts)		
	Concentration No. 1	Concentration No. 1 $\frac{1}{2}$	Concentration No. 2
Skim	6.2		
Dairy Spray	5.5	5.1	4.3
Intermediate Spray	5.6	4.7	4.2
Oven Spray	5.6	4.9	4.6
Drum	4.1	3.9	3.6
Skim - LSD ₀₁	5.5		
Skim - LSD ₀₅	5.6		
Analysis of Variance			
<u>Source</u>	<u>Degrees of Freedom</u>	<u>Mean Square</u>	<u>F</u>
Total	51	-	-
Adjusted Treatment	12	2.541735	16.33**
Error for Adjusted Treatment	27	.155603	
Adjusted Blocks	12	.234267	1.64
Intra Block Error	27	.142733	

**Significant at 1% level

of the 5 percent LSD. The average score for firmness of dairy DMS custards at concentration No. 1 fell within the 1 percent significant range. The probability is very high that the firmness of all the other custards were different from the control.

Oven DMS gave the most acceptable custard as to firmness. Dairy DMS in custards had a higher firmness score than intermediate DMS. The firmness of custards from drum DMS scored very low.

As the concentration of DMS was increased in the custards the firmness of the gel became less acceptable. In scoring the custards for firmness, the judges indicated whether a low score signified that a gel was too thin or too stiff. With the spray DMS the low score indicated that the gel was too stiff. This increase in stiffness perhaps could be attributed to the increase in protein concentration. The drum DMS had low scores for firmness because they were thin and watery, which resulted from the insolubility of the protein.

Smoothness

In Table 7 is shown the adjusted average scores and analysis of variance for smoothness. As indicated the chief source of variation among the scores was due to

TABLE 7

Adjusted Average Scores and Analysis
of Variance for Smoothness Scores

Type of Milk	Ratio (Amounts)		
	Concentration No. 1	Concentration No. 1½	Concentration No. 2
Skim	6.5		
Dairy Spray	6.2	5.9	5.6
Intermediate Spray	6.2	5.7	5.7
Oven Spray	6.0	5.8	5.7
Drum	4.1	3.4	3.4
Skim - LSD ₀₁			
Skim - LSD ₀₅			
Analysis of Variance			
<u>Source</u>	<u>Degrees of Freedom</u>	<u>Mean Square</u>	<u>F</u>
Total	51	-	-
Adjusted Treatment	12	4.503794	72.08**
Error for Adjusted Treatment	27	.062483	
Adjusted Blocks	12	.135317	2.46*
Intra Block Error	27	.054952	

**Significant at 1% level

*Significant at 5% level

different kinds and amounts of DMS. Variation due to replications was significant at the 5 percent level. This difference could have been caused by some slight variation in the experimental procedure or possibly the judges' reaction to the result. Degree of smoothness is difficult to judge and it is probable that variation on the part of the judges' reaction to smoothness could occur within replications. Also the baking time of the custards varied from day to day and this would affect the smoothness of the custard.

The highest scores for smoothness occurred with custards made from skim milk. The dairy and intermediate DMS at concentration No. 1 had equal scores for smoothness, which were just at the limit of the 5 percent LSD. The scores for custards from oven DMS at concentration No. 1 fell within the LSD at the 1 percent level. The probability that all the remaining custards varied significantly in smoothness from the control is very high.

The oven and intermediate DMS gave custards which were slightly smoother than the custards from the dairy DMS. Custards containing drum DMS were scored very low on smoothness. The protein of the drum DMS was very insoluble and consequently the custards made from this type were granular and watery.

As the concentration of DMS was increased, the custards became less smooth except with drum DMS at concentration No. $1\frac{1}{2}$ and No. 2, both of which had the same scores. These custards were so poor at concentration No. $1\frac{1}{2}$ that there was little difference as to the degree of poorness. The decrease in smoothness with spray DMS could be due to the increased concentration which made the protein slightly insoluble. They were described as being grainy.

Sweetness

Table 8 shows the average scores for sweetness and analysis of variance on these scores. The analysis of variance indicates that the principal variation among the scores was between custards made with different amounts and kinds of DMS. Variation due to replications was significant at the 5 percent level. This could have been caused by inconsistent scoring on the part of the judges, since the degree of sweetness is rather difficult to score.

The custards made with skim milk and oven DMS at concentration No. 1 received equal scores and had the most acceptable degree of sweetness. The intermediate DMS custards at concentration No. 1 and No. $1\frac{1}{2}$ scored second best. Dairy DMS at concentration No. 1 scored

TABLE 8

Adjusted Average Scores and Analysis
of Variance for Sweetness Scores

Type of Milk	Ratio (Amounts)		
	Concentration No. 1	Concentration No. 1½	Concentration No. 2
Skim	5.9		
Dairy Spray	5.5	5.3	5.0
Intermediate Spray	5.7	5.7	4.9
Oven Spray	5.9	5.4	5.2
Drum	3.9	3.8	3.2
Skim - LSD ₀₁	5.2		
Skim - LSD ₀₅	5.4		
Analysis of Variance			
<u>Source</u>	<u>Degrees of Freedom</u>	<u>Mean Square</u>	<u>F</u>
Total	51		
Adjusted Treatment	12	2.980552	24.18**
Error for Adjusted Treatment	27	.123263	
Adjusted Blocks	15	2.98055	2.46*
Intra Block Error	27	.123263	

**Significant at 1% level

*Significant at 5% level

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next and then the oven DMS at concentration No. $1\frac{1}{2}$, the average score being just at the limit of the 5 percent LSD. The analysis indicates that custards of the drum DMS and the three spray DMS at concentration No. 2 were highly significantly different from the control.

Oven DMS gave the custards with the most acceptable degree of sweetness. Dairy DMS in custards had a less acceptable degree of sweetness than intermediate DMS. Drum DMS were much too sweet in custards.

As the concentration of DMS was increased the sweetness of the custards became less desirable except with the intermediate DMS custards at concentrations No. 1 and No. $1\frac{1}{2}$. As the concentration of DMS was increased more lactose was present which would cause the custards to taste sweeter. Morse (25) suggested this sweetness could be caused by lactose dissolving in the liquid phase.

General Acceptability

Table 9 shows the adjusted average scores and the analysis of variance on acceptability. The chief source of variation for these scores was due to difference between custards made with different amounts and kinds of DMS. Variation due to replications was not significant.

TABLE 9

**Adjusted Average Scores and Analysis
of Variance for General Acceptability Scores**

Type of Milk	Ratio (Amounts)		
	Concentration No. 1	Concentration No. 1½	Concentration No. 2
Skim	5.8		
Dairy Spray	5.4	5.0	4.3
Intermediate Spray	5.6	4.8	4.5
Oven Spray	5.5	4.9	4.6
Drum	3.5	2.7	2.2
Skim - LSD ₀₁	5.2		
Skim - LSD ₀₅	5.4		

Analysis of Variance

<u>Source</u>	<u>Degrees of Freedom</u>	<u>Mean Square</u>	<u>F</u>
Total	51	-	-
Adjusted Treatment	12	4.858643	56.09**
Error for Adjusted Treatment	27	.086617	
Adjusted Blocks	15	.112375	1.38
Intra Block Error	27	.081444	

**Significant at 1% level

The custards made with skim milk received the highest score for general acceptability. The spray processed DMS at concentration No. 1 scored next with the custard containing intermediate DMS being best, then oven DMS and thirdly the dairy DMS, the average score being just at the 5 percent level of significance. All the other custards had lower scores and probably were highly significantly different in acceptability from the control.

Intermediate and oven DMS custards were of nearly equal acceptability. The dairy DMS was inferior in quality. The drum DMS was very poor in the custards. This was perhaps caused by the effect of the insolubility of the protein and the burnt flavor.

As the concentration of DMS was increased the custards were less acceptable. With spray DMS the poorer custards were the result of an increase in protein concentration, which gave a stiffer and slightly granular gel, a tougher crust and a darker color. The increased lactose gave a sweeter and a more milky flavor. Increasing the drum DMS in custards had the same effect as the spray DMS except that the custards became thinner in consistency.

Objective Tests on Baked Custards

pH Readings

The baked custards were very slightly acidic, as indicated in Table 10, with the exception of the 3 different spray DMS custards at concentration No. 1. As the concentration of DMS was increased in the custards, the acidity increased. During the baking process the acidity of the custards decreased, the only exception being custards made from drum and intermediate DMS at concentration No. 1 in which the acidity increased. The pH of fluid skim milk custards was similar to oven DMS custards at concentration No. 1½ and custards of drum DMS at concentration No. 1

Time-Temperature Curves

The time-temperature curves for the different variations of baked custards are shown in Figures 1, 2 and 3. Baked custards made from skim and drum DMS at concentration No. 1 baked in the shortest time while custards of dairy DMS concentration No. 1 took the longest time to bake.

