THE EFFECT OF VARIOUS MILKS ON THE TIME - TEMPERATURE RELATIONSHIPS IN BAKING CUSTARD, AND ON THE QUALITY OF THE PRODUCT

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THE EFFECT OF VARIOUS MILKS ON THE TIME - TEMPERATURE RELATIONSHIPS IN BAKING CUSTARD, AND ON THE QUALITY OF THE PRODUCT

By

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INTRODUCTION

During the past twenty years, milk has appeared on the market in new forms such as homogenized milk, nonfat dried milk solids, and whole dried milk solids. In the processing of these products, physical and chemical properties of the milk are altered. In turn, these properties may have an affect on the cooking qualities of the milk.

A few investigations (7, 48) have indicated that the rate of heat penetration into baked custards varied with the type of milk used. However, no extensive study has been conducted on this phase of the cooking characteristics of various milks.

The purpose of this investigation was to compare the quality of baked custards using different milks and to study the time - temperature curves for the various custards. Since custards are highly sensitive to slight changes in the mixture, custards were chosen to demonstrate differences in cooking qualities of various milks. This sensitivity of custard to small changes in the egg-sugar-milk mixture has been shown in studies by Logue (45), Carr and Trout (7), and MacDougall (48).

REVIEW OF LITERATURE

Definitions

Pasteurized Milk.

Pasteurized milk is fresh whole milk which has been heated at temperatures no lower than 142° F. with holding at such temperature continuously for not less than thirty minutes, or to a temperature not lower than 160° F. with holding at such temperature continuously for not less than fifteen seconds. The pasteurized milk is then promptly cooled to a temperature of 50° F. or lower (52).

Homogenized Milk.

As defined by the Michigan Allied Dairy Corporation (52),

> Homogenized . . . milk is milk which has been treated in such manner as to insure break-up of the fat globules to such extent that after 48 hours undisturbed storage no visible cream separation occurs on the milk and the fat percentage of the top 100 ml. of milk in a quart bottle, obtained by pouring, or of proportionate volumes in containers of other sizes, does not differ by more than 10 per cent of itself from the fat percentage of the remaining milk as determined after thorough mixing.

Skimmed Milk.

The Michigan Allied Dairy Corporation (52) has defined skimmed milk as follows:

> Skimmed milk is milk from which substantially all of the milk fat has been removed, and has a specific gravity at 60°Fahrenheit from 1.032 to 1.037 inclusive.

Evaporated Milk.

Evaporated milk is the liquid food made by evaporating sweet milk to such point that it contains not less than 7.9 per cent of milk fat and not less than 25.9 per cent of total milk solids. It may contain one or both of the following optional ingredients:

1. Disodium phosphate or sodium citrate or both, or calcium chloride, added in a total quantity of not more than 0.1 per cent by weight of the finished evaporated milk.

2. Vitamin D in such quantity as increases the total vitamin D content to not less than 7.5 U.S.P. units per avoirdupois ounce of finished evaporated milk. (72)

Nonfat Dried Milk Solids.

Nonfat dried milk solids have been defined by the Federal Food, Drug, and Cosmetics Act of 1944 (72) as follows:

> 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 1½ percentum by weight unless otherwise indicated. The term "milk", when used herein, means sweet milk of cows.

Dried Whole Milk Solids.

> Dried whole milk is the product resulting from the removal of water from milk. It contains not less than 26.00 per cent of milk-fat and not more than 5.00 per cent of moisture. (28)

Methods of Processing

Pasteurized Milk.

The first step in the processing of pasteurized milk is the clarifying or filtering of the raw milk in order to remove visible foreign particles that are present. Clarifying is usually preceded by heating to 90° - 95° F. The milk is then pasteurized in order to destroy pathogenic organisms and enzymes and to arrest the multiplication of microorganisms that could render the milk unfit for human consumption. Two pasteurization processes may be employed -- holder or flash. In the holder method, the milk is heated to 142° - 145° F. and is maintained at that temperature for at least thirty minutes. Flash pasteurization employs a temperature of 160° - 162° F. and a holding time of at least fifteen seconds at that temperature (62). One advantage of the flash process is that there is less chance of "cooked flavor" development than if the holder process is used (18). The milk is then cooled immediately to 50° F. or lower and bottled.

Homogenized Milk.

In the processing of homogenized milk, the milk is clarified, preheated, homogenized, pasteurized, cooled, and bottled. The sequence of steps may be varied, depending on the plant facilities and whether or not a whole vat of milk will be homogenized. If only part of the vat of milk is to be homogenized, the milk is pasteurized prior to homogenization. If the milk is homogenized before pasteurization, the milk should be preheated to temperatures of 130° - 135° F. or higher at which temperatures the milk should be homogenized (69). The high preheating temperature is necessary to inactivate the enzyme lipase which would otherwise cause the development of off flavors due to the increased fat globule surfaces produced by homogenization. In the homogenizing process, the fat globules are broken up and reduced in size by forcing the milk under pressure through very small holes. Normally, a pressure of 2,000 - 2,500 pounds per square inch is used (69).

Skimmed Milk.

The production of skimmed milk involves the separation of whole milk into cream and skimmed milk by means of a centrifugal cream separator. The milk is fed into a rapidly spinning bowl and distributes itself onto separating discs that impart a swirling action to the milk. Being heavier, the skimmed milk forms a layer on the outside edge of the bowl while the cream collects on the inside edge of the layer of rotating milk and cream. The incoming unseparated milk forces the separating layers up from the bottom and out at the top of the bowl. According to Farrall (22), the ideal temperature for separating milk is 85° - 100° F. Under efficient operating conditions, the fat content of the skimmed milk varies from 0.06 - 0.10 per cent (62). After separation, the skimmed milk is pasteurized, cooled, and bottled.

__Evaporated Milk.__

Milk to be evaporated is usually standardized to the desired ratio of fat to solids-not-fat prior to clarification. After clarification, the milk is forewarmed usually at temperatures ranging from 200° F. to boiling with an exposure time of ten to twenty-five minutes (36). Following preheating, the milk is condensed to the desired concentration in a vacuum pan. The evaporated milk is then homogenized, cooled, and put into cans. The filled cans are sealed and sterilized for fifteen - seventeen minutes at temperatures ranging from 238° - 245° F. The final step is the cooling of the cans of milk.

__Dried Milk Solids.__

Dried milk powders are manufactured by two principal processes - spray and roller. Since the dried milk powders used in this study were spray dried, the discussion will include only this process. The milk is first preheated and pasteurized. According to Coulter (16), this heat treatment improves the keeping quality of the powder due to the production of sulfhydryl groups that act as antioxidants. Following pasteurization, the milk is partially condensed to 40 per cent solids to increase the drying speed. The partially concentrated milk is then sprayed by means of centrifugal force or pressure into a chamber through which a current of heated air is directed. The milk particles lose moisture in a few seconds and drop to the floor of the drying chamber in the form of a fine powder. The force of gravity or cyclonic motion removes the milk powder from the air. In the production of dried whole milk solids, the whole milk is usually homogenized before drying if the centrifugal spray method is used. In the pressure spray drying, the fat globules are homogenized by their passage through the spray nozzle.

Physical and Chemical Properties of Milk as Affected by Processing

The properties of milk may be affected by processing methods. In turn, these characteristics may modify the cooking qualities of the milk as shown in baked custards by Carr and Trout (7), MacDougall (48), and Hollender and Weckel (34).

<u>Flavor</u>.

Fresh raw milk has a mildly sweet flavor. When the milk is subjected to heat treatment, as in pasteurization, a heated or "cooked" flavor develops (25). Upon more drastic heat treatment, such as in the processing of evaporated milk, a caramelized flavor is developed. According to Trout and co-workers (70), homogenized milk seemed to have a richer flavor than unhomogenized milk.

The development of "cooked" flavor has been attributed to the liberation of sulfhydryl groups during the heating of the milk. Gould (25) reported a close correlation between development of "cooked" flavor and the formation of -SH groups, both occurring simultaneously at 172° F. Josephson and Doan (40) found that cooked flavor developed in milk heated to 155° F. for thirty minutes, 160° F. for fifteen minutes, and 170° F. flash heated. Liberation of sulfhydryl groups occurred at these points. Hutton and Patton (38) studied the source of -SH groups in skimmed milk and found them to be present in the serum proteins. Fractionation of the serum proteins indicated that most of the sulfhydryl groups were in the - lactoglobulin portion. On the other hand, Josephson and Doan (40) attributed a positive nitroprusside test to the albumin portion of the serum proteins.

As shown by several investigators (17, 57, 58, 65), prolonged heat treatment of milk at high temperatures results in a decrease in the quantity of volatile sulphides in milk. At the same time, there is a gradual transition in flavor from cooked to caramelized. This flavor change is accompanied by the development of a brown color. Coulter and co-workers (17) suggested that the reduction in sulfhydryl groups is dependent on a reaction involving casein and lactose.

Color.

The color of milk is dependent upon its pigments and upon suspended particles of such size that they are capable of reflecting light. The white color in milk is due to the permanently dispersed casein while the colors other than white are due to lactochrome (water soluble pigment) and carotene (milk fat pigment) (36). Whole milk has a more white color and no blue tinge as compared to skimmed milk, due to the presence of fat globules which reflect and scatter the light rays and to the presence of carotene (62). As shown by Tracy (66) and Henderson (32), the color of homogenized milk is whiter than unhomogenized milk due to the increased fat globule surfaces.

Upon prolonged heating of milk at high temperatures, a brown color develops in milk. This has been a problem with evaporated milk and dried milk solids. Bell and Webb (3) showed that in the processing of evaporated milk, fore-warming can be continued for a longer time at a low temperature than at a high one without intensifying the color. According to several investigators (31, 54, 56, 60, 75), casein and lactose are the principal reactants in the color production. A brownish color developed as a result of the condensation of the free aldehyde group on the lactose molecule with the amino group of the protein. Kass and Palmer (41) and Wright (77), on the other hand, ascribed

the color development to the caramelization of lactose and the adsorption of the lacto-caramel pigment on the casein.

Butterfat.

The fat content and the nature of the fat globule may be altered by processing methods to which the milk is subjected. According to Sommer (62), the fat content of whole milk is not changed by pasteurization. He also reported that the fat content of skimmed milk, as measured by ether extraction, varied from 0.06 - 0.10 per cent under efficient cream separating conditions. Whole milk solids contain at least 26 per cent fat (1), while nonfat dried milk solids contain only 0.9 per cent butterfat (2).

The process of homogenization changes the nature of the fat globule. Nonhomogenized fat globules vary markedly in size and show a tendency to cluster or bunch together. Homogenized fat globules, however, are quite small, more uniform in size, and comparatively even in distribution (69). Doan and Minster (21) reported that the average diameter of the fat globules in normal milk was four to eight microns, while after homogenization, the diameter was less than two microns. According to Trout and co-workers (70), the surface area of the fat globules is increased five to six times as a result of homogenization. Gould and Trout (27) found no appreciable effect of homogenizing pasteurized milk on such fat constants as the Reichert - Meissl number, the Polenske number or the refractive index. When raw milk was homogenized, however, the acid degree of the fat increased four to six times within a few minutes, due to the greater fat splitting action of the lipase on the increased fat surface.

Lampitt and Bushill (42), studying the fat properties of dried whole milk powders, reported that much more free fat was extracted by organic solvents with roller dried whole milk powders as compared to powder dried by the spray process. On pressing fresh spray powder between layers of paper, no fat soaked into the paper, while the fat of the roller powder soaked into the paper very readily. The difference in extractibility of fat was believed to have been caused by the stabilization of the fat emulsion by the spray process or destabilization by the roller process. The pressure spray process provided for considerable homogenization of the fat and the increased adsorption of protein at the fat globule surface tended to prevent extraction of the fat. In the roller process, the contact of milk with the hot drum and the pressure of the knives might be expected to disrupt the naturally occurring membrane that stabilizes the fat emulsion.

Maxcy and Sommer (51) found that rising of fat occurred in evaporated milk on prolonged storage. They indicated that it was due to the density of the fat particles being lower than that of the concentrated plasma in which they were suspended.

Protein.

Homogenization affects the proteins of milk in some manner, lowering their stability towards various reagents and temperatures. The exact mechanism of the homogenization effect is not fully known. Doan (19) and Doan and Minster (21) found that the proteins of milk were destabilized by homogenization when fat was present. The proteins of skimmed milk were not affected by homogenization. The investigators indicated the calcium ion concentration present might be a prime factor. The lowering of the curd tension of milk by homogenization as shown by Tracy (67), Maack and Tracy (47), and Caulfield and Martin (8), has been attributed to the adsorption of protein on the increased fat surface by Wolman (76).

Brunner and co-workers (4, 5, 6) studied the effect of homogenization on the fat globule membrane. The immediate surface of the fat globule is surrounded by a covering of absorbed substances, consisting of a phospholipid-protein complex. The outer layer is composed of milk plasma, chiefly casein. As shown by amino acid composition, sedimentation diagrams and electrophoretic patterns, the character of the fat globule membrane proteins was changed by homogenization.

Spray dried milk powders are 99 per cent soluble and retain many of the properties of fluid milk (36). Howatt and Wright (35) found that maximum protein solubility in water occurred at 50° C. Exposure to high temperatures during pre-condensing or drying, such as used in the roller process, results in a partial coagulation of the protein and lessens the solubility of the dried milk powder. (17, 43).

Lactose.

Lactose is present in spray dried milk powders in a non-crystalline form as a very concentrated solution or glass (71). Dried milks assume some of the properties of lactose (36). Choi and co-workers (13) found that lactose was nonhydroscopic in fresh dried milk solids of low moisture content. As the moisture content of the powder increased, the lactose changed to crystalline α- lactose hydrate. The critical moisture level for spray dried nonfat dried milk solids was 7.5 - 8.0 per cent, very little lactose crystallization taking place below these levels. Spray dried whole milk solids with a lower lactose content, had a lower critical moisture level (6.5 - 7.0 per cent), indicating that the critical moisture level may depend on the amorphous lactose content of the powder. At these moisture levels, the powders became less soluble and developed browning, caking, and undesirable odors and flavors (59).

Heat Coagulation of Proteins

The formation of a gel in custards depends on the coagulation of protein which holds within its meshes the solution from which it was precipitated (55). Since only about 0.75 per cent of milk is heat coagulable, eggs supply the larger percentage of heat coagulable protein in custard (46).

In milk, the chief nitrogenous constituents involved in heat coagulation are lactalbumin and casein. The albumin is present to the extent of 15 per cent of the milk proteins and is partially coagulated by heat in normal milk. In evaporated milk, the stabilizing effect of preheating at relatively high temperatures is due largely to the precipitation of the albumin (36). Essentially, coagulation of milk is closely connected with the coagulation of casein since casein is the major protein of milk. It represents about 80 per cent of the total nitrogenous substances in milk and is present in fresh milk as a calcium salt. Coagulation of casein does not occur at ordinary temperatures. It coagulates in approximately twelve hours at 100° C., about one hour at 135° C. and approximately three minutes at 150° C. (46).

The main factor controlling the heat stability of milk is the salt concentration of the milk (18, 63, 64). According to Sommer and Hart (63, 64), the action of calcium and magnesium opposes that of citrate and phosphate. Excess or deficiency of any one of these lowers the heat stability of the casein. Of these ions, calcium is of primary importance. In the processing of milk, heating the milk to high temperatures or lengthening the preheating period precipitates a portion of the soluble casein salts, thereby removing an excess of calcium and rendering the casein more stable (63). In the processing of evaporated milk, heat coagulation difficulties may occur due to the absence of the proper balance of salts but may be guarded against by addition of salts for the correction of the salt balance prior to condensing. Homogenization of milk renders the protein less heat stable, probably by the withdrawal of the salts by adsorption on the increased surface area of the fat (20, 62).

Protein coagulation by heat takes place in three steps, according to Gortner (24). The first step is denaturation in which there is an intra-molecular rearrangement whereby certain groups such as sulfhydryl and disulfide not detectable in the native protein become so in the denatured. Probably the cooked flavor in heated milk becomes evident at this point. The second step is the flocculation of the denatured protein and the third step is the coagulation which results in the formation of an insoluble gel. Chick and Martin (9) thought that coagulation occurred in two stages, the denaturation preceding the coagulation.

Heat coagulation of milk and custards may be influenced by acid, alkali, salt, temperature and time relationships, protein concentration, and sugar.

Effect of Temperature and Time.

Chick and Martin (9) indicate that the heat coagulation of protein solutions is a reaction between protein and water. Heat accelerates the reaction and the rate of coagulation increases with a rise in temperature. The relation of time to temperature has an effect on protein coagulation. Custards coagulate at a lower temperature with a slow rate of heating. With a faster heating rate, the coagulation temperature is raised (46). Harland and co-workers (30) indicate that high-temperature -- short-time pasteurization of milk causes less heat denaturation of the milk serum proteins than the holder method.

Effect of Salt.

The general role of salts in the heat coagulation of milk has previously been discussed. Lowe (46) reports that the concentration of the salt and the valence of the ion have an effect on the coagulation of custards. In general, the coagulation power of the ion increases with increasing valence.

Effect of Acid.

Milk is very sensitive to pH changes in two ranges, pH 6.4 - 6.2 and 5.4 - 5.2. Chick and Martin (10) state that the addition of an acid solution hastens the clotting, the second part of the heat coagulation process. However, denaturation, the first part of the process, is not accelerated. The influence of acid in speeding the coagulation rate is at first rather small, but with increasing amounts of acid, its influence becomes disproportionately greater. Hunzicker (36) found that the heat stability of milk was lowered by an increase in acid content.

Effect of Alkali.

Chick and Martin (11) found that in alkaline solution, denaturation of egg protein increased with increasing concentration of hydroxyl ions. The second part of the coagulation process, the clotting of the protein, did not occur. If the alkali was neutralized with acid after heating, coagulation occurred.

Effect of Protein Concentration.

The protein concentration affects the coagulation temperature, the temperature being lowered as the protein concentration increases (18, 46). Morse and co-workers (53) found that the gel strength of custards increased with an increased protein concentration.

Effect of Sugar.

The addition of sugar to egg proteins elevates the coagulation temperature, due to the peptization of the protein by the sugar. According to Lowe (46), the effect is proportional to the amount added.

Endothermic Nature of Heat Coagulation.

Leighton and Mudge (44) have shown that the process of heat coagulation is an endothermic reaction. When skimmed milk was heated, a marked heat absorption coincided with the appearance of visible curds. This was accompanied by the precipitation of calcium and magnesium as phosphate and citrate. At this point, the thermometer reading remained constant or showed a slight drop. When fat was present, the rate of heat absorption was constant but slower.

Baked Custards as a Medium of Testing Various Milks

Because custards are highly sensitive to slight changes in the egg-sugar-milk mixture, custards were chosen to demonstrate differences in cooking qualities of various milks. This sensitivity was shown in a study on the cooking quality of four grades of eggs by Logue (45) and in studies by Carr and Trout (7) and MacDougall (48) on the cooking properties of various milks and nonfat dried milk solids.

There is no one internal temperature to which custards should be baked. The temperature at which gelation starts varies with different proportions of ingredients, rate of cooking, and egg quality. With a slow rate of heating, the custard has a serving consistency at 82° - 84° C. (46). Under normal baking conditions, curdling usually occurs between 85° and 87° C. If rapidly cooked, the custards may be too thin to serve at 87° - 89° C. and may curdle before a desirable consistency is attained.

It appears that one of the factors influencing the rate of heat penetration into custards is the type of milk used. Cook and Husseman (15) observed that the temperature required to reach gels of similar consistency was 1° C. higher when whole or nonfat dried milk solids were used instead of whole milk or evaporated milk. Carr and Trout (7) found that the total baking time in custards made with homogenized milk was longer by fifteen to twenty minutes than in those made with unhomogenized milk. Custards made with homogenized milk could withstand higher baking temperatures without seriously affecting the gel stability. Hollender and Weckel (34), however, found that homogenized milk custards baked in a shorter time than unhomogenized milk custards and had a more critical cooking temperature. MacDougall (48) observed that heat penetration varied with different types of nonfat dried milk solids.

Carr and Trout (7) found that unhomogenized milk custards seemed to have a sweeter flavor than homogenized milk custards. Since the unhomogenized milk custards showed a greater amount of syneresis, they suggested that the sugars are concentrated in the liquid phase and therefore unhomogenized milk custards seem sweeter in taste. Cook and Husseman (15) noted that evaporated milk custards had a distinctive flavor and that flavor scores were lower than when whole milk or dried milk solids were used. Possibly the distinctive flavor of evaporated milk custards could be attributed to a caramelized taste which is developed as a result of the high processing temperatures to which evaporated milk is subjected.

The color and consistency of the custard crust is affected by the milk used. Carr and Trout (7) found that custards made with unhomogenized milk had a tender crust which browned easily. Custards made with nonfat dried milk solids or homogenized milk had tough crusts which browned very little except at the edges (7, 48, 53). Crusts of nonfat dried milk custards showed wrinkling and cracking (48). Carr and Trout (7) thought that the difference in browning and tenderness was due to the butterfat which collected at the top of the unhomogenized milk custards.

Since protein stability is decreased by homogenization, it would seem that the protein would be more easily coagulated by heat and that therefore custards made with homogenized milk would have a firmer gel than those made with unhomogenized milk baked to the same internal temperature. Carr and Trout (7) reported that homogenized milk custards had a firmer and more stable gel than those made with unhomogenized milk. Opposite results were found by Hollender and Weckel (34). Serum separation was greater with homogenized milk and increased with a longer cooking time. Firmness of the gel as measured by the curd tension meter was less with homogenized milk than with unhomogenized milk. Custards fortified with dried milk solids had a firmer gel (15, 48, 53). As the concentration of dried milk solids was increased, the gel structure became firmer. There was also less tendency for serum separation (48).

Subjective and Objective Measurements of Baked Custards

Subjective Measurements.

Although the limitations of a taste panel for judging the palatability or eating quality of food are realized by investigators, there are still organoleptic factors which cannot be expressed by objective measurements. Factors such as appearance, color, and flavor are better judged by a scoring panel. Results of objective tests are often correlated with those obtained by subjective means.

Objective Measurements.

Several tests have been developed for measuring some of the physical characteristics of baked custards. The principal measurements include the gel strength, syneresis, and the rate of heat penetration during baking.

Syneresis: There is a tendency for gels, upon standing for several hours, to separate into two phases, solid and liquid. This separation has been termed syneresis or weeping. Various means of measuring syneresis have been used by investigators. MacDougall (48) used a fine wire screen through which the liquid drained while others employed the use of adsorbent paper. The liquid was weighed and used as a measure of the syneresis.

Gel Strength: A number of methods can be used to measure the gel strength of baked custard. Three tests were used in this study: penetrometer, standing index, and curd tension meter.

Penetrometer: The penetrometer* has been used to determine the consistency of foods by measuring their penetrability. The instrument measures the depth of penetration or depression caused by a force released for a certain length of time. Depending upon the type of material tested, a penetrometer needle, disc, or cone may be used. Logue (45) used a special cone and rod attachment to measure the depth of penetration into baked custards. MacDougall (48) found a significant positive correlation between judges' scores

* New York Testing Laboratory Penetrometer

for crust toughness and penetrometer readings on the crust of baked custards. However, there was no significant correlation between firmness scores of the judges and firmness of the gel on the inverted custards or on the top of the custards with the crust removed.

Standing Index: The standing index measures the ability of the custard to hold its shape while standing. It is the ratio of the height of the custard to the average diameter. Upon standing, the gel structure weakens and the custard spreads. The standing index value decreases as a result of the increasing width and decreasing height. Carr and Trout (7) measured the standing index value of baked custards over a three hour period while MacDougall (48) used a five hour testing period.

Curd Tension Meter: Hill (33) first used the curd tension meter to measure the firmness of the curd from cows' milk. A modification of this instrument was used by several investigators (7, 34, 48) to measure the difference in gel strength in custards made with various milks. MacDougall (48) indicated that the curd tension meter was a better measure of the gel strength of custards than the penetrometer, as shown by highly significant correlations between judges' scores for firmness and the results obtained with the curd tension meter.

PROCEDURE

Design of Experiment

Baked custards prepared from various milks were compared subjectively and objectively. The milks used included pasteurized milk, homogenized milk, skimmed milk, evaporated milk, intermediate spray dried nonfat dried milk solids, and spray dried whole milk solids. Two series were conducted on the baked custards, each series being scored separately. In Series I, each lot of custard was baked to the optimum internal temperature for the particular type of milk as determined by preliminary trials. The custards in Series II were all baked to the same internal temperature (86° C.).

The statistical pattern used in this experiment was the balanced incomplete block, only a part of the total number of variations being judged at each test period. The distribution of samples was randomized throughout the days.

Pasteurized milk was used as the control. Three treatments were prepared each day. Five replications of each variation were baked for each series. Seventeen custards of each variation were baked at one time. Four custards were used for the subjective tests, twelve for the objective tests, and one for the time temperature readings.

Ingredients

The fresh milks were obtained from the College Creamery the day before the test period. The remaining ingredients were secured from the College Stores at the beginning of the study. The dried milk powders were stored in tightly closed polyethylene bags under refrigeration. The evaporated milk was stored in the original containers at room temperature.

Formula

Lowe (46) was the source for the basic custard formula used.

Milk	-	6 cups	-	1464 grams
Sugar	-	3/4 cup	-	150 grams
Eggs	-	6	-	288 grams
Salt				0.75 grams

The dried whole milk solids were substituted for pasteurized milk in the formula on the basis of whole fluid milk containing 13 per cent solids and 87 per cent water. Evaporated milk was reconstituted using 50 per cent water and 50 per cent evaporated milk. The nonfat dried milk solids were reconstituted on the basis of skimmed milk containing 9½ per cent solids and 90½ per cent water. The proportion of solids to water used was as follows:

732 grams evaporated milk + 732 grams water = 1464 grams fluid whole milk.

140.25 grams nonfat dried milk solids + 1323.75 grams water = 1464 grams fluid skimmed milk.

205.55 grams dried whole milk solids + 1258.45 grams water = 1464 grams fluid whole milk.

Preliminary Preparation

For one lot of custard, 288 grams of fresh egg, 75 grams of sugar, and 0.75 grams of salt were mixed together. The remainder of the sugar (75 grams) was added to the milk the day before the custards were prepared. Enough egg mixture for seven lots of custard - 2016 grams of egg, 525 grams of sugar, and 5.25 grams of salt - were mixed with an electric mixer* at No. 1 speed for eight minutes. The mixture was then strained into a container and the procedure was repeated until enough egg-sugar-salt mixture for the entire series had been obtained. After thorough blending, the mixture was weighed into 363.75 gram portions and placed in pint freezing containers. The containers were sealed, marked, and placed in a freezer held at 0^{o} F.

Preparation of Custard Mix

Three cartons of the egg-sugar-salt mixture were removed from the freezer and were thawed in the refrigerator for seventeen hours.

* Kitchen Aid Model K5-A

The day before the test period, each milk was combined with half the total sugar in the following manner. All ingredients were weighed on a torsion balance. The fluid milks - pasteurized, homogenized, skimmed, or reconstituted evaporated - were blended with the sugar, stirring with a metal tablespoon until the sugar was dissolved. The dried milk solids and sugar were mixed with a metal tablespoon using twenty strokes. The necessary amount of water was heated to 50° C. and transferred to a large size bowl of an electric mixer*. The mixer was operated at No. 2 speed and the dried milk solids were sprinkled into the water in four portions, each portion being beaten with the water forty-five seconds before the next portion was added. After the last addition of solids, the mixture was beaten at No. 2 speed for 1-3/4 minutes and than an additional 1/2 minute at No. 5 speed. The milks were then placed in enamel bowls, covered and placed in the refrigerator over night.

The day of the testing, the egg mixture and milk were combined in the electric mixer and blended for 1/2 minute at No. 2 speed. Any froth formed was removed.

Custard Cups

Five ounce custard cups were filled with the custard mix to within 1/2 inch of the top, as measured with a depth

* Kitchen Aid Model K5-A

gauge. The custard cups contained 98.3 $\pm$ 3.3 grams of mix. The cups were placed in a baking pan in a randomized order as to the subjective and objective tests for which they would be used.

Baking

The custards were placed in a baking pan and water at 35° C. was added to the pan until it came up to the level of the custard mix. The pan was put on the lowest rack of the oven regulated at 325° F. A thermometer, suspended from the top rack of the oven, was placed in the center of a custard designated in the plan. Another thermometer was placed in the water bath. The tips of the thermometer bulbs were 1/2 inch from the bottom of the pan.

In series I, each type of custard was baked to its optimum internal temperature as had been determined in preliminary trials. Custards made with pasteurized milk, spray dried whole milk solids, and evaporated milk were baked to an internal temperature of 86° C. Those made with skimmed milk, homogenized milk, and nonfat dried milk solids were baked to an internal temperature of 88° C. The higher internal temperature for homogenized milk is in accord with Carr and Trout (7) who reported homogenized milk custards could withstand higher baking temperatures than unhomogenized milk custards, but is not in accord with Hollender and Weckel (34) who found the opposite results. For Series II, custards made with all the types of milk were baked to an internal temperature of 86° C.

The custards were removed from the water bath when the desired internal temperature was reached, and were cooled at room temperature on wire racks for 1½ to 2 hours.

Subjective Tests

A panel of four judges from the Foods and Nutrition Department scored the baked custards for appearance, crust, color inside, flavor, smoothness, firmness, sweetness, and general acceptability. The judges were asked to record comments concerning any unusual characteristics noted. A sample of the score sheet is shown on page 111 in the appendix. The highest possible score was seven and the lowest one, for each factor.

Objective Tests

Recordings of the room temperature and relative humidity were made at the beginning and end of each test period.

Time - Temperature Recordings.

Temperature readings of the custards were taken just before the custards were placed in the oven, ten minutes after placement in the oven and every five minutes thereafter until the desired internal temperatures of the custards were reached. The time - temperature curves for the five replications of each treatment were averaged and plotted.

pH Readings.

The pH of the fluid mixture before baking was recorded. The pH of the baked custard was determined by mixing thoroughly two grams of custard with ten milliliters of distilled water. The pH was measured by using a Beckman pH meter.

Syneresis.