The rate of heat penetration in custards made from the different spray DMS was very similar. Custards of drum DMS had a slower rate of heat penetration than the

TABLE 10

Average pH Readings on the Unbaked and Baked Custards

Variation	Unbaked	Baked
Skim milk	6.86	6.90
Spray Processed		
Dairy Type		
Concentration #1	7.17	7.22
" #1½	6.88	6.96
" #2	6.71	6.84
Intermediate #1	7.13	7.01
Concentration #1½	6.91	6.95
" #2	6.77	6.85
Oven Concentration #1	7.06	7.11
" #1½	6.89	6.92
" #2	6.75	6.85
Drum Processed		
Concentration #1	6.93	6.90
" #1½	6.74	6.82
" #2	6.58	6.69

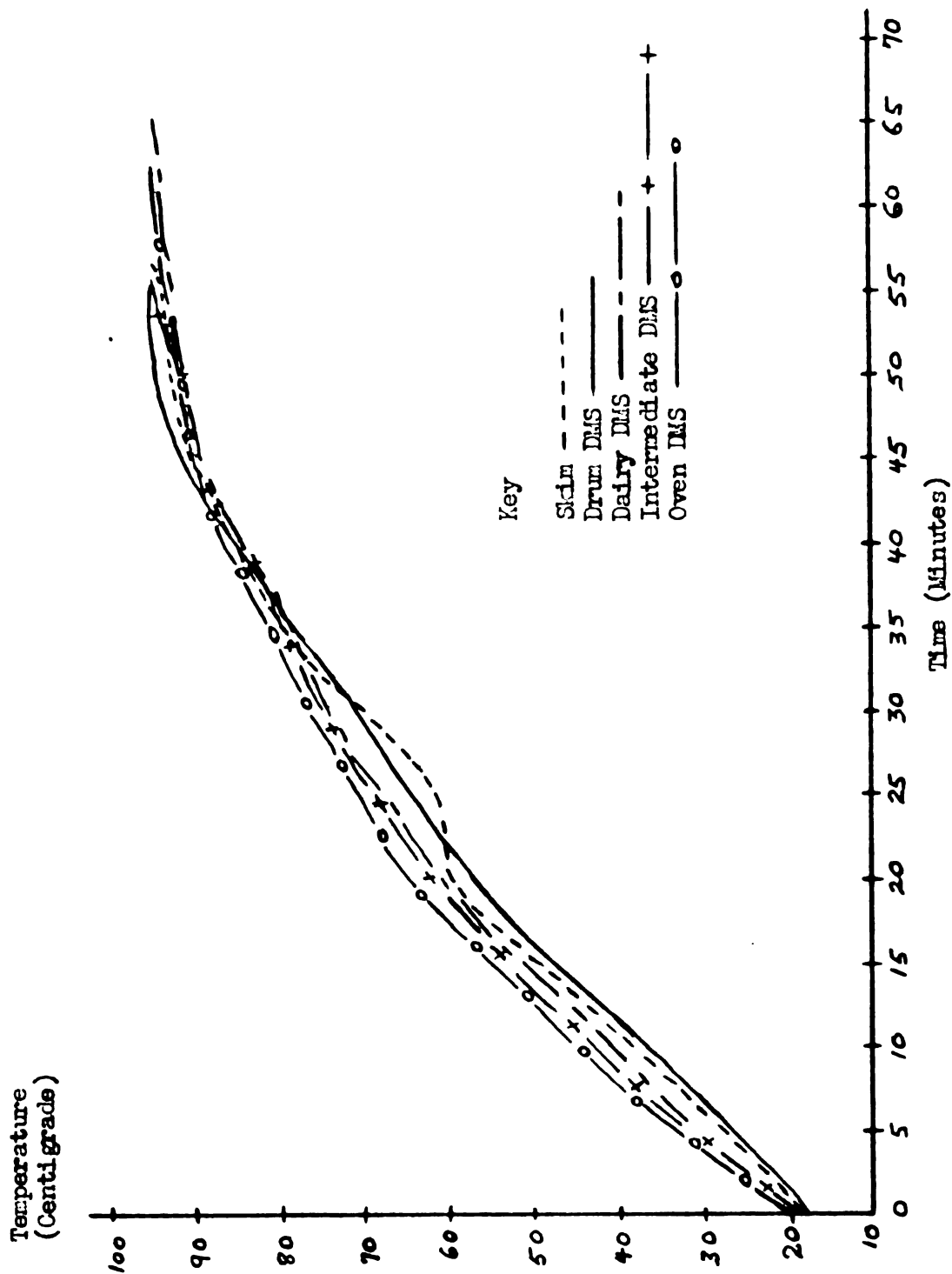


Figure 1. Average Time-Temperature Curves for Baked Custards at Concentration No. 1.
(Each point represents the average of the four replications of each variable)

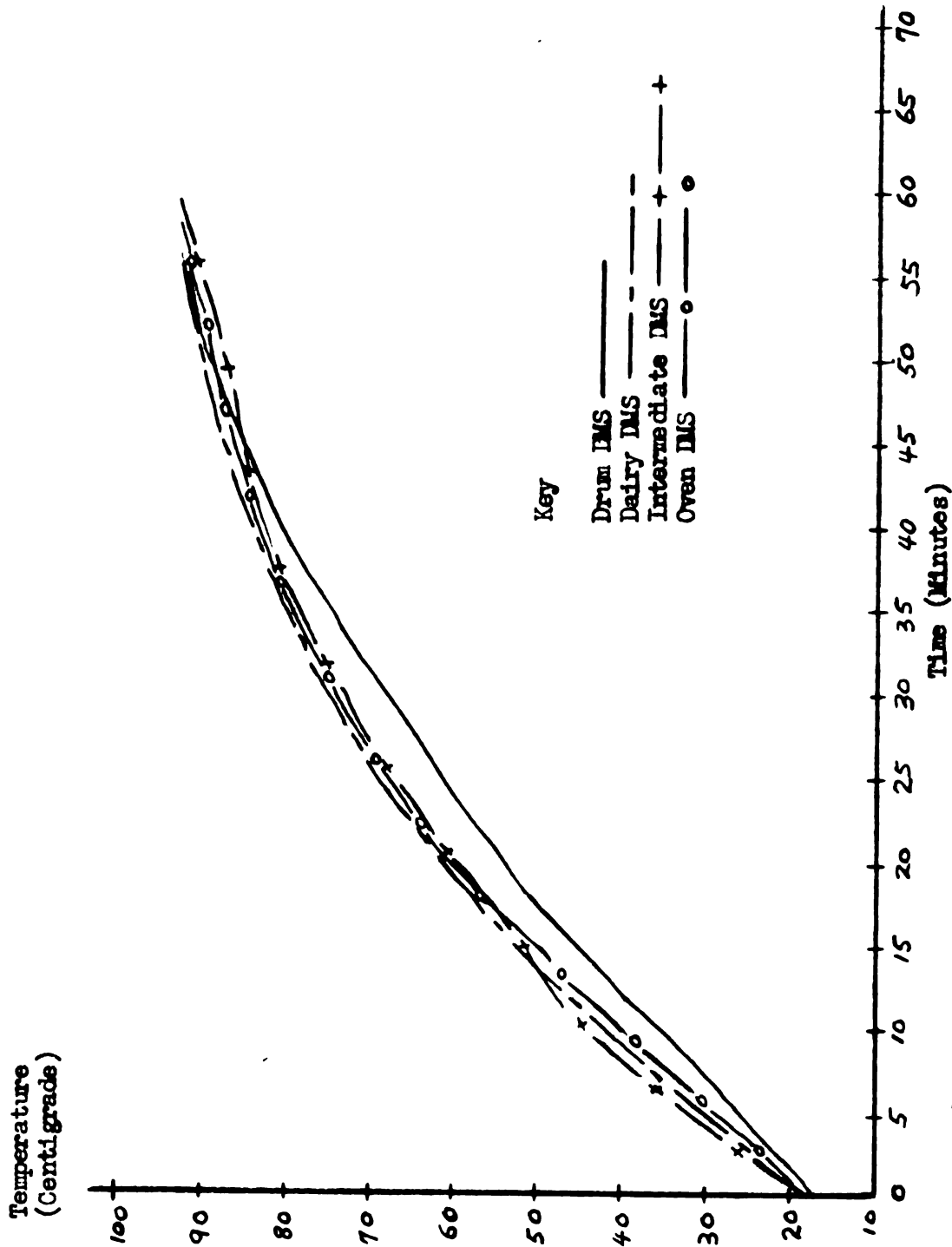


Figure 2. Average Time-Temperature Curves for Baked Custards at Concentration No. 1 1/2.
(Each point represents the average of the four replications of each variable)

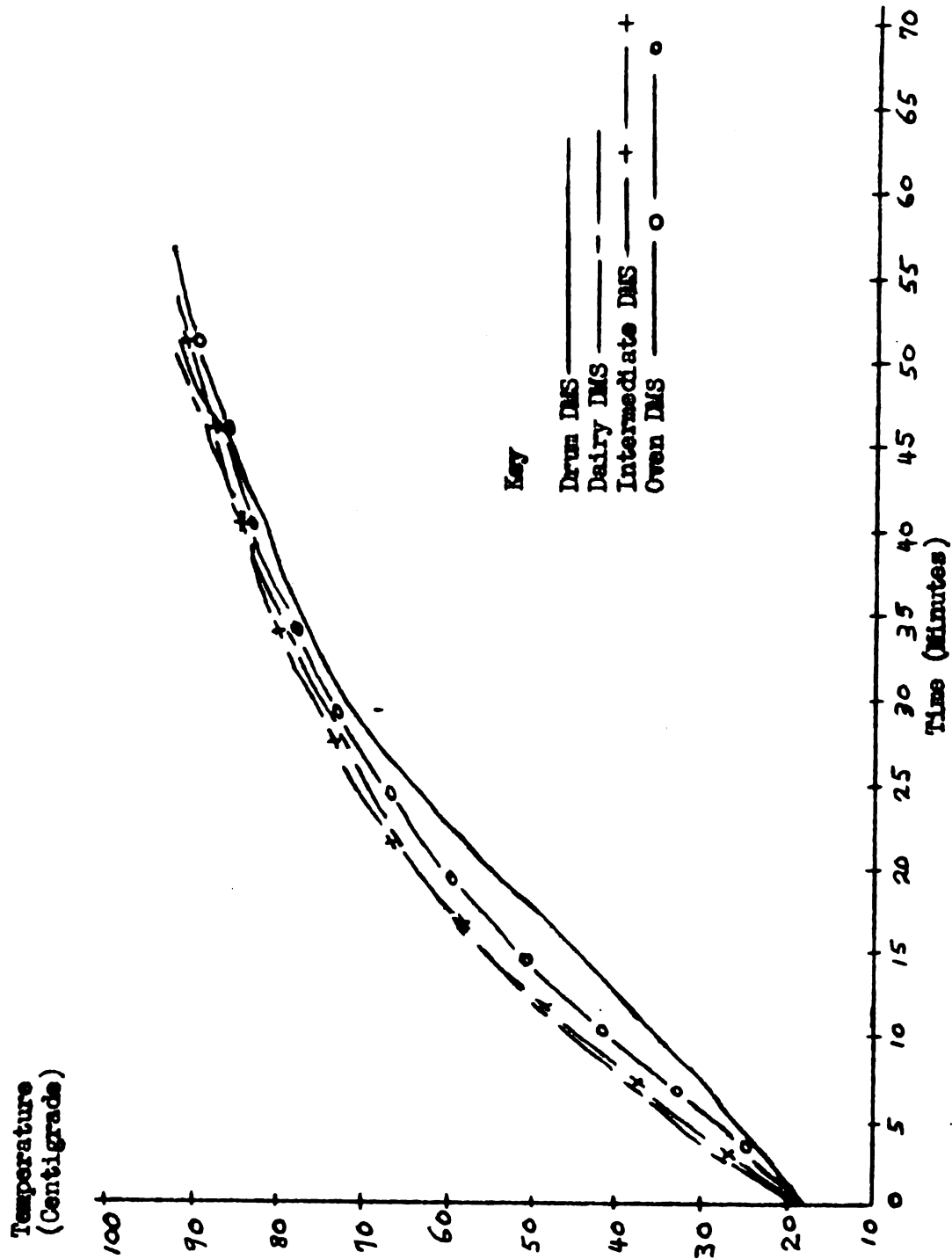


Figure 3. Average Time-Temperature Curves for Baked Custards at Concentration No. 2.
 (Each point represents the average of the four replications of each variable)

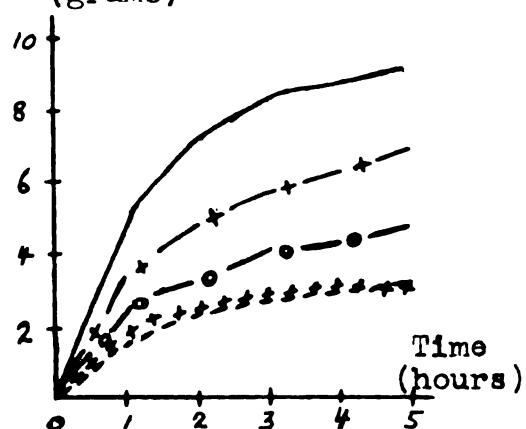
spray DMS custards until an internal temperature of 82° - 84° C was reached, when the heat penetration was much more rapid than in the spray DMS custards. The curve for the rate of heat penetration of the control custards fell between the heat penetration curves for the dairy and drum DMS custards until an internal temperature of 80° C was attained and then resemble closely the curves of the custards containing drum DMS. The different rates of heat could possibly be accounted for by the effect of the various heat treatments on the protein in the manufacture of the milk.

Upon increasing the concentration of DMS, the baking time was shortened. The decreased baking time could be accounted for by the increased protein concentration.

Syneresis

The syneresis shown by the different custards, at intervals of 1 hour, for a total of a 5 hour period is graphed in Figure 4. The protein of drum DMS was very insoluble and these custards had the highest syneresis. The custards of dairy and oven DMS had the least syneresis. Some of the gels of the custards with spray DMS were soft and thus part of the custard passed through the mesh screen.

Syneresis
(grams)



(a) Dried Milk Solids
at Concentration No. 1

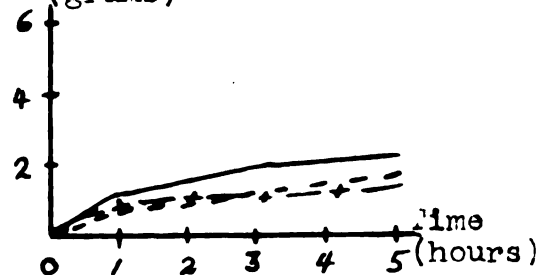
Key (a)

Oven +++++
Drum ———
Skim —+—+
Spray Dairy ----
Intermediate —o—

Key (b, c, d, e)

Concentration No. 1 ———
Concentration No. 1½ ----
Concentration No. 2 —+—+

Syneresis
(grams)



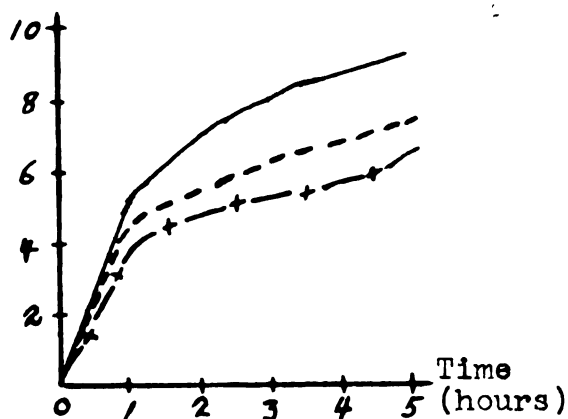
(b) Spray Dairy DMS

Syneresis
(grams)



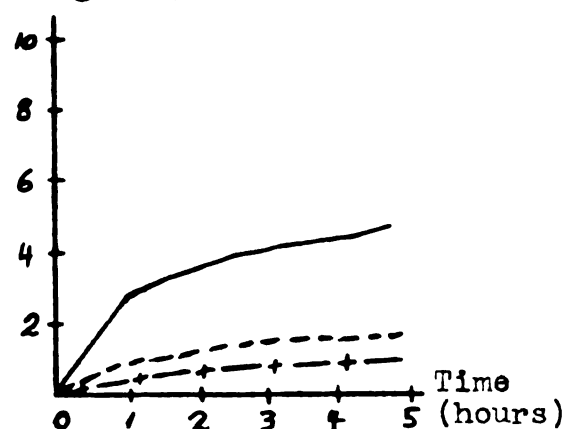
(c) Spray Oven DMS

Syneresis
(grams)



(d) Drum DMS

Syneresis
(grams)



(e) Spray Intermediate DMS

Figure 4. Syneresis (grams per hour)

In general the greatest amount of syneresis in the custards occurred during the first hour of testing. With oven DMS the increase in syneresis per hour after this was small but fairly constant. The increase in syneresis after the first hour of testing in intermediate DMS custards was slightly greater than during the three following hours. The increase in syneresis with dairy DMS was fairly constant for the first 3 hours of testing and then the syneresis leveled off as indicated in Figure 4c. The amount of syneresis in drum DMS custards was very great during the first hour, somewhat less but constant during the second and third hours and occurred to a lesser extent the last two hours.