The crust was removed from the custard with a knife. The custard was inverted on a fine screen under which a weighed petri dish was placed. The weight of the petri dish was recorded every hour for three hours. The amount of syneresis each hour was measured by taking the difference in weight. Two replications of each type of custard were used. To prevent evaporation, the custards were covered between readings.

Standing Index.

After removing the crust, the custard was removed from the cup and inverted on a flat square glass plate. The plate was placed on a paper on which concentric circles had been drawn.* The height of the custard in inches was measured with a depth gauge. The spread of the custard was taken in quadrant readings. These measurements were recorded at the beginning of the test period and every hour for three hours.

* As used by Grawemeyer and Pfund (29).

The standing index was calculated as the ratio of the height of the custard to the average diameter. The standing index figures reported are the average of two samples for each variable. The samples were covered between readings to prevent evaporation.

Penetrometer.

A penetrometer* was used to measure the compressibility of the custard. The custard in the cup was compressed for two seconds by a flat disc carrying a total weight of seventy-five grams. Measurements were made in millimeters. The compressibility of the crust and the compressibility of the top of the custard with the crust removed were recorded for each type of custard. Duplicate readings were made for each measurement.

Curd Tension Meter.

The curd tension meter was used to measure the firmness of the custard. This instrument has been described by Carr and Trout (7). The cutter was brought into contact with the custard. The amount of displacement of the float was a measure of the curd strength of the custard. Measurements were recorded in grams. Two types of readings were made on the custards, one on the top of the custard with the crust removed and the other on the inverted custard. Duplicate readings for each measurement were used.

* New York Testing Laboratory Penetrometer

Statistical Methods

Since all treatments could not be baked at the same time, the balanced incomplete block given by Cochran and Cox (14) was employed. The design allows for adjustment of the data in the analysis of variance, since all the treatments were not prepared on the same day. The corrected mean values are indicated as average mean scores.

The least significant difference was calculated, using the corrected pasteurized milk scores as a standard. Calculation of the least significant difference determines a range around the standard. Any score falling outside this range is considered to be significantly different.

Correlation coefficients were calculated according to the methods of Snedecor (61). Calculations were made on the following pairs of items for each series: crust score versus penetrometer reading (crust on), firmness score versus penetrometer reading (crust off), firmness score versus curd tension reading (crust off), penetrometer reading (crust off) versus curd tension reading (crust off).

DISCUSSION OF RESULTS

The quality of baked custards was evaluated by a judging panel and by objective tests. For simplification purposes, nonfat DMS and whole DMS will be used to designate custards prepared from nonfat dried milk solids and whole dried milk solids, respectively. The results of each subjective and objective test will be discussed as follows: the results of Series I will be given, followed by the results of Series II, and finally, a comparison between the two series. In Series I, pasteurized milk, whole dried milk solids, and evaporated milk custards were baked to an internal temperature of 86° C. Homogenized milk, skimmed milk, and nonfat dried milk solids custards were baked to 88° C. internal temperature. In Series II, all the custards were baked to an internal temperature of 86° C.

Palatability Scores

Accompanying the discussion of each factor judged is a table containing the average adjusted scores and analysis of variance for that characteristic. The average judging scores for each replication are shown on page 103 of the appendix.

The least significant difference added to and/or subtracted from the scores of pasteurized milk custard (control), is designated as pasteurized ± LSD. When the scores were lower than that of the standard (pasteurized milk), only the negative half of the LSD was calculated. When the scores were higher and lower than that of the control, both positive and negative halves of the LSD were computed. Any score falling outside of this range was considered significantly different from the control.

Appearance.

The adjusted average scores and analysis of variance for Series I are shown in Table 1. The chief source of variation among the scores as shown by the analysis of variance was the kinds of milk used. Variation due to replications was not statistically significant.

Custards made from pasteurized milk had the highest scores for appearance. Custards made from all other types of milk were highly significantly different from the control. It was noted that except for the control, the crusts of the custards showed varying amounts of cracking and wrinkling and were shiny in appearance. Homogenized milk and whole DMS custards were most like the control in appearance. They were slightly shiny and showed some evidence of wrinkling, the whole DMS slightly more than homogenized milk. Custards made with nonfat DMS and skimmed milk had equal scores and were quite cracked and wrinkled in appearance. The crusts were quite shiny. Evaporated milk custard

Table 1

ADJUSTED[1] AVERAGE SCORES AND ANALYSIS OF VARIANCE FOR APPEARANCE - SERIES I

Type of Milk	Adjusted Average Score
Pasteurized	6.7
Homogenized	6.1
Skimmed	4.6
Nonfat DMS	4.6
Evaporated	4.2
Whole DMS	5.8
Pasteurized - LSD_{01}	6.3
Pasteurized - LSD_{05}	6.4

ANALYSIS OF VARIANCE

Source	Degrees of Freedom	Mean Square	F
Total	29	--	--
Adjusted treatment	5	5.0272	95.39 **
Error for adjusted treatment	15	0.0527	--
Adjusted blocks	9	0.0742	1.52
Intra block error	15	0.0488	--

** Significant at 1 per cent level.

1. Adjusted according to method given by Cochran and Cox (14).

received the lowest appearance score, probably due to the extremely glossy crust, orange color, and wrinkled appearance.

Evidently, the presence of butterfat aids the appearance of the custard. When the fat collected at the top of the custard, as with pasteurized milk, the crust was smooth and even. Homogenization of the fat, as in homogenized milk and whole DMS, produced custards with slight degrees of wrinkling. An exception was evaporated milk custard. One of the factors in the low score might have been the orange color. When no fat was present, as in skimmed milk and nonfat DMS, the custard surface was quite cracked.

The adjusted average scores and analysis of variance (Table 2) indicate that the main source of variance among custards in Series II was the type of milk. Pasteurized milk had the highest score for appearance and the other treatments were highly significantly lower than the control. Whole DMS had the next highest score and then homogenized milk. The score for skimmed milk was slightly higher than nonfat DMS. Evaporated milk had the poorest appearance.

The appearance scores for the treatments in Series II followed the same order of rank as in Series I. Evidently, the lower internal temperature of skimmed milk and nonfat DMS in Series II improved the appearance as compared with the higher internal temperatures to which they were baked

Table 2

ADJUSTED AVERAGE SCORES AND ANALYSIS OF VARIANCE FOR APPEARANCE - SERIES II

Type of Milk	Adjusted Average Score
Pasteurized	6.8
Homogenized	5.5
Skimmed	5.1
Nonfat DMS	4.8
Evaporated	3.9
Whole DMS	5.8
Pasteurized - LSD_{01}	6.4
Pasteurized - LSD_{05}	6.5

ANALYSIS OF VARIANCE

Source	Degrees of Freedom	Mean Square	F
Total	29	--	--
Adjusted treatment	5	4.7884	33.98 **
Error for adjusted treatment	15	0.1409	--
Adjusted blocks	9	0.1900	4.31 **
Intra block error	15	0.0441	--

** Significant at 1 per cent level.

in Series I. Slightly less cracking was noted in the crusts when the custards were baked to a lower internal temperature. A lower internal temperature did not improve the appearance of homogenized milk custards.

Crust.

The crusts were scored only for tenderness or toughness. Variation in crust scores in Series I can be attributed to the different milks used as shown in Table 3.

Pasteurized milk gave the most tender crust. The crust scores for all other types of milk were highly significantly lower than that of the control. Evaporated milk had the highest crust score of all the other milks. The crust score of whole DMS was slightly lower than that of evaporated milk. Homogenized milk and skimmed milk had equal crust scores. The judges considered the crust of the custard made with nonfat DMS to be the most tough.

The tenderness of the crust made with pasteurized milk can be attributed to the butterfat which collected at the top of the custard mix. This has been suggested by Carr and Trout (7) and MacDougall (48) who found that when butter was added to homogenized or nonfat DMS custard mixes, softer crusts were formed. Possibly the slightly higher crust scores for the homogenized milk over the nonfat milks might be due to the presence of fat which helped to tenderize the crust.

Table 3

ADJUSTED AVERAGE SCORES AND ANALYSIS OF VARIANCE
FOR CRUST - SERIES I

Type of Milk	Adjusted Average Score
Pasteurized	6.8
Homogenized	4.5
Skimmed	4.5
Nonfat DMS	3.6
Evaporated	4.9
Whole DMS	4.8
Pasteurized - LSD_{01}	6.0
Pasteurized - LSD_{05}	6.2

ANALYSIS OF VARIANCE

Source	Degrees of Freedom	Mean Square	F
Total	29	--	--
Adjusted treatment	5	5.3519	26.29 **
Error for adjusted treatment	15	0.2036	--
Adjusted blocks	9	0.3017	1.61
Intra block error	15	0.1870	--

** Significant at 1 per cent level.

The adjusted average crust scores and analysis of variance for Series II are shown in Table 4. As indicated by the analysis of variance, the chief source of variation was the type of milk used. Custards made with pasteurized milk had the most tender crust, as indicated by the judges' scores. All other crust scores were highly significantly lower than that of the control. Custards made with nonfat DMS and evaporated milk received slightly higher crust scores than the other types of milk. Custard made with homogenized milk had the next highest score while that of whole DMS was slightly lower. Skimmed milk had the lowest crust score.

Apparently, the lower internal temperature (86° C.) and shorter baking time of the custards made with homogenized milk and nonfat DMS in Series II, as compared to the results of Series I, had a tenderizing effect upon the crust. The judges did not consider the skimmed milk crust in Series II to be more tender than that of Series I, although results of the penetrometer reading indicated that the crust made with skimmed milk was more tender in Series II than in Series I.

<u>Color Inside</u>.

As indicated in Table 5, the chief source of variation in color was the type of milk in Series I. Variation due to replication was significant at the [illegible] per cent level. This

Table 7

ADJUSTED AVERAGE SCORES AND ANALYSIS OF VARIANCE FOR FLAVOR - SERIES I

Type of Milk	Adjusted Average Score
Pasteurized	6.2
Homogenized	6.0
Skimmed	6.1
Nonfat DMS	5.3
Evaporated	4.2
Whole DMS	4.9
Pasteurized - LSD_{01}	5.2
Pasteurized - LSD_{05}	5.5

ANALYSIS OF VARIANCE

Source	Degrees of Freedom	Mean Square	F
Total	29	--	--
Adjusted treatment	5	3.2318	10.75 **
Error for adjusted treatment	15	0.3007	--
Adjusted blocks	9	0.2564	<1
Intra block error	15	0.3173	--

** Significant at 1 per cent level.

The results of the analysis of variance for flavor scores in Series II are shown in Table 8. The chief source of variation among custards seemed to be the type of milk used.

Homogenized milk had the highest flavor score. Pasteurized milk and nonfat DMS had equal scores, which were slightly lower than that of homogenized milk. Skimmed milk had a slightly less desirable flavor. Flavor scores for evaporated milk and whole DMS were highly significantly different from the control, evaporated milk receiving the lowest score.

The higher flavor scores for homogenized milk and nonfat DMS in Series II as compared to the scores in Series I might be attributed to the lower internal temperature and to the shorter baking time to which they were subjected. However, this was not true with skimmed milk and no explanation can be given for the lower flavor scores in Series II.

Possibly the lower score for whole DMS in Series II might be due to the greater length of storage which could have produced deterioration in flavor. Due to its high fat content, whole DMS has relatively poor keeping quality as compared to nonfat DMS. Oxidation of the fat during storage results in the development of a tallowy flavor. The fat oxidation can be controlled only by eliminating atmospheric oxygen from the system. This can be accomplished by gas packing of the powder and by use of high preheating temperatures

Table 6

ADJUSTED AVERAGE SCORES AND ANALYSIS OF VARIANCE
FOR COLOR INSIDE - SERIES II

Type of Milk	Adjusted Average Score
Pasteurized	6.4
Homogenized	6.4
Skimmed	6.3
Nonfat DMS	6.4
Evaporated	3.8
Whole DMS	6.5
Pasteurized - LSD_{01}	6.1
Pasteurized - LSD_{05}	6.2

ANALYSIS OF VARIANCE

Source	Degrees of Freedom	Mean Square	F
Total	29	--	--
Adjusted treatment	5	5.5177	253.10 **
Error for adjusted treatment	15	0.0218	--
Adjusted blocks	9	0.0719	3.89 **
Intra block error	15	0.0185	--

** Significant at 1 per cent level.

that produce sulfhydryl groups that act as antioxidants (16, 49, 50). Possibly the lower score for whole DMS could be due to the greater length of storage and exposure to air which could have produced deterioration in flavor, since Series II was judged after Series I. Each judging period extended over five weeks. At the end of the experimental period, the whole DMS had been in storage for ten weeks.

Firmness.

The average adjusted scores and analysis of variance (Table 9) indicate that the main source of variation in firmness was the type of milk in Series I.

Pasteurized milk custard had the most acceptable firmness score. Homogenized milk and skimmed milk custards had firmness scores which were within the limit of the 5 per cent LSD. The average score for firmness of the whole DMS custard was significantly lower than the control. The firmness scores of the other custards were highly significantly different from the control.

The firmness scores indicated only the degree of acceptability. The judges noted the degree of firmness in an accompanying table on the score sheet. The custards made with nonfat DMS were the most firm, followed by skimmed milk and homogenized milk custards. Pasteurized milk custard was

Table 9

ADJUSTED AVERAGE SCORES AND ANALYSIS OF VARIANCE FOR FIRMNESS - SERIES I

Type of Milk	Adjusted Average Score
Pasteurized	6.5
Homogenized	6.1
Skimmed	6.2
Nonfat DMS	5.2
Evaporated	5.2
Whole DMS	5.6
Pasteurized - LSD_{01}	5.5
Pasteurized - LSD_{05}	5.8

ANALYSIS OF VARIANCE

Source	Degrees of Freedom	Mean Square	F
Total	29	--	--
Adjusted treatment	5	1.5537	5.81 **
Error for adjusted treatment	15	0.2674	--
Adjusted blocks	9	0.1402	<1
Intra block error	15	0.4556	--

** Significant at 1 per cent level.

intermediate in firmness. Custards made with evaporated milk and whole DMS were soft in the center and firm on the bottom. Syneresis was evident in the evaporated milk custards.

The analysis of variance and adjusted average scores for firmness of custards in Series II are shown in Table 10. As indicated by the analysis of variance, variation in firmness of the custards was attributed to the kinds of milk. Variation due to replication was not significant.

The custards made with pasteurized milk had the highest firmness scores. The firmness score of the whole DMS lay just at the 1 per cent LSD limit. All other firmness scores were highly significantly different from the standard.

When the custards were all baked to the same internal temperature (86° C.) in Series II, all the milks gave less firm custards than pasteurized milk and had varying degrees of softness in the center. The difference in firmness when the custards were baked to the same internal temperature might be due to the casein-salt balance which was altered during processing of the milk. Evaporated milk as a result of processing has a lowered heat stability (36), and this is borne out by the fact that the evaporated milk custards showed evidence of syneresis at 86° C., indicating that the bottom of the custard had coagulated at a faster rate. Custards made with homogenized milk, skimmed milk,

Table 10

ADJUSTED AVERAGE SCORES AND ANALYSIS OF VARIANCE
FOR FIRMNESS - SERIES II

Type of Milk	Adjusted Average Score
Pasteurized	6.4
Homogenized	4.8
Skimmed	4.7
Nonfat DMS	5.0
Evaporated	4.8
Whole DMS	5.3
Pasteurized - LSD_{01}	5.3
Pasteurized - LSD_{05}	5.6

ANALYSIS OF VARIANCE

Source	Degrees of Freedom	Mean Square	F
Total	29	--	--
Adjusted treatment	5	2.1943	6.75 **
Error for adjusted treatment	15	0.3252	--
Adjusted blocks	9	0.3284	1.01
Intra block error	15	0.3243	--

** Significant at 1 per cent level.

and nonfat DMS were firmer in Series I than in Series II, possibly due to the higher internal temperature and longer baking time used in Series I.

The results with homogenized milk in both series are at variance with the literature and no satisfactory explanation can be given by the investigator. Homogenized milk as shown by Doan and Minster (21) has a lessened protein stability. Therefore, it would seem that homogenized milk custards would coagulate more readily than unhomogenized milk custards and be more firm when baked to the same internal temperature. Homogenized milk custards baked to the same internal temperature as pasteurized milk custards were less firm, which was opposite to the results obtained by Carr and Trout (7). Also, a more desirable firmness was obtained at a higher internal temperature which was in accord with Carr and Trout (7) who reported homogenized milk custards could withstand higher baking temperatures, but not with Hollender and Weckel (34), who found that homogenized milk custards had more critical cooking temperatures than unhomogenized milk custards.

Smoothness.

In Series I, the type of milk accounted for the greatest amount of variation in smoothness between custards as shown by the adjusted average scores and analysis of variance in Table 11. Variation due to type of milk was significant at the 5 per cent level. There was no significant variation due to replication.

The highest scores for smoothness occurred with custards made with pasteurized milk. The custards made with homogenized and skimmed milks scored second best. Nonfat and whole DMS custards received equal smoothness scores that were just at the limit of the 5 per cent LSD. The smoothness of the evaporated milk custards was highly significantly different from that of the control.

The results of the analysis of variance and adjusted average scores (Table 12) for Series II indicate that the main source of variation was the type of milk used. Variation due to replication was not significant.

As indicated by the scores, custards made with pasteurized milk were the smoothest. Custards made with homogenized milk had a score just at the 5 per cent LSD limit. Skimmed milk and nonfat DMS custards had equal scores that were significantly different from the control. The analysis indicated that the adjusted average scores for the other milks were highly significantly different from the control.

The results of Series I would seem to indicate that increased heat treatment during processing such as with dried milk solids and evaporated milk produced slightly less

Table 11

ADJUSTED AVERAGE SCORES AND ANALYSIS OF VARIANCE FOR SMOOTHNESS SCORES - SERIES I

Type of Milk	Adjusted Average Score
Pasteurized	6.4
Homogenized	6.1
Skimmed	6.1
Nonfat DMS	6.0
Evaporated	5.6
Whole DMS	6.0
Pasteurized - LSD_{01}	5.8
Pasteurized - LSD_{05}	6.0

ANALYSIS OF VARIANCE

Source	Degrees of Freedom	Mean Square	F
Total	29	--	--
Adjusted treatment	5	0.3339	2.96 *
Error for adjusted treatment	15	0.1129	--
Adjusted blocks	9	0.1887	1.69
Intra block error	15	0.1118	

* Significant at 5 per cent level.

Table 12

ADJUSTED AVERAGE SCORES AND ANALYSIS OF VARIANCE
FOR SMOOTHNESS SCORES - SERIES II

Type of Milk	Adjusted Average Score
Pasteurized	6.5
Homogenized	6.2
Skimmed	6.1
Nonfat DMS	6.1
Evaporated	5.0
Whole DMS	5.8
Pasteurized - LSD_{01}	6.1
Pasteurized - LSD_{05}	6.2

ANALYSIS OF VARIANCE

Source	Degrees of Freedom	Mean Square	F
Total	29	--	--
Adjusted treatment	5	1.2518	22.51 **
Error for adjusted treatment	15	0.0556	--
Adjusted blocks	9	0.0670	1.26
Intra block error	15	0.0531	--

** Significant at 1 per cent level.

smooth custards. Evaporated milk custards were described as being granular in feel. There was also a slight trend towards greater smoothness when custards made with homogenized milk and nonfat DMS were baked to lower internal temperatures.

Sweetness.

The adjusted average sweetness scores and analysis of variance for Series I are shown in Table 13. As indicated, the main source of variation was the type of milk. Difference due to replication was highly significant. This could have been due to inconsistent scoring by the judges, since degree of sweetness is difficult to judge.

Custards made with homogenized milk, skimmed milk, and nonfat DMS showed the most acceptable sweetness scores. Pasteurized milk had a slightly lower sweetness score, followed by whole DMS. The sweetness scores for evaporated milk were highly significantly lower than those of the control.

As indicated by the analysis of variance and adjusted average scores (Table 14) for Series II, the chief source of variation was the type of milk used. There was a highly significant variation due to replication, probably for the same reason as in Series I.

Pasteurized milk custards had the most acceptable sweetness score. Custards made with homogenized milk, skimmed

Table 13

ADJUSTED AVERAGE SCORES AND ANALYSIS OF VARIANCE
FOR SWEETNESS - SERIES I

Type of Milk	Adjusted Average Score
Pasteurized	6.4
Homogenized	6.6
Skimmed	6.6
Nonfat DMS	6.6
Evaporated	5.6
Whole DMS	6.3
Pasteurized $\pm$ LSD_{01}	6.0 - 6.8
Pasteurized $\pm$ LSD_{05}	6.1 - 6.7

ANALYSIS OF VARIANCE

Source	Degrees of Freedom	Mean Square	F
Total	29	--	--
Adjusted treatment	5	0.6452	10.90 **
Error for adjusted treatment	15	0.0592	--
Adjusted blocks	9	0.2734	5.54 **
Intra block error	15	0.0493	--

** Significant at 1 per cent level.

Table 14

ADJUSTED AVERAGE SCORES AND ANALYSIS OF VARIANCE
FOR SWEETNESS - SERIES II

Type of Milk	Adjusted Average Score
Pasteurized	6.5
Homogenized	6.4
Skimmed	6.4
Nonfat DMS	6.4
Evaporated	5.9
Whole DMS	6.1
Pasteurized - LSD_{01}	6.2
Pasteurized - LSD_{05}	6.3

ANALYSIS OF VARIANCE

Source	Degrees of Freedom	Mean Square	F
Total	29	--	--
Adjusted treatment	5	0.2910	12.44 **
Error for adjusted treatment	15	0.0234	--
Adjusted blocks	9	0.1319	6.83 **
Intra block error	15	0.0193	--

** Significant at 1 per cent level.

milk, and nonfat DMS had equal sweetness scores. The whole DMS had a sweetness score significantly lower than the control. The results indicated that the custards made with evaporated milk were highly significantly different in sweetness from pasteurized milk custards.

The judges indicated in both series that the evaporated milk custards were too sweet. Carr and Trout (7) suggested that the degree of sweetness might be influenced by the amount of syneresis shown by the custards, due to the concentration of sugars in the liquid phase. In their work unhomogenized milk custards had a sweeter taste and showed more syneresis than homogenized milk custards. The results of Series I substantiated this theory since evaporated milk and whole DMS custards were considered sweeter by the judges than the other custards and showed the greatest amount of syneresis. This was not true with Series II, however. Homogenized milk, skimmed milk, and nonfat DMS custards which showed the greatest amount of syneresis were not considered to be sweeter than those custards which had less syneresis.

General Acceptability.

In Table 15 are shown the average adjusted scores and analysis of variance for general acceptability in Series I. The analysis of variance indicated that the main source of variation was the type of milk used. There was no significant difference that could be attributed to replication.

Table 15

ADJUSTED AVERAGE SCORES AND ANALYSIS OF VARIANCE
FOR GENERAL ACCEPTABILITY - SERIES I

Type of Milk	Adjusted Average Score
Pasteurized	6.3
Homogenized	5.9
Skimmed	5.6
Nonfat DMS	5.1
Evaporated	4.1
Whole DMS	4.9
Pasteurized - LSD_{01}	5.7
Pasteurized - LSD_{05}	5.9

ANALYSIS OF VARIANCE

Source	Degrees of Freedom	Mean Square	F
Total	29	--	--
Adjusted treatment	5	3.0168	34.44 **
Error for adjusted treatment	15	0.0876	--
Adjusted blocks	9	0.1489	1.89
Intra block error	15	0.0789	--

** Significant at 1 per cent level.

Custards made with pasteurized milk received the highest score for general acceptability. The score for the custard made with homogenized milk was just at the 5 per cent level of significance. All other custards had lower scores and were highly significantly different from the control in acceptability. The low acceptability of evaporated milk custard could probably be attributed to its poor color and flavor. The whole DMS was consistently marked unacceptable by one judge, probably due to her dislike of the flavor.

In Series II, variation in general acceptability scores can be attributed to the type of milk as shown in Table 16, where adjusted average scores and analysis of variance are given. There was no significant variation due to replication.

Pasteurized milk custards had the highest general acceptability scores. All other custards were highly significantly different from the control. With the exception of nonfat DMS which had a slightly higher score in Series II than in Series I, homogenized milk and skimmed milk custards were less acceptable when baked to lower internal temperatures (Series II). The lower acceptability scores possibly were due to decreased firmness of the custards when baked to the lower internal temperatures. In both series, whole DMS and evaporated milk custards were the least acceptable.

Table 16

ADJUSTED AVERAGE SCORES AND ANALYSIS OF VARIANCE
FOR GENERAL ACCEPTABILITY - SERIES II

Type of Milk	Adjusted Average Score
Pasteurized	6.2
Homogenized	5.4
Skimmed	5.2
Nonfat DMS	5.3
Evaporated	3.7
Whole DMS	4.7
Pasteurized - LSD_{01}	5.5
Pasteurized - LSD_{05}	5.7

ANALYSIS OF VARIANCE

Source	Degrees of Freedom	Mean Square	F
Total	29	--	--
Adjusted treatment	5	3.4961	23.91 **
Error for adjusted treatment	15	0.1462	--
Adjusted blocks	9	0.0959	<1
Intra block error	15	0.1774	--

** Significant at 1 per cent level.

Objective Tests

Time - Temperature Curves.

The time - temperature curves for each series are shown in three figures. The first figure represents the average time - temperature curves for all the custards in the series. Since the rate of heat penetration was similar for the various custards, the time - temperature curves were then plotted on two graphs, three variations to a figure, in order to distinguish more clearly the rates of heat penetration. In Table 17 is indicated the time to reach the required internal temperature for each series.

The time - temperature curves for Series I are shown in Figures I, II, and III. Of the three types of custards baked to an internal temperature of 86° C., pasteurized milk baked in the shortest time (Table 17). Evaporated milk custards required an average of two minutes longer than whole DMS to reach the same internal temperature. The custards baked to a higher internal temperature (88° C.) required a longer baking period. Homogenized milk and skimmed milk custards required on the average the same length of time in the oven while nonfat DMS custard baked two minutes longer to reach its optimum internal temperature.

The rate of temperature rise in all the types of milk was similar until an internal temperature of about 70° C. was reached. At this point, the curve for pasteurized milk

Table 17

LENGTH OF TIME TO REACH REQUIRED INTERNAL TEMPERATURES OF BAKED CUSTARDS

Milk	Minutes	Internal Temperature (Degrees Centigrade)
Series I		
Pasteurized	57	86
Homogenized	87	88
Skimmed	87	88
Nonfat DMS	89	88
Evaporated	72	86
Whole DMS	70	86
Series II		
Pasteurized	58	86
Homogenized	76	86
Skimmed	83	86
Nonfat DMS	75	86
Evaporated	75	86
Whole DMS	76	86

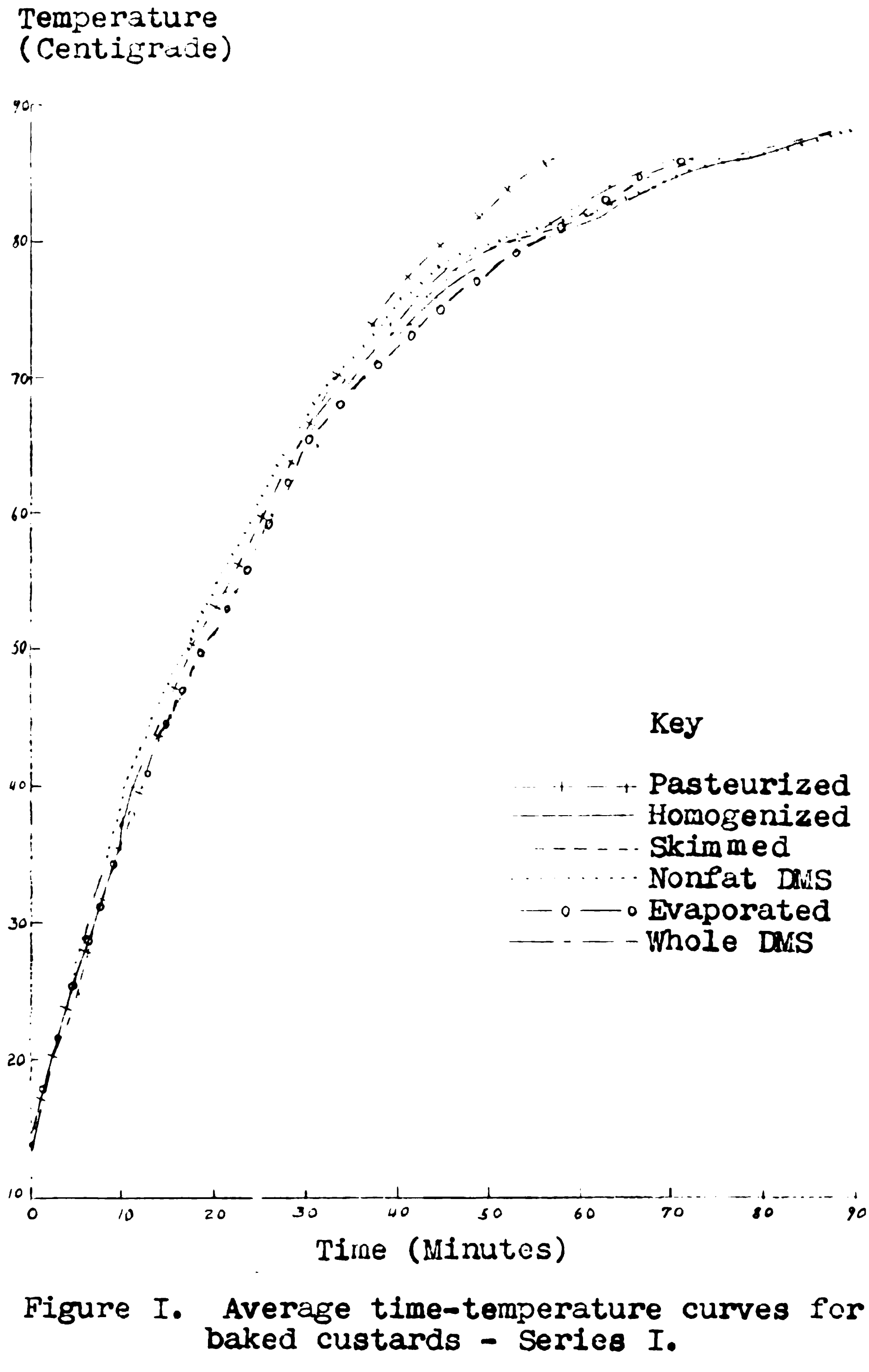


Figure I. Average time-temperature curves for baked custards - Series I.