As indicated in Figures 4(b, c, d, e) an increase in the concentration of DMS caused the amount of syneresis to decrease. The only exception noted was the dairy DMS custard at concentration No. $1\frac{1}{2}$ and No. 2, which showed practically equal syneresis. The amount of decrease was much greater when the level was increased from concentration No. 1 to No. $1\frac{1}{2}$ than when the concentration was increased from No. $1\frac{1}{2}$ to No. 2. The decrease probably was due to increased protein content which contributed a larger number of protein strands to form a denser mesh work to hold the liquid. The results indicate that when

a certain concentration of protein is reached, additional protein has only a slight effect on the decrease of syneresis.

Gel Strength

The strength of the gel in the custards was measured by three methods, the curd tension meter, the penetrometer, and the standing index. The results of these tests are discussed in the following pages.

Curd Tension Meter: The cutting strengths of the gel at the top of the custard with the crust removed and the bottom were measured by the curd tension meter, the results being indicated in Figure 5. As shown in the graph, the top of the custards had a less tender gel than the bottom in all kinds of custards with the exception of drum and intermediate DMS at concentration No. $1\frac{1}{2}$, which had nearly equal gel strengths at the top and bottom. The tougher gel at the bottom could be caused by the protein coagulating at the outer edges and bottom first and then at the center and just under the crust.

The most tender gel was in custards from skim milk. The dairy DMS were next most tender, then the intermediate DMS and lastly the oven and drum DMS, which had nearly

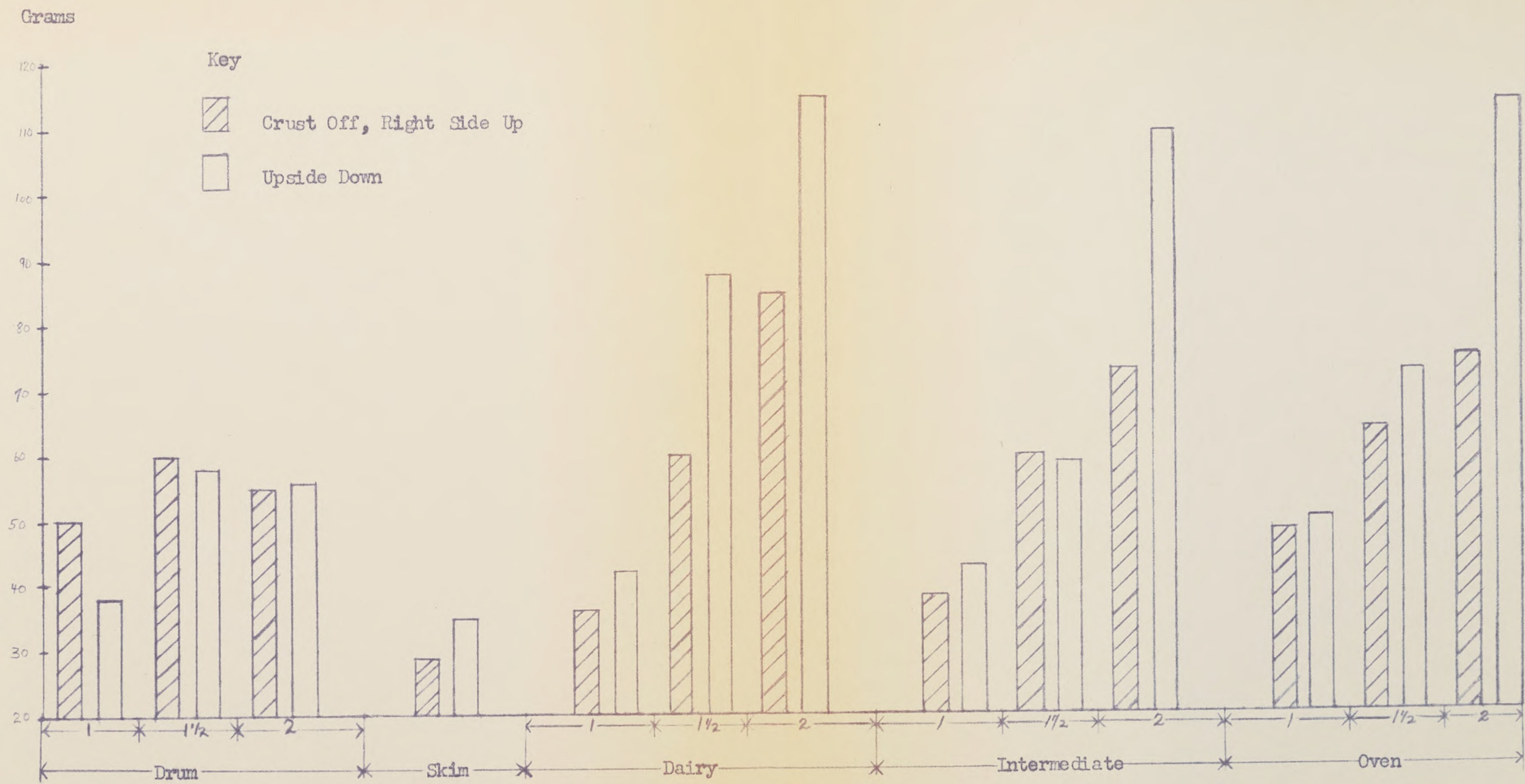


Figure 5. Average Curd Tension Meter Readings on Baked Custards (Grams)

equal gel strengths. This difference in gel strength could be accounted for by the temperature used in the manufacture of these DMS. The data indicate that the gel was tougher when a higher temperature was used in the manufacture of the DMS.

As the concentration of DMS was increased, the gels were tougher except with custards from drum DMS concentration No. 2. The increased toughness could be caused by increasing the protein concentration which gave a denser mesh work for the gel. The decrease in cutting strength of gel in drum DMS at concentration No. 2 could be the high percentage of insolubility of the solids. With increased concentration of the solids, the difference in gel strength of the bottom and top of the custard increased greatly. The increase possibly could be caused by an increased insolubility in spray DMS as their concentration increased, and thus the insoluble particles settled to the bottom. This theory is substantiated by the judges' scores for smoothness, which were low due to the graininess of the custards.

Penetrometer: The compressibility of the gel at the top and bottom of the custard and the breaking strength of the crust was measured with the penetrometer. The

compressibility readings increase with the tenderness of the gel.

Figure 6 shows that drum DMS in custards had the greatest amount of compressibility, skim milk custards slightly less and then the oven DMS custards. The readings for compressibility were slightly higher for custards containing intermediate DMS than for those containing dairy DMS.

The gel at the bottom of a custard was more easily compressed than at the top except with custards of drum DMS at concentration No. 2. These findings are just the reverse of the results using the curd tension meter.

As the concentration of DMS was increased, a tougher gel resulted. The only exception to this increase in toughness was with the custards from dairy DMS at concentration No. $1\frac{1}{2}$, which had the same gel toughness as at concentration No. 1.

The penetrometer readings for breaking strength of the crust indicated that drum DMS custards had the most tender crust, with the control custard next. The intermediate DMS custards had the most tender crust of the spray DMS custards and the oven DMS gave the toughest crusts in all the custards.

Millimeters

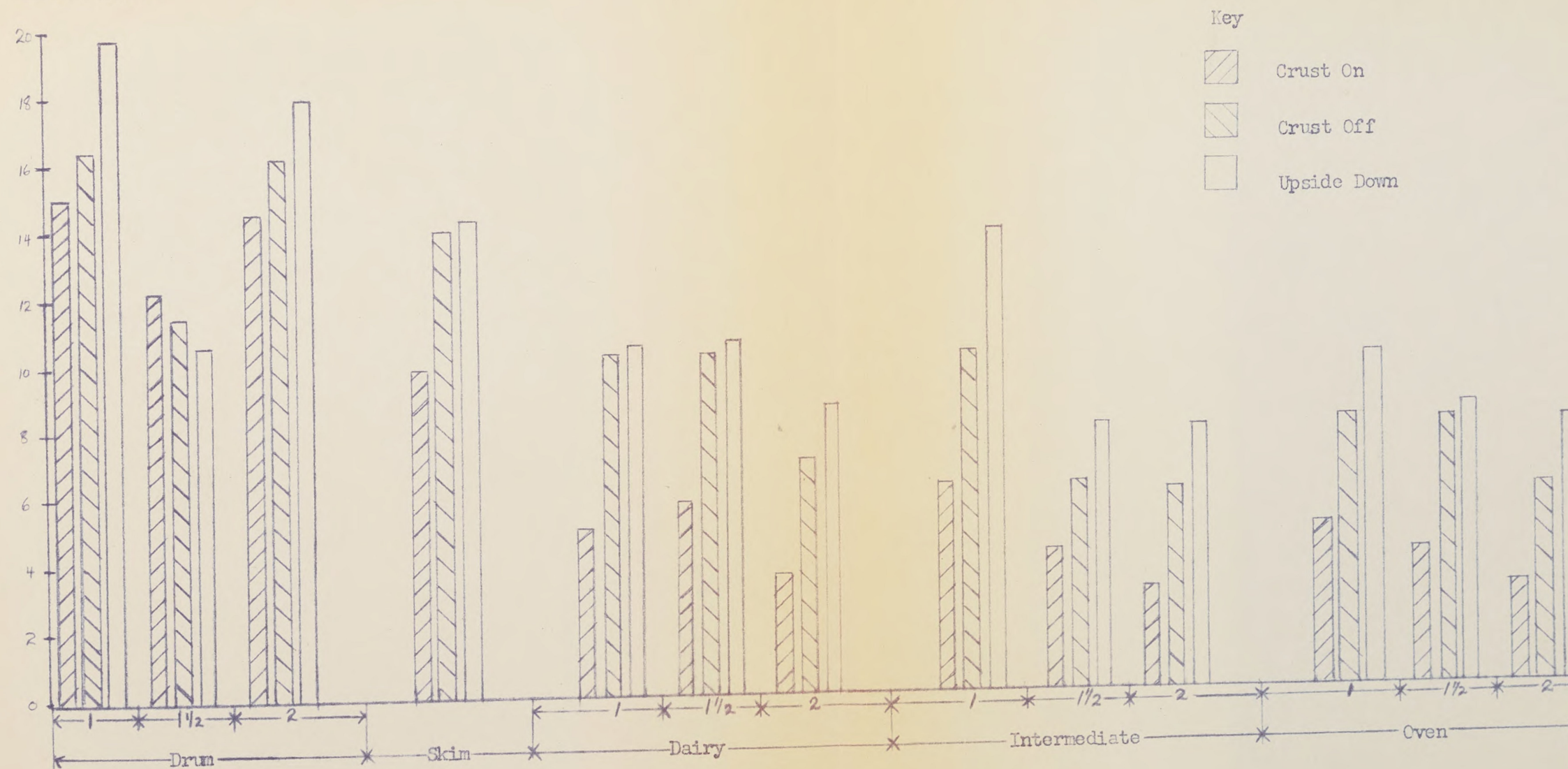


Figure 6. Average Penetrometer Readings on Baked Custards (Millimeters)

When the concentration of DMS was increased the crusts became tougher. The exceptions were the crusts on custards from drum DMS at concentration No. 2 and dairy DMS at concentration No. $1\frac{1}{2}$ which were less tough than the crusts on the custards containing a lower concentration of DMS.

Correlations were calculated on the penetrometer and curd tension meter readings to find out which agreed more closely with the judges' scores. There was no significant correlation between the judges' scores for firmness and the penetrometer readings for compressibility as indicated in Table 11, but a significant correlation at the 1 percent level existed between the judges' scores for firmness and the curd tension readings for the top of the custards with the crust off. A significant correlation at the 5 percent level existed between the curd tension meter readings on the custards upside down and judges' scores for firmness. These results suggest that the curd tension meter gave a better measure of gel strength than the penetrometer.

Table 11 indicates that the negative correlation between the judges' scores for firmness and the penetrometer readings on the crust was significant at the 1 percent level. The positive correlation between the penetrometer readings and the judges' scores for the crusts was even

TABLE 11

Correlation between some Subjective
and Objective Measures

Crust score vs penetrometer reading (crust on)	+0.6167**
Crust score vs difference between penetrometer reading for crust on and off	+0.1522
Firmness score vs penetrometer reading (crust on)	-0.3595**
Firmness score vs penetrometer reading (crust off)	-0.0999
Firmness score vs penetrometer reading (custard upside down)	-0.0992
Firmness score vs curd tension meter readings (crust off)	-0.4777**
Firmness score vs curd tension meter readings (custard upside down)	-0.3283*

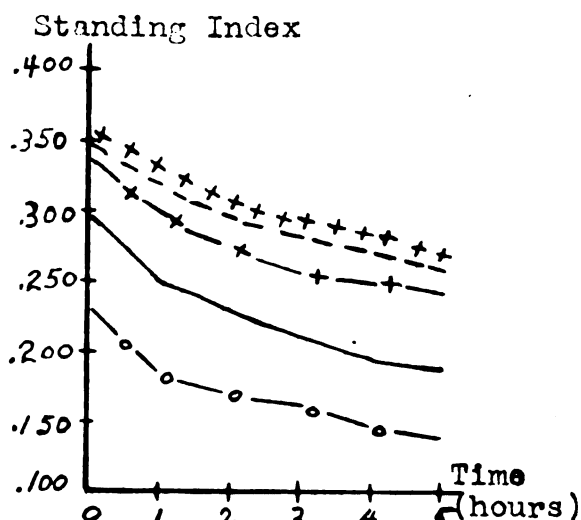
**Significant at 1% level

*Significant at 5% level

more highly significant. The reason for the positive correlation was the tougher the crust the less the penetration and also the lower the judges' scores.

The cause of the toughness of crusts on custards with spray DMS could be the absence of fat which would seem to act as a protecting agent for the protein from the dry heat of the oven. Carr and Trout (3) found that homogenized custards had a tougher crust than custards of whole milk. On adding butter or cream to the custard, the crust improved in tenderness. To test this hypothesis, a supplementary series was done, in which melted butter was added to the DMS custard mix before cooking. The crusts were more tender on these custards.

Standing Index: The data for the standing index of the various custards is represented in the graphs in Figure 7. The standing index was taken at intervals of 1 hour for a 5 hour period. A smaller ratio indicates a weaker gel structure. As indicated by the graphs, a considerable difference existed in the ability of the gels of the custards to hold up at the beginning of the test period. The results indicate that custards of drum DMS had the weakest gels. The spray DMS custards had gel strengths that differed only slightly: the oven DMS



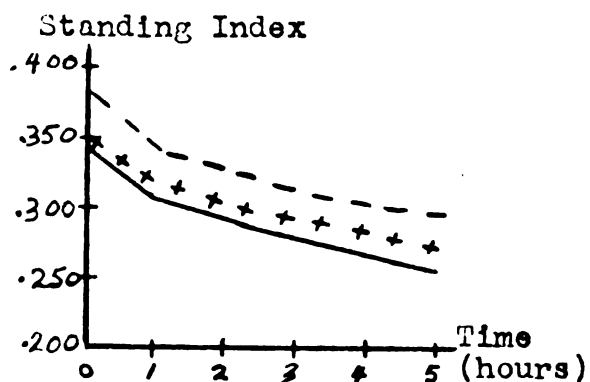
(a) Dried Milk Solids at Concentration No. 1

Key (a)

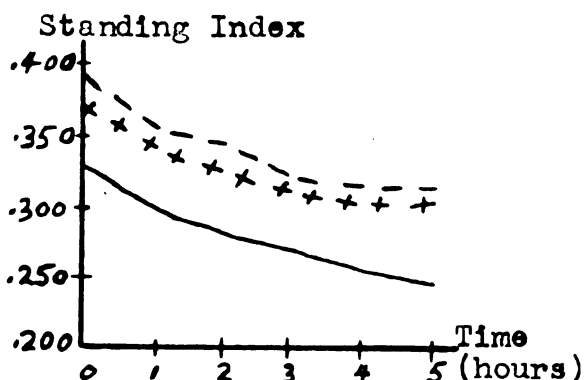
Skim (Control) —————
 Spray Dairy - - - - -
 Spray Intermediate — + — +
 Spray Oven + + + + +
 Drum — o — o

Key (b, c, d, e)

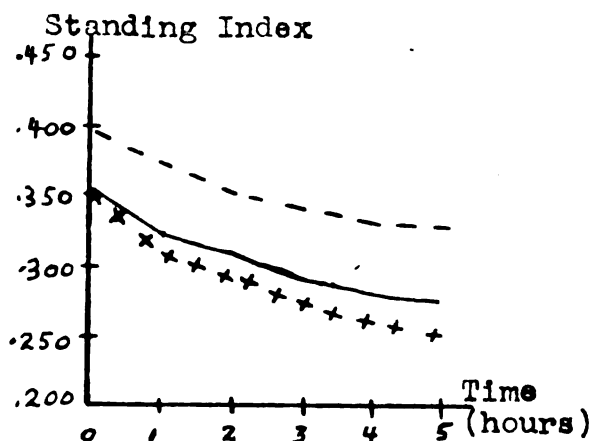
Concentration No. 1 —————
 Concentration No. $1\frac{1}{2}$ + + + + +
 Concentration No. 2 - - - - -



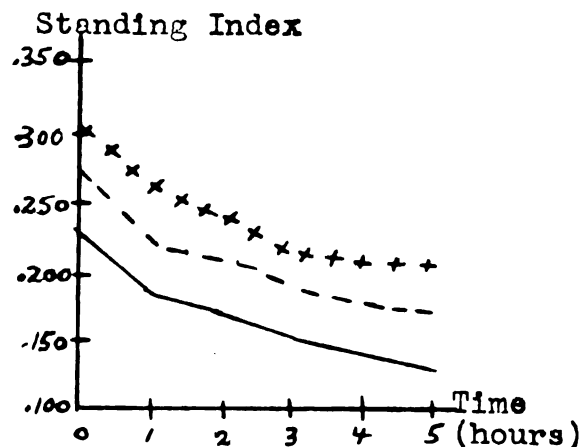
(b) Spray Dairy DMS



(c) Spray Intermediate DMS



(d) Spray Oven DMS



(e) Drum DMS

Figure 7. Average Standing Index Readings

giving the custard with the firmest gel, the intermediate DMS having the weakest gel and the dairy DMS with an intermediate gel strength. The gel strength of skim milk custards was between that of the spray and drum DMS custards.