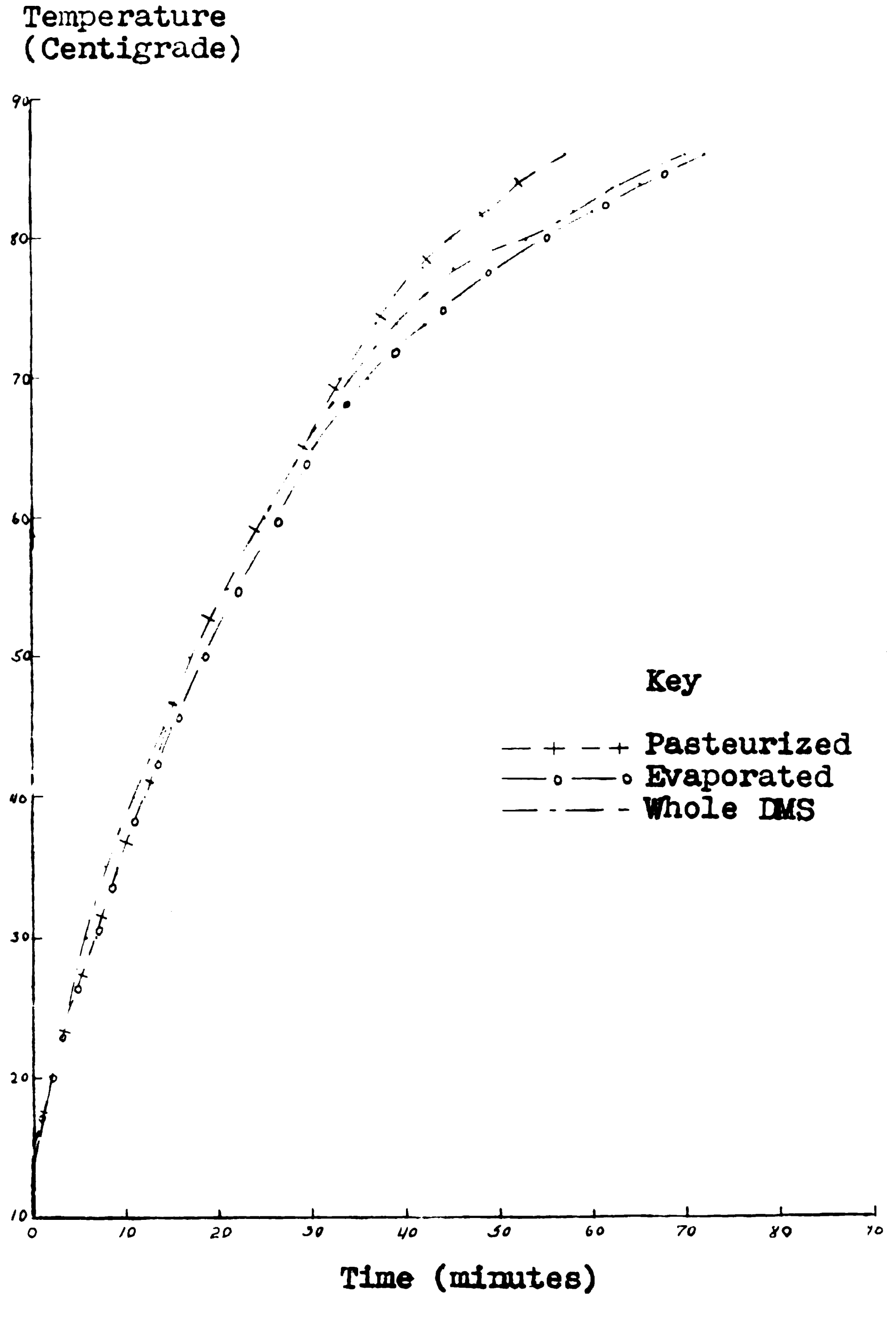


Figure II. Average time-temperature curves for baked custards - Series I.

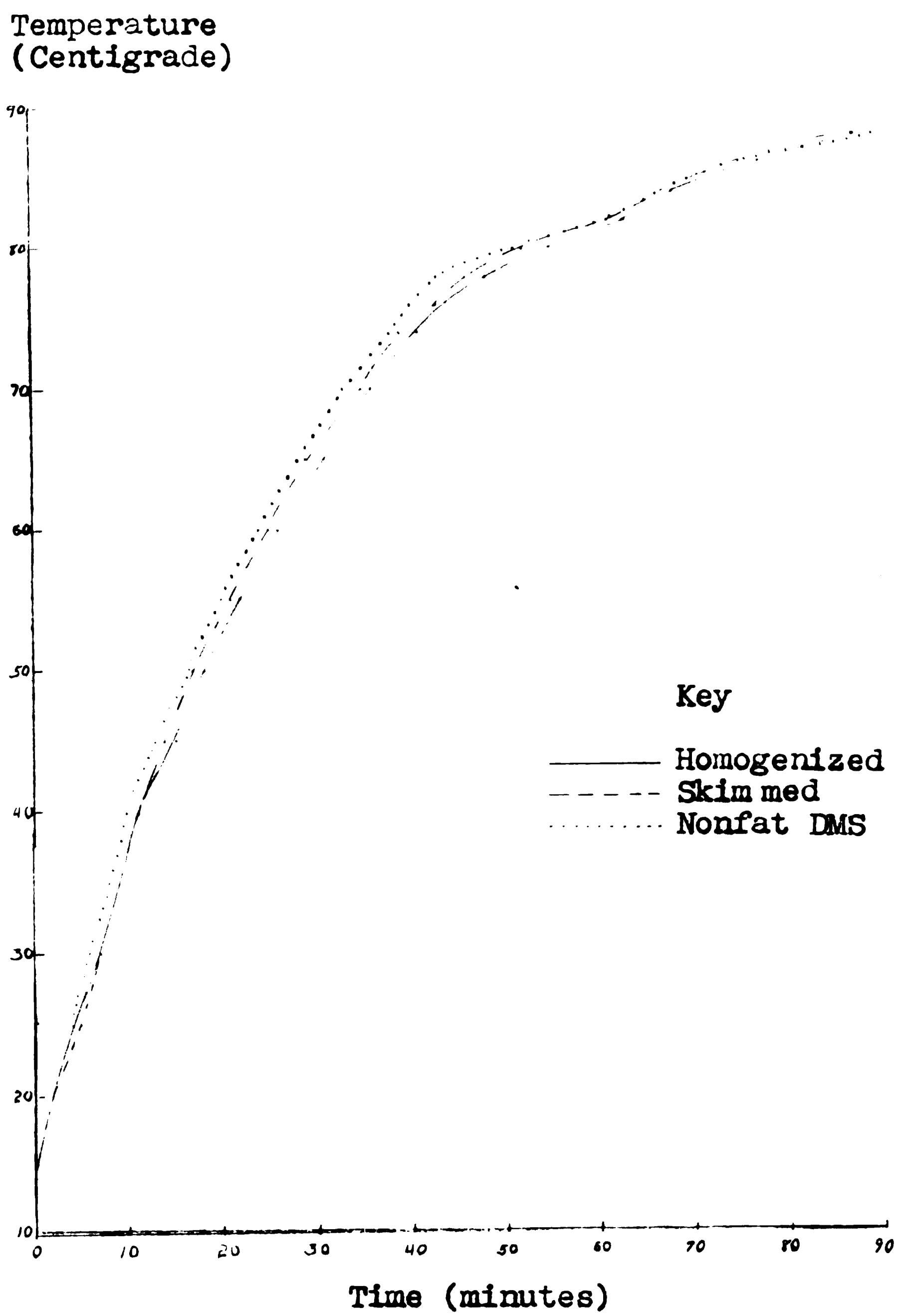


Figure III. Average time-temperature curves for baked custards - Series I.

custards contined to rise rapidly and did not tend to reach a plateau. The custards made with the other types of milk had curves that tended to flatten out at 78° - 80° C. After this point, temperature rise was more gradual. From about 70° C. to 80° - 82° C. internal temperature, nonfat DMS custards had the most rapid temperature rise of the other milks. Rate of heat absorption into the custards at this range was progressively slower in the following order: whole DMS, skimmed milk, homogenized milk, and evaporated milk. From 80° - 82° C. to 86° C. internal temperature, the time - temperature curve rose faster with custards made with evaporated milk and whole DMS than with those made with skimmed milk, homogenized milk, or nonfat DMS. Heat absorption into the latter three milks at the higher internal temperatures was similar.

The time - temperature curves for Series II in which all variations were baked to 86° C. internal temperature are shown in Figures IV, V, and VI. As in Series I, the pasteurized milk custard required the shortest baking time. The custards made with homogenized milk, evaporated milk, and whole and nonfat DMS required on the average a baking time of seventy-five to seventy-six minutes. The results obtained with homogenized and pasteurized milk custards are in agreement with those of Carr and Trout (7). Skimmed milk custards took the longest time to bake.

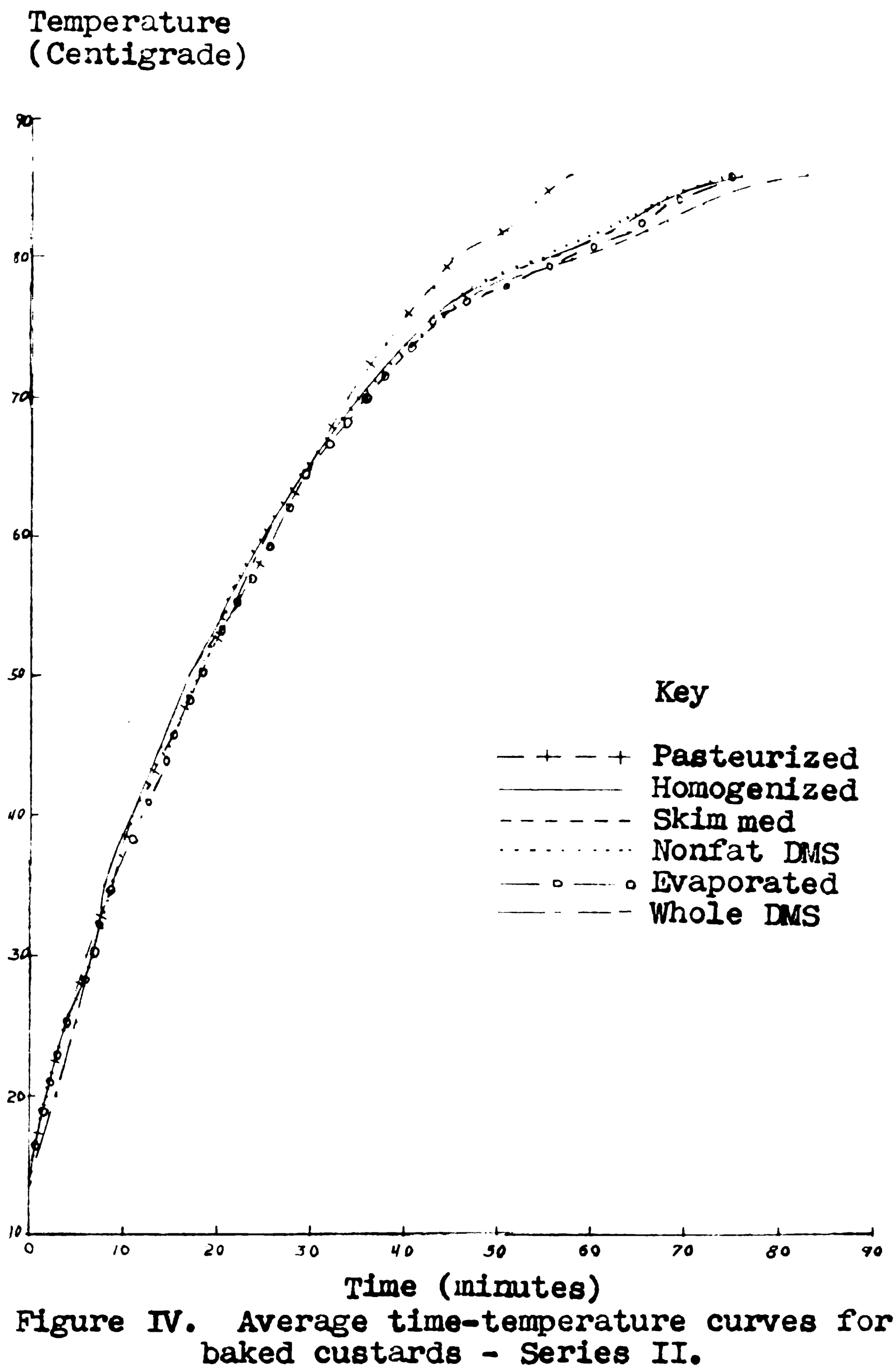


Figure IV. Average time-temperature curves for baked custards - Series II.

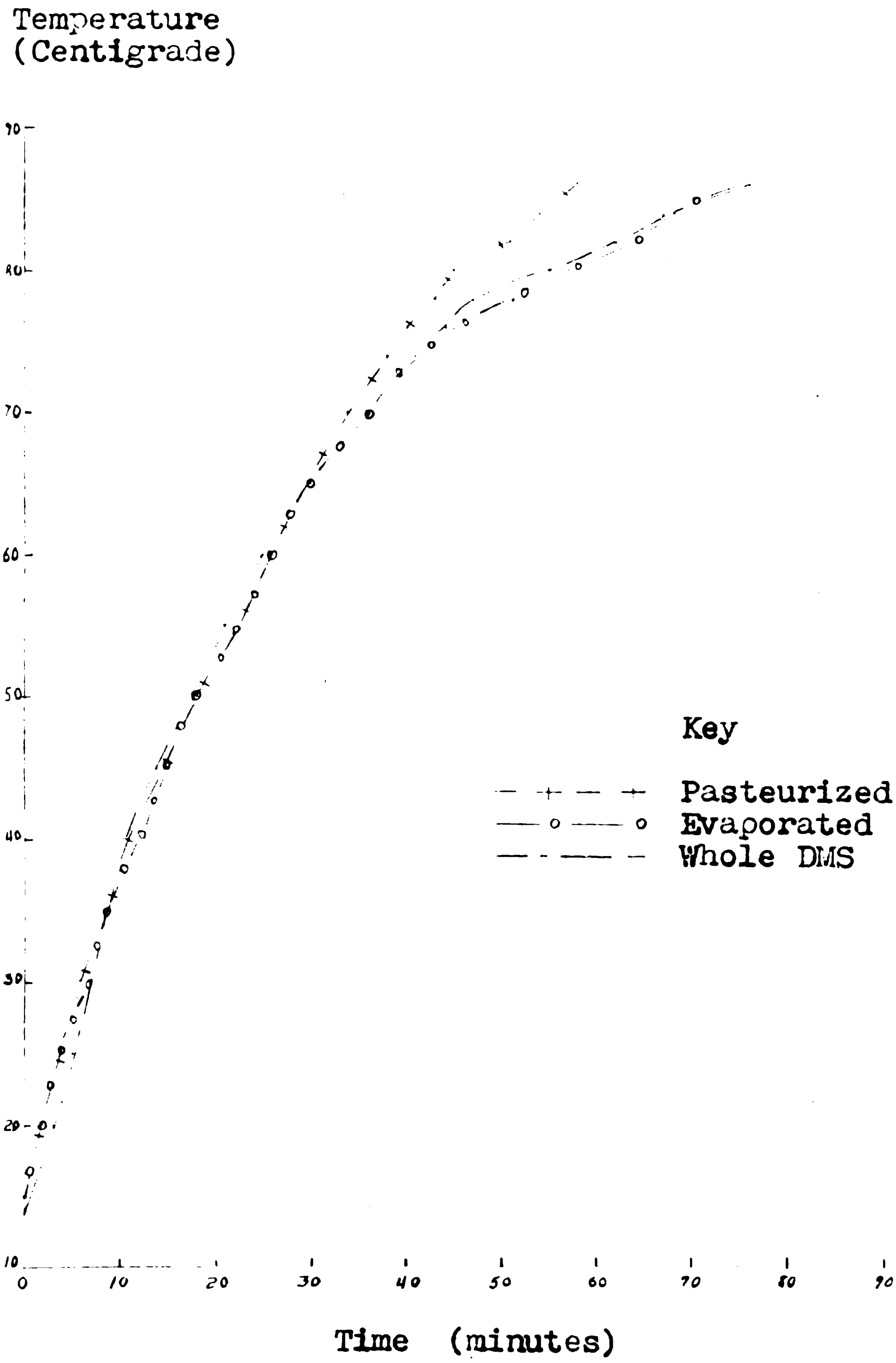


Figure V. Average time-temperature curves for baked custards - Series II.

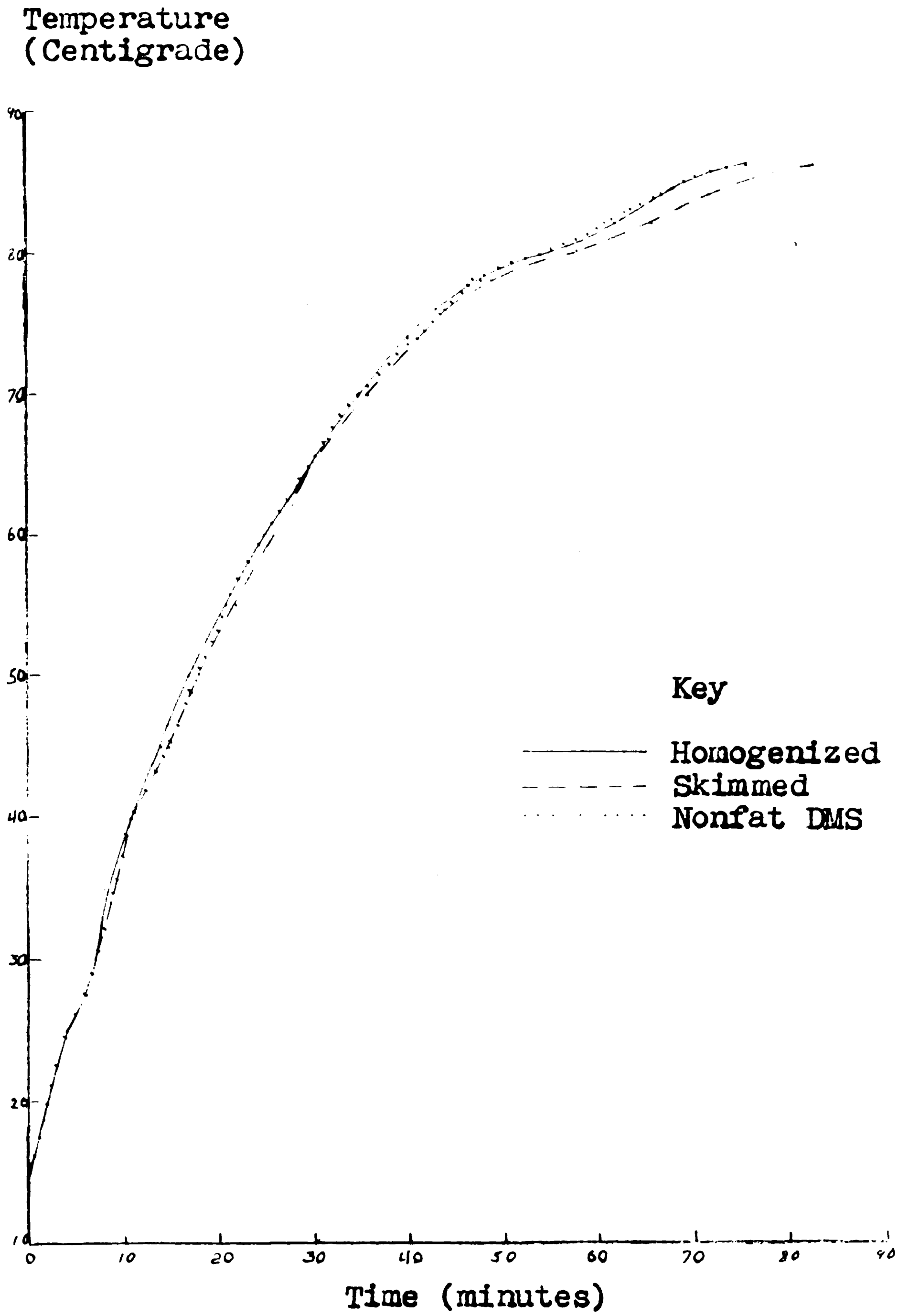


Figure VI. Average time-temperature curves for baked custards - Series II.

In general, the rate of heat absorption in Series II was similar to that obtained in Series I with the following exceptions. In Series II, length of baking time for evaporated milk and whole DMS custards was greater on the average by three to six minutes than in Series I. Also in Series II, skimmed milk custards required an eighty-three minute average baking period to reach 86° C. internal temperature, while in Series I, a period of seventy minutes was needed to reach that temperature. Possibly these discrepancies could have been caused by slight variations in the oven temperature, as shown by the water bath temperatures. As shown in Table 18, the determining factor in the baking time of one treatment seemed to be the rate of rise in the water bath temperature in the higher temperature ranges. Although the initial rise in the water bath temperature was similar, the temperature rose at different rates in the 86° - 91° C. range. With a faster rise in water bath temperature in this range, the custard temperature rose at a faster rate (Series I). In Series II, the water bath temperature rise of these replications was slower in this range and the temperature of the custards accordingly rose more gradually.

The literature gives little or no explanation for the different rates of temperature rise. Leighton and Mudge (44) found that when whole milk was heated, the rate of temperature rise was constant but slow. When no fat was

Table 18

SOME TIME-TEMPERATURE READINGS FOR SKIMMED MILK CUSTARDS AND WATER BATHS

	Degrees Centigrade					
	Series I		Series II			
Minutes	Custard	Water Bath	Custard	Water Bath	Custard	Water Bath
0	14	35	15	35	19	35
10	34	42	35	42	39	44
15	42	50	42	48	45	50
20	50	57	50	55	52	57
25	58	62	56	61	59	63
30	64	68	62	67	65	69
35	69	73	67	72	69	73
40	74	78	70	76	72	77
45	76	81	74	79	76	81
50	78.5	84	77	83	78.5	83
55	80	86	78	84	79	86
60	82	88	79	86	80	87
65	84	90	81	88	81	89
70	85.5	91	82	88	83	89
75	86.5	91	84	89	84	90
80	87.5	91	85	89	85	91
85	88	91	86	90	86	91

present, as in skimmed milk, the time - temperature curve rose more rapidly and tended to reach a plateau in a shorter time. Webb and Bell (74) noted that skimmed milk did not have the same type of heat stability curve as whole milk. Perhaps the difference in rate of temperature rise in the different custards might have been caused by the alteration in protein and salt balance. During the processing of the milk, the balance was altered and the heat stability of the protein was changed. The greater the degree of alteration, the greater the effect on the coagulation temperature and on the rate of temperature rise.

pH Readings.

The results of the pH readings for Series I and II are shown in Table 19. In Series I, the custard mixes were slightly acidic, with the exception of those made with whole and nonfat DMS. As a result of the baking process, all the custards increased in alkalinity. The decrease in acidity of custards during baking was noted also by Morse and co-workers (53) and MacDougall (48). The custards in Series II showed the same general trends as in Series I. An exception to this was evaporated milk custard, which had the same pH before and after baking. Probably the greater alkalinity of the evaporated milk custard after baking in Series I was due to two readings of considerably greater alkalinity for that variation.

Table 19

AVERAGE pH READINGS ON UNBAKED AND BAKED CUSTARDS

Type of milk	Unbaked	Baked
Series I		
Pasteurized	6.87	6.96
Homogenized	6.90	6.99
Skimmed	6.86	6.99
Nonfat DMS	7.12	7.20
Evaporated	6.75	6.88
Whole DMS	7.00	7.11
Series II		
Pasteurized	6.90	6.98
Homogenized	6.94	7.00
Skimmed	6.92	7.02
Nonfat DMS	7.13	7.25
Evaporated	6.75	6.75
Whole DMS	7.03	7.09

Syneresis.

In Figures VII and VIII are shown the syneresis of the different custards over a three hour period, for Series I and II, respectively. In Series I, custards made with evaporated milk and whole DMS showed the greatest amount of syneresis. The centers of the custards were quite soft and some of the custard fell through the wire screen for these two variations. Skimmed milk custards were intermediate in syneresis, while homogenized milk and pasteurized milk custards showed similar amounts of syneresis. Nonfat DMS custards had the least amount of syneresis.

The data indicated that in general the greatest amount of syneresis occurred during the first hour of testing. The increase in syneresis of pasteurized milk custards was fairly constant over the three hour period. With the other types of custards, the syneresis was greatest during the first hour and then leveled off to a constant rate.

In Series II (Figure VIII), the greatest amount of syneresis was shown by nonfat DMS custards, followed by homogenized milk, skimmed milk, evaporated milk, and whole DMS custards. Pasteurized milk custards showed the least syneresis. As in Series I, the custards in Series II, with the exception of pasteurized milk custards, tended to show the greatest amount of syneresis during the first hour of testing and then

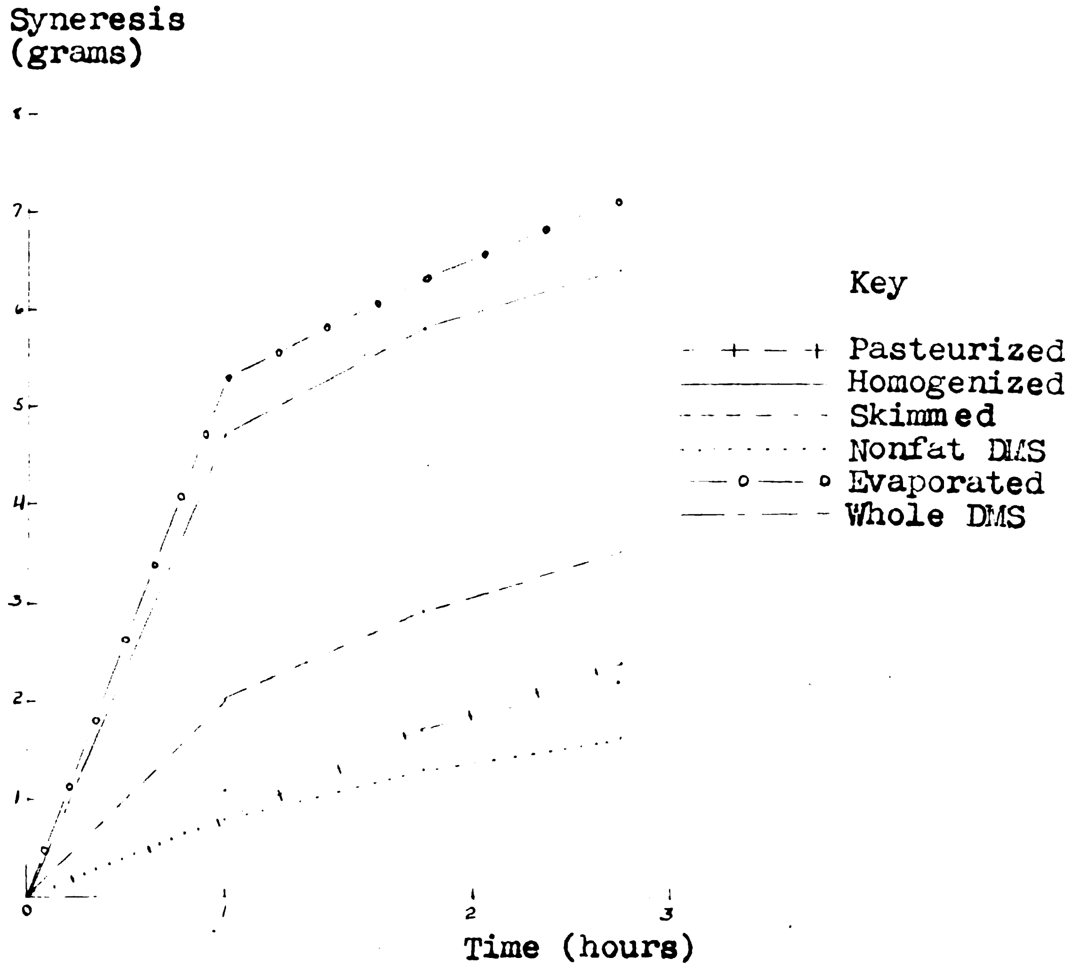


Figure VII. Average syneresis readings (grams) on baked custards - Series I.