The greatest decrease in the standing index occurred during the first hour of testing. The decrease after the first hour in all the spray DMS custards was small but fairly constant. This was true also with custards made from skim milk. The gel of the drum DMS slumped more between the second and third hours of testing than during the last 2 hours. The total decrease in the standing index over the 5 hour period for the 3 spray DMS custards was nearly the same and less than the drum DMS and skim milk custards, which had practically equal decreases in the total standing index.

As indicated in Figure 7(b, c, d, e), when the concentration of dairy and intermediate DMS were increased the gel strength was greater. With oven DMS custards the gel strength was weaker at concentration No. $1\frac{1}{2}$ than at concentration No. 1. Figure 7e indicates that the gel strength of drum DMS custards at concentration No. 2 was weaker than at concentration No. $1\frac{1}{2}$. Of all the custards, the gel strength of drum DMS custards at concentration No. $1\frac{1}{2}$ is closest to the gel strength of the control custard.

SUMMARY AND CONCLUSIONS

The merits of various processed nonfat dried milk solids at 3 concentrations were compared in baked custards. Custards were selected for this study because the literature indicated that they had a high degree of sensitivity to slight changes in egg-milk-sugar mixtures.

Two types of dried milk powders were used, drum and spray processed. The spray processed powders were treated at different temperatures during processing, low being called dairy DMS, high, oven DMS and a third at intermediate temperatures called intermediate DMS. The 4 dried milks were used at 3 concentrations. Concentration No. 1 was equivalent to the solids in fluid skim milk, concentration No. $1\frac{1}{2}$ being equal to one and a half times the solids in fluid skim milk and concentration No. 2 equalling twice the concentration of skim milk solids. Custards made from skim milk were the control for the experiment.

Objective and subjective techniques for judging the quality of baked custards were used. The custards were scored subjectively for appearance, crust, color inside, flavor, smoothness, sweetness and general acceptability. Objective measurements included the solubility index and

moisture content of the dried milks, the pH of the custard before and after baking, the time-temperature curves for the rate of heat penetration, a test for syneresis and three tests for gel strength - the curd tension meter, the penetrometer and the standing index.

The chief source of variation among the palatability scores was due to different treatments, not variation within replications. The preference for various baked custards indicated by the general acceptability scores were skim milk custards and spray DMS custards at concentration No. 1 in the following order: intermediate DMS, oven DMS and dairy DMS. The data show that all other custards differed significantly from the control. As the concentration of DMS was increased the flavor and color of the custards were less acceptable, the gel too firm, the texture too grainy and the crusts too tough.

In general, the results of the objective tests agreed with the palatability scores. All the custards showed some syneresis, but the degree of syneresis varied greatly between treatments. A highly significant negative correlation existed between the judges' scores for firmness and results of the curd tension meter. No significant correlation between the firmness scores by the judges and penetrometer readings was evident. This indicates the curd tension

meter was more nearly measuring the thing the judges scored for firmness than the penetrometer. A highly significant positive correlation between the judges' scores on the crust and the penetrometer readings on breaking strength of the crusts existed. This indicates a good relationship between the penetrometer readings and the judges' scores for the crust.

From these results it appears that:

1. Skim milk custards were superior to custards made of DMS.
2. Spray DMS gave the most acceptable product of the DMS used.
3. Results of this experiment did not indicate one type of spray DMS to be superior.
4. The best concentration of DMS to use is an amount equivalent to the concentration of solids in fluid skim milk.

REFERENCES CITED

1. American Dry Milk Institute, Inc., 1942. The grading of dry milk solids. Rev. ed. Chicago, Illinois.
2. Beach, B. F., 1952. Private communication. Michigan Producers Dairy Company, Adrian, Michigan.
3. Carr, E. and Trout, G. M., 1942. Some cooking qualities of homogenized milks. I. Baked and soft custards. Food Research 7: 360.
4. Chick, H. and Martin, C. J., 1910. I. On "heat coagulation" of proteins. J. Physiol. 40: 404.
5. ———, 1911. The action of hot water upon egg-albumen and the influence of acids and salts upon reaction velocity. J. Physiol. 43: 1.
6. ———, 1912. The influence of alkali upon the reaction velocity. J. Physiol. 45: 61.
7. ———, 1912. The conditions controlling the agglutination of proteins already acted upon by hot water. J. Physiol. 45: 261.
8. Choi, R. P., Totter, C. W. and O'Malley, C. M., 1951. Lactose crystallization in dry products of milk. 1) A method for estimating the degree of crystallization. 2) The effects of moisture and alcohol. J. Dairy Sci. 34: 845.
9. Coulter, S. T., Jenness, R. and Geddes, W. F., 1951. Physical and chemical aspects of the product, storage and utility of dry milk products. Advances in Food Research 3: 45. Edited Mrak, E. M. and Stewart, G. F. Academic Press Inc., New York.
10. Cochran, W. G. and Cox, G. M., 1950. Experimental design. 1st ed. John Wiley and Sons, Inc., New York.
11. Davies, W. L., 1939. The chemistry of milk. 2nd ed. D. Van Nostrand Company, Inc., New York.

12. Gortner, R. A., Gartner, R. A. Jr., and Gartner, Willis, 1949. Outlines of biochemistry. 3rd ed. John Wiley and Sons, New York.
13. Grawemeyer, E. H. and Pfund, M. C., 1943. Line spread as an objective test for consistency. Food Research 8: 105.
14. Harland, H. A. and Ashworth, A. S., 1947. A rapid method for estimation of whey proteins as an indication of baking quality of nonfat dry milk solids. Food Research 12: 247.
15. Hill, R. L., 1923. A test for determining the character of the curd from cows' milk and its application to the study of curd variance as an index to the food value of milk for infants. J. Dairy Sci. 6: 509.
16. Hollender, H. and Weckel, K. G., 1941. Homogenized milk in cookery practice. Food Research 6: 341.
17. Holm, G. E., 1949. Dried milks. U.S.D.A. Research Administration, Bureau of Dairy Industry Information Bulletin No. 25.
18. Howak, G. R. and Wright, N. C., 1933. Factors affecting the solubility of milk powders. II. The influence of temperature of reconstitution on protein solubility. J. Dairy Res. 4: 265.
19. Howatt, G. R., Smith, J. A. B., Waite, R. and Wright, N. C., 1939. Factors affecting the solubility of milk powders. IV. The influence of speed and duration of stirring on solubility, with a description of a rapid method for solubility determinations. J. Dairy Res. 10: 498.
20. Hunziker, O. T., 1949. Condensed milk and milk powders. 7th ed. Published by the author, LaGrange, Illinois.
21. Kitzes, A. S., 1948. Factors influencing the design and operation of a spray drier. Ph. D. Thesis, University of Minnesota Library, Minneapolis, Minnesota. (Original not available for examination; cited in Advances in Food Research 3: 45.)

22. Logue, L. E., 1940. Some qualities of eggs affecting the gel strength of custards. M. S. Thesis, Iowa State College, Ames, Iowa.
23. Lowe, B., 1943. Experimental cookery. 3rd ed. John Wiley and Sons, Inc., New York.
24. McBain, J. W., 1950. Colloid chemistry. D. C. Heath and Company, Boston.
25. Morse, L. M., Davis, D. and Jack, E. L., 1950. Use and properties of nonfat dry milk solids in food preparation. II. Use in typical foods. Food Research 15: 216.
26. Nason, E. H., 1939. Introduction to experimental cookery. McGraw Hill, New York.
27. O'Malley, C. M., 1951. Dry milk in prepared mixes. Cereal Chem. 9: 116.
28. Paul, P. C. and Aldrich, P. J., 1953. Using nonfat dry milk solids. Amer. Dietet. Assoc. J. 29: 234.
29. Paul, P. and Plummer, J., 1949. Home storage of nonfat dry milk solids. J. Home Econ. 41: 198.
30. Platt, W., 1937. Some fundamental assumptions pertaining to the judgment of food flavors. Food Research 2: 237.
31. Ramsey, J., Tracy, P. H. and Rhee, H. S., 1933. The use of corn sugar manufacture of sweetened condensed milk. J. Dairy Sci. 16: 17.
32. Snedecor, G. W., 1950. Statistical methods. 4th ed. Iowa State College Press, Ames, Iowa.
33. Tray, H. C. and Sharp, P. F., 1930. α and β lactose in some milk products. J. Dairy Sci. 13: 140.
34. United States Statutes at Large, 1944. 78th Congress, 2nd Session. Volume 58, Part 1, Public Laws.
35. Watt, B. K. and Merrill, A. L., 1950. Composition of foods - raw, processed, prepared. Agr. Handbook No. 8, U. S. Dept. Agr.

36. Wright, N. C., 1932. Factors affecting the solubility of milk powders. I. The affect of heat on the solubility of milk proteins. J. Dairy Sci. 4: 122.

APPENDIX

TABLE 12
Average Daily Scores for Appearance

Day								
1	(4)	1.8	(6)	5.0	(7)	5.4	(8)	5.4
2	(1)	5.8	(5)	4.6	(6)	5.0	(9)	4.8
3	(2)	4.2	(3)	2.8	(5)	4.8	(8)	4.8
4	(8)	5.4	(9)	4.8	(11)	4.6	(13)	5.0
5	(4)	2.6	(5)	4.6	(10)	5.2	(13)	5.8
6	(3)	2.4	(6)	4.2	(11)	4.6	(13)	4.8
7	(5)	4.2	(7)	5.0	(11)	4.6	(12)	5.6
8	(2)	3.5	(6)	5.0	(10)	5.0	(12)	4.3
9	(3)	2.8	(7)	4.6	(9)	5.0	(10)	4.8
10	(2)	4.4	(1)	5.6	(7)	4.8	(13)	4.6
11	(2)	3.8	(4)	3.0	(9)	5.2	(11)	4.8
12	(3)	3.0	(4)	2.4	(1)	5.2	(12)	4.8
13	(1)	6.0	(8)	4.5	(10)	4.8	(12)	4.8

Key

- (1) Skim milk custard (control)
- (2) Drum DMS custard concentration No. 1
- (3) Drum DMS custard concentration No. $1\frac{1}{2}$
- (4) Drum DMS custard concentration No. 2
- (5) Dairy DMS custard concentration No. 1
- (6) Dairy DMS custard concentration No. $1\frac{1}{2}$
- (7) Dairy DMS custard concentration No. 2
- (8) Intermediate DMS custard concentration No. 1
- (9) Intermediate DMS custard concentration No. $1\frac{1}{2}$
- (10) Intermediate DMS custard concentration No. 2
- (11) Oven DMS custard concentration No. 1
- (12) Oven DMS custard concentration No. $1\frac{1}{2}$
- (13) Oven DMS custard concentration No. 2

TABLE 13

Average Daily Scores for Crust

<u>Day</u>							
1	(4)	3.4	(6)	4.4	(7)	4.4	(8) 5.4
2	(1)	5.4	(5)	4.4	(6)	4.6	(9) 4.2
3	(2)	6.0	(3)	6.4	(5)	4.4	(8) 4.4
4	(8)	4.6	(9)	4.6	(11)	4.8	(13) 4.0
5	(4)	5.2	(5)	5.2	(10)	4.6	(13) 4.6
6	(3)	4.8	(6)	4.4	(11)	5.0	(13) 4.0
7	(5)	4.8	(7)	4.4	(11)	5.0	(12) 4.6
8	(2)	5.3	(6)	4.3	(10)	4.5	(12) 4.3
9	(3)	6.2	(7)	4.0	(9)	4.2	(10) 3.8
10	(2)	5.0	(1)	5.2	(7)	3.8	(13) 3.8
11	(2)	5.8	(4)	5.0	(9)	4.0	(11) 4.6
12	(3)	5.6	(4)	5.4	(1)	5.0	(12) 4.2
13	(1)	5.0	(8)	4.3	(10)	4.0	(12) 4.5

TABLE 14

Average Daily Scores for Color Inside

<u>Day</u>							
1	(4)	2.8	(6)	6.0	(7)	5.4	(8) 6.2
2	(1)	6.2	(5)	5.4	(6)	5.6	(9) 5.8
3	(2)	4.2	(3)	3.6	(5)	6.0	(8) 6.2
4	(8)	6.0	(9)	5.6	(11)	5.6	(13) 5.8
5	(4)	3.2	(5)	6.0	(10)	5.6	(13) 5.8
6	(3)	3.4	(6)	5.6	(11)	6.2	(13) 5.4
7	(5)	5.6	(7)	5.6	(11)	5.8	(12) 6.0
8	(2)	3.9	(6)	5.5	(10)	5.5	(12) 5.8
9	(3)	3.2	(7)	5.4	(9)	5.8	(10) 5.8
10	(2)	4.2	(1)	6.2	(7)	5.4	(13) 5.6
11	(2)	4.4	(4)	3.0	(9)	5.8	(11) 5.8
12	(3)	3.4	(4)	2.8	(1)	6.2	(12) 5.4
13	(1)	6.0	(8)	5.8	(10)	5.0	(12) 5.8

TABLE 15

Average Daily Scores for Flavor

<u>Day</u>							
1	(4)	2.8	(6)	5.0	(7)	4.8	(8) 5.8
2	(1)	5.6	(5)	5.0	(6)	5.2	(9) 5.4
3	(2)	3.6	(3)	3.4	(5)	5.4	(8) 5.4
4	(8)	5.6	(9)	5.4	(11)	5.0	(13) 5.0
5	(4)	2.6	(5)	5.8	(10)	5.6	(13) 5.0
6	(3)	3.0	(6)	5.4	(11)	6.0	(13) 5.2
7	(5)	5.6	(7)	4.4	(11)	6.0	(12) 5.6
8	(2)	2.9	(6)	5.0	(10)	4.5	(12) 5.5
9	(3)	2.8	(7)	5.2	(9)	5.0	(10) 5.2
10	(2)	3.4	(1)	6.2	(7)	4.8	(13) 5.0
11	(2)	3.4	(4)	2.4	(9)	5.2	(11) 6.0
12	(3)	3.2	(4)	1.8	(1)	6.2	(12) 5.0
13	(1)	6.3	(8)	6.0	(10)	5.0	(12) 5.5

TABLE 16

Average Daily Scores for Firmness

<u>Day</u>							
1	(4)	3.4	(6)	4.6	(7)	4.0	(8) 5.8
2	(1)	5.2	(5)	4.6	(6)	5.2	(9) 4.6
3	(2)	4.2	(3)	5.0	(5)	5.6	(8) 5.6
4	(8)	5.8	(9)	5.0	(11)	4.8	(13) 4.4
5	(4)	3.6	(5)	6.0	(10)	4.2	(13) 4.8
6	(3)	3.6	(6)	5.6	(11)	6.0	(13) 4.6
7	(5)	5.8	(7)	4.6	(11)	6.2	(12) 4.8
8	(2)	4.5	(6)	4.9	(10)	4.0	(12) 4.9
9	(3)	4.0	(7)	4.4	(9)	4.6	(10) 4.4
10	(2)	4.0	(1)	6.4	(7)	4.2	(13) 4.6
11	(2)	3.8	(4)	3.6	(9)	4.4	(11) 5.4
12	(3)	3.4	(4)	3.6	(1)	6.6	(12) 5.0
13	(1)	6.3	(8)	5.3	(10)	4.3	(12) 5.0

TABLE 17

Average Daily Scores for Smoothness

<u>Day</u>							
1	(4)	2.8	(6)	6.0	(7)	5.6	(8) 6.0
2	(1)	6.2	(5)	5.8	(6)	5.6	(9) 5.4
3	(2)	4.2	(3)	3.4	(5)	6.2	(8) 6.0
4	(8)	6.2	(9)	5.6	(11)	5.6	(13) 5.6
5	(4)	3.6	(5)	6.2	(10)	5.8	(13) 5.8
6	(3)	3.4	(6)	6.0	(11)	6.2	(13) 5.8
7	(5)	6.4	(7)	5.6	(11)	6.0	(12) 6.0
8	(2)	3.3	(6)	5.5	(10)	5.3	(12) 5.5
9	(3)	3.4	(7)	5.6	(9)	5.8	(10) 5.6
10	(2)	4.6	(1)	6.6	(7)	5.8	(13) 6.0
11	(2)	4.2	(4)	3.6	(9)	6.0	(11) 6.4
12	(3)	3.4	(4)	3.8	(1)	6.6	(12) 5.8
13	(1)	6.8	(8)	6.3	(10)	5.8	(12) 5.8