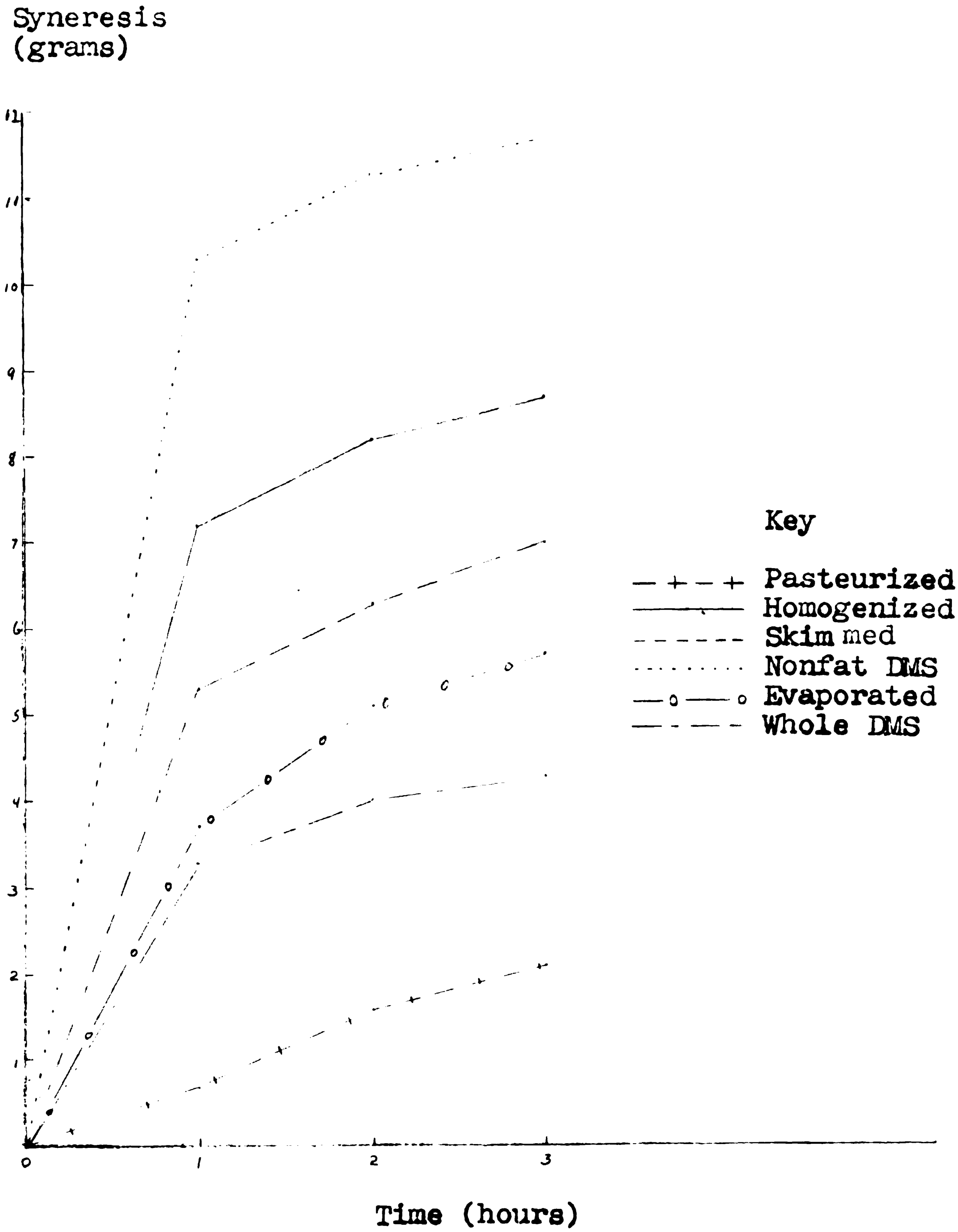


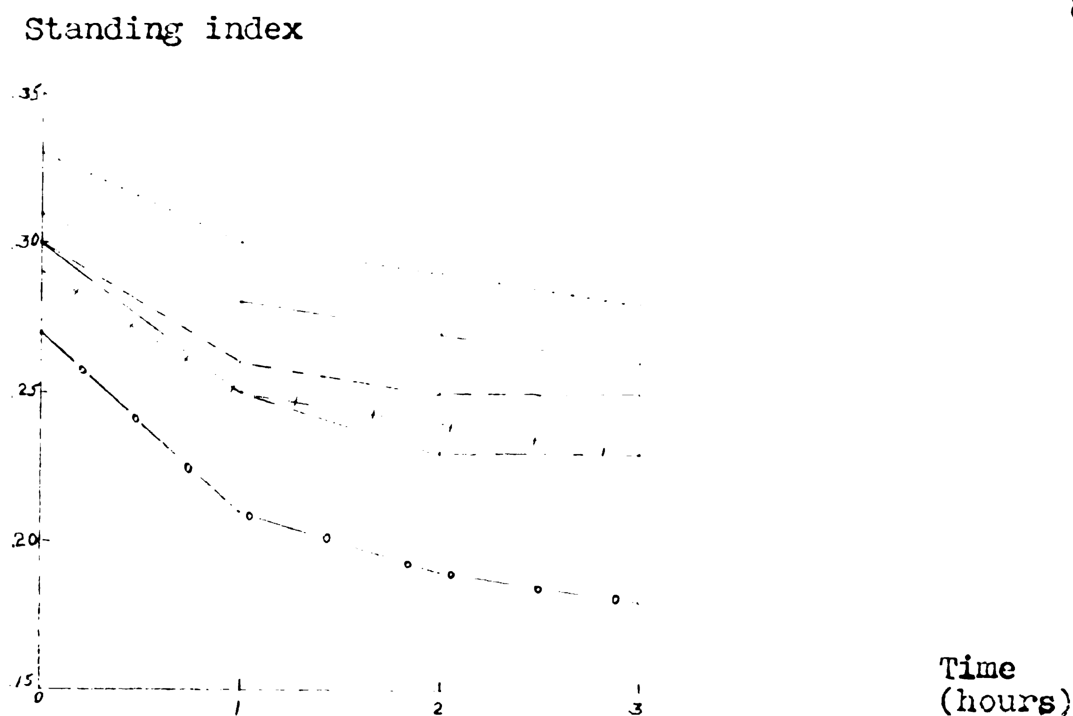
Figure VIII. Average syneresis readings (grams) on baked custards - Series II.

the syneresis leveled off to a constant rate. Pasteurized milk custards showed a fairly constant increase in syneresis throughout the test period. The results obtained with homogenized and pasteurized milk custards are opposite to those obtained by Carr and Trout (7).

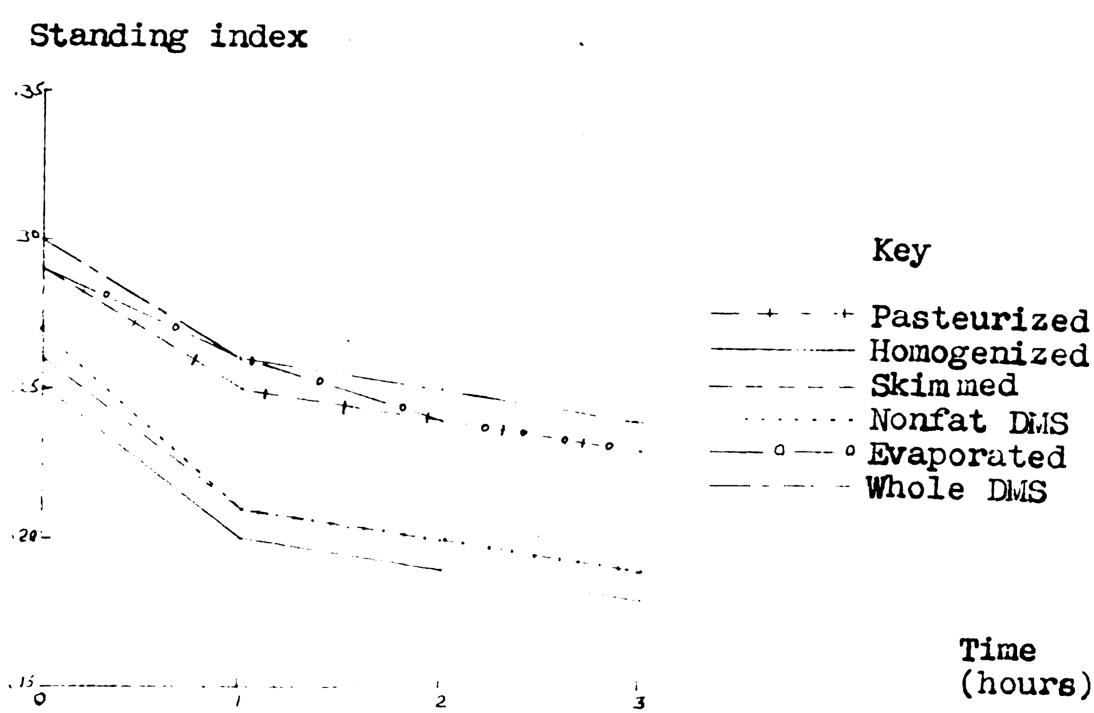
The results indicated that the custards made from the different types of milk varied in their ability to hold the liquid within their meshes. In Series I, the custards baked to a higher internal temperature (88° C.) showed less syneresis in general than those baked to a lower internal temperature (86° C.). The same custards - homogenized milk, skimmed milk, and nonfat DMS, when baked to an internal temperature of 86° C. in Series II, showed a greater amount of syneresis as compared to the custards which had obtained optimum consistency at 86° C. internal temperature. Evidently, homogenized milk, skimmed milk, and nonfat DMS custards had not coagulated firmly enough at 86° C. internal temperature to hold the liquid.

Standing Index.

The results of the standing index test for Series I and II are shown in Figure IX. A high standing index indicates a firm gel, a smaller ratio a weaker gel. The data indicated that there was a considerable difference in the ability of the various gels to hold up at the beginning of



(a) Series I



(b) Series II

Figure IX. Average standing index readings on baked custards.

the test period. In Series I, the gel strengths of nonfat DMS milk and homogenized milk custards were the greatest at the beginning of the test period. Custards made with skimmed milk, whole DMS, and pasteurized milk had initial gel strengths that varied only slightly. Custards of evaporated milk had the weakest gels.

In general, the standing index showed the greatest decrease during the first hour of testing and decreased at a fairly constant rate during the following two hours. Custards made with skimmed milk and whole DMS did not show further slumping after two hours. Although the initial standing index was similar for skimmed milk, pasteurized milk, and whole DMS custards, the ratio decreased least for skimmed milk of the three custards. Whole DMS showed the greatest decrease in the standing index of the three types of custards.

In Series II, whole DMS had the highest initial standing index while those of evaporated and pasteurized milk were the same. The initial gel strength of the other types of custard were weaker in the following descending order: nonfat DMS, skimmed milk, and homogenized milk.

As in Series I, the standing index ratio showed the greatest decline during the first hour of testing. Although the initial ratios of pasteurized and whole DMS were identical,

pasteurized milk custards slumped more during the first two hours of testing. During the last hour the standing index of the two custards was the same. Nonfat DMS custards showed a greater decrease during the first hour of testing than skimmed milk, but during the following hours, the decrease was the same. Carr and Trout (7) obtained opposite results with homogenized and pasteurized milk custards, reporting that baking to an internal temperature of 86° C. caused homogenized milk custards to have a higher standing index than unhomogenized milk custards.

The results of Series I indicated that the custards baked to 88° C. had firmer gels than when baked to 86° C. These same custards when baked to 86° C. in Series II had weaker gels than the pasteurized milk, evaporated milk, and whole DMS custards which reached optimum internal temperatures at 86° C.

Penetrometer.

The results of the penetrometer readings are shown in Figures X and XI for Series I and II, respectively. Tenderness of the crust and gel increases with an increase in compressibility readings.

Figure X shows that crusts of the control custard were the most tender in Series I, followed by evaporated milk.

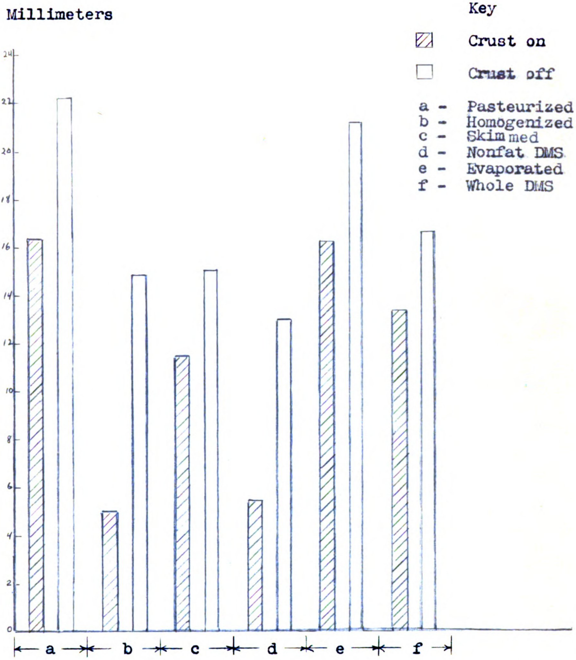


Figure X. Average penetrometer readings (millimeters) on baked custards - Series I.

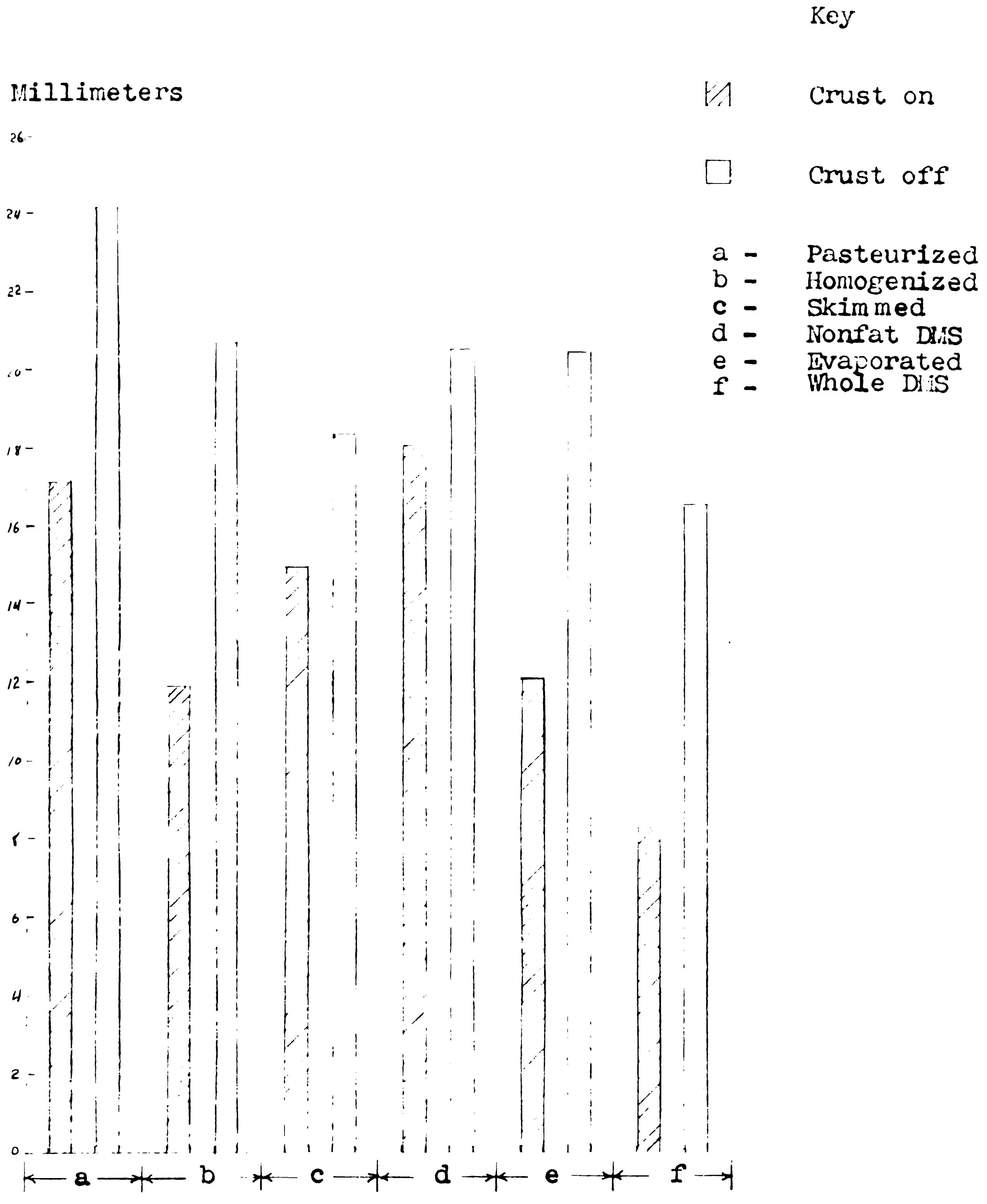


Figure XI. **Average penetrometer readings (millimeters) on baked custards - Series II.**

Whole DMS custards had the next most tender crust. The crust of skimmed milk custard was less tender, followed by nonfat DMS and homogenized milk. The results, substantiated by the judges' scores, indicated that the presence of butterfat on top of the custard, as with pasteurized milk, increased the tenderness of the crust.