TABLE 18

Average Daily Scores for Sweetness

Day							
1	(4)	3.8	(6)	5.4	(7)	4.6	(8) 5.8
2	(1)	6.2	(5)	5.6	(6)	5.0	(9) 6.6
3	(2)	4.0	(3)	4.0	(5)	5.8	(8) 5.8
4	(8)	5.8	(9)	5.4	(11)	5.4	(13) 5.4
5	(4)	3.8	(5)	6.0	(10)	5.6	(13) 5.6
6	(3)	4.0	(6)	5.8	(11)	6.0	(13) 4.8
7	(5)	5.2	(7)	5.0	(11)	5.8	(12) 5.2
8	(2)	3.9	(6)	4.9	(10)	4.0	(12) 5.5
9	(3)	3.8	(7)	5.4	(9)	5.6	(10) 5.0
10	(2)	4.0	(1)	5.8	(7)	5.0	(13) 5.4
11	(2)	3.6	(4)	2.8	(9)	5.4	(11) 6.0
12	(3)	3.4	(4)	2.6	(1)	6.0	(12) 5.2
13	(1)	5.5	(8)	5.5	(10)	5.0	(12) 5.0

TABLE 19

Average Daily Scores for General Acceptability

Day							
1	(4)	2.0	(6)	4.6	(7)	4.0	(8) 5.8
2	(1)	5.4	(5)	4.8	(6)	5.2	(9) 5.0
3	(2)	3.6	(3)	3.0	(5)	5.4	(8) 5.4
4	(8)	5.6	(9)	4.8	(11)	4.8	(13) 4.6
5	(4)	2.4	(5)	5.8	(10)	5.0	(13) 4.6
6	(3)	2.4	(6)	5.2	(11)	5.6	(13) 4.6
7	(5)	5.6	(7)	4.4	(11)	5.8	(12) 4.8
8	(2)	3.9	(6)	4.9	(10)	4.0	(12) 4.9
9	(3)	2.4	(7)	4.2	(9)	4.8	(10) 4.4
10	(2)	3.0	(1)	5.8	(7)	4.6	(13) 4.6
11	(2)	3.4	(4)	2.4	(9)	4.4	(11) 5.6
12	(3)	3.0	(4)	2.2	(1)	6.0	(12) 5.0
13	(1)	6.0	(8)	5.5	(10)	4.5	(12) 5.0

TABLE 20

Score Sheet for Baked Custards

NAME _____	DATE _____
FACTOR	
APPEARANCE	
CRUST	
COLOR INSIDE	
FLAVOR	
FIRMNESS	
SMOOTHNESS	
SWEETNESS	
GENERAL ACCEPTABILITY	
ACCEPTABILITY - Yes or No	

Key

- 7 - Excellent
 6 - Very good
 5 - Good
 4 - Medium
 3 - Fair
 2 - Poor
 1 - Very poor

Appearance - glossy smooth crust, light yellow in color

Crust - tough or tender

Color, inside - light yellow color, even

Flavor - bland

Firmness - holds shape when cut, no leakage, not too firm

Smoothness - homogenous texture, smooth, not granular or

separated

Sweetness - degree

Remarks

TABLE 21

Illustration of Statistical Calculations
for Flavor Scores

First Stage Analysis of Variance on Flavor Data

<u>Source</u>	<u>Degrees of Freedom</u>	<u>Sum of Squares</u>	<u>Mean Square</u>	<u>F</u>
Total	51	65.6852		
Treatments (unadjusted)	12	61.6327		
Blocks (adjusted)	12	0.7242	0.06035(E_b)	< 1
Intra block error	27	3.3283	0.12327(E_e)	

Second Stage

Adjusted Treatment	12	59.805814	4.983818	53.2186**
--------------------	----	-----------	----------	-----------

Error for Adjusted Treatment	27		0.093648	
------------------------------	----	--	----------	--

$$\begin{array}{ll} \text{LSD}_{05} = \pm 2.052 (0.2164) & \text{LSD}_{01} = \pm 2.771 (0.2164) \\ = \pm 0.44 & = \pm 0.60 \end{array}$$

$$\text{Skim} - \text{LSD}_{05} = 5.54$$

$$\text{Skim} - \text{LSD}_{01} = 5.38$$

Treatment Number

Adjusted Treatment Mean

1	5.98
2	3.29
3	3.10
4	2.47
5	5.51
6	5.08
7	4.85
8	5.73
9	5.18
10	5.09
11	5.70
12	5.38
13	5.16

TABLE 21 (Contd.)

B_t = total of all blocks within which treatment occurs

G = grand total

t = number of treatments = 13

b = number of blocks = 13

r = number of replications = 4

K = number of samples per block = 4

$$B_t = 4G$$

T = treatment totals

Steps

$$1. \text{ Correction Term: } C = \frac{(\sum X)^2}{N} = \frac{(250.1)^2}{52} = 1202.8848$$

$$\begin{aligned} 2. \text{ Sums of squares (total)} &= (x_1)^2 + (x_2)^2 + (x_3)^2 + \dots + (x_{52})^2 - C \\ &= (2.8)^2 + (5.6)^2 + (3.6)^2 + \dots + (5.5)^2 - 1202.8848 \\ &= 65.6852 \end{aligned}$$

$$\begin{aligned} 3. \text{ Sums of squares (Treatment totals)} &= \frac{(24.3)^2 + (13.3)^2 + \dots + (20.3)^2}{4} \\ &\quad - 1202.8848 \\ &= 61.6327 \end{aligned}$$

4. W - found for each treatment

$$W = (t-k) T - (t-1) B_t + (K-1) G$$

$$= 9T - 12 B_t + 3 G$$

$$\text{ie.} = 218.7 - 955.2 + 750.3 = 13.8$$

5. Sums of Squares for blocks (adjusted)

$$= \frac{\sum W^2}{tr(t-k)(K-1)} = \frac{(13.8)^2 + (4.8)^2 + \dots + (-15.9)^2}{13 \times 4 \times 9 \times 3} = \frac{1016.82}{1404}$$

$$= 0.7242$$

TABLE 21 (Contd.)

6. Mean Sq. for blocks = $\frac{.7242}{12} = .06035 (E_b)$
(adjusted)
7. Intra block error = Total - (Treatment + Block)

$$= 65.6852 - (61.6327 + .7242)$$

$$= 3.3283$$
8. Mean Square for intra block error = $\frac{\text{Sum of Squares intra block error}}{(tr - 2t + 1)}$

$$= \frac{3.3283}{27} = .12327 = (E_e)$$
9. $F = \frac{\text{Mean Square adjusted blocks}}{\text{Mean Square adjusted intra block error}} = \frac{.06035}{.12327} = < 1$
10. $\mu = \frac{E_b - E_e}{t(k-1)E_b} = \frac{0.06035 - 0.12327}{13(3)(0.06035)} = \frac{-0.06292}{2.35365} = -0.0267$
11. Adjusted Treatment Total = $T + \mu W$

$$= 24.3 + (-.36846) = 23.93154$$
12. Adjusted Treatment Mean = $\frac{T + \mu W}{r} = \frac{23.93154}{4} = 5.98$
13. S.S. for adjusted treatment Means = $\frac{\sum (T + \mu W)^2}{r} - C$

$$= \frac{(23.93154)^2 + \text{----} + (20.69662)^2}{4} - C$$

$$= 59.805814$$
14. Mean Square for Adjusted Treatment Mean

$$= \frac{59.805814}{12} = 4.9838178$$
15. Effective Error . Mean Square per unit = $E_e [1 - (t-k)\mu]$

$$= 0.12327 [1 + (13-4)(-0.0267)]$$

$$= 0.12327 [1 - 0.2403]$$

$$= 0.093648$$

TABLE 21 (Contd.)

16. Standard error (S_d) for differences between 2 adjusted

$$\text{means} = \sqrt{\frac{2 (\text{effective error mean square})}{r}}$$

$$S_d = \sqrt{\frac{2(0.093648219)}{4}} = 0.2164$$

17. Least Significant Difference

$$LSD_{05} = t_{05} S_d$$

$$t_{05} (df = 27) = 2.052$$

$$LSD_{05} = \pm 2.052 (0.2164)$$

$$= \pm 0.44$$

$$\text{Skim} - LSD_{05} = 5.54$$

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