The compressibility of the top of the custard with the crust removed indicated that homogenized milk custard had the firmest gel, followed by nonfat DMS. Skimmed milk custards were slightly less compressible than whole DMS custards. Custards made with pasteurized milk and evaporated milk showed the greatest degree of compressibility.

The compressibility results for Series II indicated that the nonfat DMS custards had the most tender crust, followed by those of pasteurized milk and skimmed milk. Homogenized milk and evaporated milk custards had almost equally tender crusts. The crust of whole DMS custard was the toughest.

Tenderness of the gel with the crust removed in Series II showed that pasteurized milk custardshad the most tender gel. Those of homogenized milk, nonfat DMS, and evaporated milk custards were almost equal in firmness. Skimmed milk custard had a slightly less tender gel while the gel of whole DMS was the least compressible.

The results indicated that the crust and gel were less tender in the custards made with homogenized milk, skimmed milk, and nonfat DMS when baked to an interal temperature of 88° C. than when baked to 86° C. internal temperature. When these three custards were baked to 86° C. internal temperature, the crust tenderness and gel compressibility increased. Evidently, a longer baking period and higher internal temperature increase the gel and crust toughness.

Curd Tension Meter.

The curd tension meter was used to indicate the cutting strength of the inverted gel and of the gel of the top of the custard with the crust removed. The results of both series are shown in Figure XII. As the gel becomes tougher, the curd tension readings become greater.

The results of Series I indicated that the tops of the custards were less firm than the bottom with the exception of pasteurized milk custard in which the reverse was shown. The firmer gels at the bottom of the custard could possibly be caused by the protein coagulating at the outer edges and bottom first, followed by coagulation at the center and under the crust.

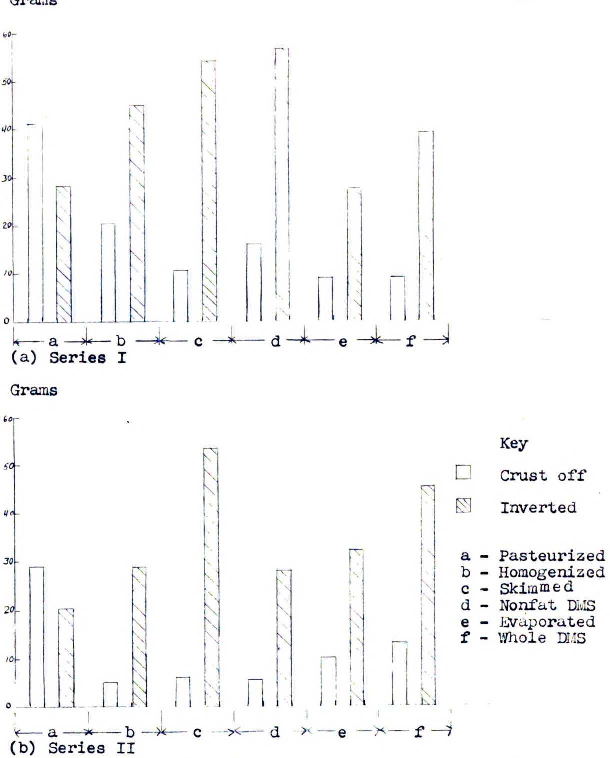


Figure XII. Average curd tension readings (grams) on baked custards.

The custards in Series II showed the same tendency to have a more tough gel on the bottom than on the top, with the exception of pasteurized milk. The gel at the top of the custard was quite tender with custards of homogenized milk, skimmed milk, and nonfat DMS. Those of custards made with evaporated milk and whole DMS were more firm. Pasteurized milk had the most firm gel at the top.

The gel strength of the inverted custard was least with pasteurized milk custard, followed by nonfat DMS and homogenized milk custards. The bottom of the custards made with evaporated milk were slightly more firm. The bottoms of the custards made with whole DMS and skimmed milk were the least tender.

A comparison of the results of the two series showed that a higher internal temperature resulted in more firm gels at the top and bottoms of the custards. Increasing the internal temperature does not seem to have as great an effect on the bottom of skimmed milk custard as on nonfat DMS or homogenized milk custard.

To determine which agreed more closely with the judges' scores, correlation coefficients were calculated on curd tension and penetrometer readings. The results are indicated in Table 20. There was a positive significant correlation between the judges' scores for crust tenderness

Table 20

CORRELATION BETWEEN SOME SUBJECTIVE AND OBJECTIVE MEASUREMENTS

Crust scores vs. penetrometer readings (crust on) - Series I	+ 0.6169 **
Crust scores vs. penetrometer readings (crust on) - Series II	+ 0.3993 *
Firmness scores vs. penetrometer readings (crust off) - Series I	+ 0.0477
Firmness scores vs. penetrometer readings (crust off) - Series II	+ 0.1434
Firmness scores vs. curd tension meter readings (crust off) - Series I	+ 0.5330 **
Firmness scores vs. curd tension meter readings (crust off) - Series II	+ 0.6003 **
Curd tension meter readings vs. penetrometer readings (crust off) - Series I	+ 0.1987
Curd tension meter readings vs. penetrometer readings (crust off) - Series II	+ 0.0923

** Significant at 1% level
* Significant at 5% level

and the penetrometer readings on the crust for both series. There was no significant correlation between the judges' scores for firmness and the penetrometer readings for the top of the custard with the crust off. However, a highly significant correlation was shown between the curd tension readings for the top of the custard with the crust removed and the judges' firmness scores. These results are in accord with those of MacDougall (48) and the indications are that the curd tension meter is a better measure of gel strength than the penetrometer. No significant correlation between the curd tension meter and penetrometer readings was found.

SUMMARY AND CONCLUSIONS

The quality of baked custards prepared from various milks was compared. The time - temperature curves for the custards were studied. Two series were conducted on the custards. In Series I, each variation was baked to its optimum internal temperature: 86° C. for pasteurized milk, whole dried milk solids, and evaporated milk custards, and 88° C. for homogenized milk, skimmed milk, and nonfat dried milk solids custards. All custards in Series II were baked to 86° C. internal temperature.

The quality of the custards was judged by objective and subjective measurements. The custards were scored subjectively for appearance, crust, color inside, flavor, firmness, smoothness, sweetness, and general acceptability. Objective tests included pH of the custard before and after baking, time - temperature curves, syneresis, and gel strength as indicated by the standing index, penetrometer, and curd tension meter.

The main source of variation among the palatability scores was the type of milk, not variation within replications. The order of preference for the various baked custards in Series I as indicated by the general acceptability scores were: pasteurized milk, homogenized milk, skimmed milk, nonfat dried milk solids, whole dried milk solids, and evaporated milk custards. With the exception of nonfat dried milk solids which had a slightly higher score in Series II than in Series I, homogenized milk and skimmed milk custards were less acceptable when baked to a lower internal temperature in Series II, primarily due to less firm gels of the custards.

The results of objective tests were similar to the results of the palatability scores. In general, gel strength of homogenized milk, skimmed milk, and nonfat dried milk solids custards was greater when those custards were baked to a higher internal temperature. All the custards showed some syneresis and decline in standing index, the amount varying among treatments. Highly significant correlations were found between crust scores and penetrometer readings for crust tenderness and between firmness scores and curd tension meter firmness readings. However, there was no correlation between firmness scores and penetrometer readings for gel firmness.

The rate of heat penetration into the various custards was similar until an internal temperature of about 70° C. was reached. After this point, pasteurized milk custards continued to absorb heat rapidly and reached the desired internal temperature in the shortest time. The time - temperature curves for the other variations were similar and these custards reached 86° C. internal temperature in approximately the same time.

On the basis of these results, it appears that:

1. Of the various milks, pasteurized milk produced the best quality baked custard.
2. The optimum internal temperature for baked custard varied with the milk used.
3. The rate of heat penetration into baked custard as shown by time - temperature curves was affected by the kind of milk used.

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APPENDIX

Table 21

AVERAGE DAILY SCORES FOR APPEARANCE

	Type of Milk					
Day	Pasteur-ized	Homogen-ized	Skimmed	Nonfat DMS Solids	Evapo-rated	Whole DMS Solids
Series I						
1	6.7	6.3	4.3			
2			5.0	5.0	4.3	
3			4.3	4.3		5.7
4	6.5			5.0	4.5	
5	6.8				4.2	5.8
6		6.2			4.0	5.8
7	6.5		4.5			5.8
8		6.2		4.2		6.0
9	6.8	5.3		4.5		
10		6.0	4.8		4.2	
Series II						
1			5.3	4.7		5.7
2		5.5			4.0	5.8
3	6.2		4.5			5.2
4		6.0	5.5		4.0	
5		5.5		4.8		6.2
6	6.2			4.8	3.8	
7	7.0				4.0	6.0
8	7.0	5.5	4.8			
9	7.0	5.5		4.8		
10			5.2	5.2	4.0	

Table 22

AVERAGE DAILY SCORES FOR CRUST

Day	Type of Milk					
	Pasteurized	Homogenized	Skimmed	Nonfat DMS Solids	Evaporated	Whole DMS Solids
Series I						
1	6.7	5.3	4.0			
2			4.7	4.3	5.0	
3			5.0	4.0		5.7
4	6.5			4.0	4.5	
5	6.8				5.2	4.2
6		5.0			5.0	5.0
7	6.8		4.5			4.2
8		4.2		2.8		4.8
9	6.8	4.0		3.2		
10		4.0	4.5		4.8	
Series II						
1			5.3	5.0		5.0
2		4.8			4.8	4.8
3	7.0		4.2			4.0
4		4.8	4.0		5.5	
5		5.0		5.5		4.8
6	7.0			5.5	4.8	
7	7.0				4.8	4.8
8	7.0	4.8	4.2			
9	7.0	4.8		4.5		
10			5.0	5.2	5.0	

Table 23

AVERAGE DAILY SCORES FOR COLOR INSIDE

	Type of Milk					
Day	Pasteurized	Homogenized	Skimmed	Nonfat DMS Solids	Evaporated	Whole DMS Solids
Series I						
1	6.7	7.0	6.7			
2			5.7	5.7	4.0	
3			6.0	6.3		6.0
4	6.8			6.8	4.2	
5	6.5				4.2	6.8
6		7.0			4.2	6.8
7	6.5		6.8			6.5
8		6.2		6.5		6.2
9	6.8	6.5		6.5		
10		6.5	6.0		3.8	
Series II						
1			6.0	6.3		6.3
2		6.2			3.8	6.2
3	6.2		6.2			6.2
4		6.5	6.5		4.0	
5		6.5		6.2		6.5
6	6.2			6.5	3.8	
7	6.8				3.8	6.8
8	6.5	6.5	6.5			
9	6.5	6.5		6.5		
10			6.5	6.5	4.0	

Table 24

AVERAGE DAILY SCORES FOR FLAVOR

	Type of Milk					
Day	Pasteur-ized	Homogen-ized	Skimmed	Nonfat DMS Solids	Evapo-rated	Whole DMS Solids
Series I						
1	6.7	6.3	6.0			
2			6.0	5.3	4.7	
3			6.3	6.0		4.3
4	5.8			6.0	4.0	
5	6.0				4.5	5.5
6		6.2			4.0	5.2
7	6.2		6.0			5.8
8		6.2		5.0		3.5
9	6.5	5.8		4.2		
10		6.0	6.0		4.0	
Series II						
1			5.7	6.0		4.0
2		5.8			3.0	5.0
3	6.5		5.5			4.2
4		6.2	5.2		3.5	
5		6.0		5.2		4.0
6	5.5			6.2	3.5	
7	6.0				4.0	5.8
8	6.2	6.5	5.8			
9	5.8	6.0		5.8		
10			5.8	6.2	3.5	

Table 25

AVERAGE DAILY SCORES FOR FIRMNESS

Day	Type of Milk					
	Pasteurized	Homogenized	Skimmed	Nonfat DMS Solids	Evaporated	Whole DMS Solids
Series I						
1	6.3	6.3	6.3			
2			6.3	6.0	3.7	
3			6.0	5.3		5.0
4	6.8			5.5	4.8	
5	6.0				5.5	6.2
6		6.8			5.8	4.8
7	6.8		5.5			6.5
8		6.0		5.2		5.0
9	6.5	5.8		5.0		
10		6.0	5.8		6.0	
Series II						
1			3.7	6.3		5.0
2		4.5			5.2	5.8
3	6.2		4.0			4.8
4		4.8	4.8		4.2	
5		4.5		4.8		5.0
6	6.2			4.5	4.2	
7	6.8				5.2	5.8
8	6.5	5.0	5.8			
9	6.5	5.2		4.8		
10			5.0	4.5	5.2	

Table 26

Day	Type of Milk					
	Pasteur-ized	Homogen-ized	Skimmed	Nonfat DMS Solids	Evapo-rated	Whole DMS Solids
Series I						
1	6.3	6.7	6.3			
2			6.3	6.3	6.3	
3			6.3	5.7		6.0
4	6.8			6.5	5.2	
5	6.5				5.5	6.0
6		6.2			5.2	6.2
7	6.5		5.8			6.2
8		5.5		6.0		5.5
9	5.8	6.2		5.5		
10		6.0	6.0		5.8	
Series II						
1			6.0	6.0		6.0
2		6.0			5.0	5.0
3	6.5		6.0			6.0
4		6.0	6.2		5.0	
5		6.2		6.2		5.8
6	6.5			6.2	5.2	
7	6.5				4.8	6.2
8	6.5	6.5	6.0			
9	6.5	6.2		6.0		
10			6.5	6.2	5.2	

Table 27

AVERAGE DAILY SCORES FOR SWEETNESS

Day	Pasteurized	Homogenized	Skimmed	Nonfat DMS Solids	Evaporated	Whole DMS Solids
Series I						
1	6.7	6.7	6.7			
2			6.0	6.0	4.7	
3			6.7	6.3		5.7
4	6.5			6.8	6.2	
5	6.5				5.8	6.5
6		6.8			6.0	6.5
7	6.8		6.5			6.8
8		6.5		6.5		6.2
9	6.0	6.5		6.5		
10		6.5	6.5		5.5	
Series II						
1			6.3	6.3		6.3
2		6.5			6.0	6.2
3	6.8		6.5			6.2
4		6.0	6.5		5.8	
5		6.5		6.5		6.0
6	6.0			6.0	5.5	
7	6.5				6.0	6.0
8	6.8	6.8	6.8			
9	6.5	6.5		6.5		
10			6.2	6.2	5.5	

Table 28

AVERAGE DAILY SCORES FOR GENERAL ACCEPTABILITY

	Type of Milk					
Day	Pasteur-ized	Homogen-ized	Skimmed	Nonfat DMS Solids	Evapo-rated	Whole DMS Solids
Series I						
1	6.7	6.0	5.7			
2			5.7	5.3	4.3	
3			5.7	5.0		4.7
4	6.2			5.5	4.2	
5	6.0				4.2	5.2
6		6.0			4.0	4.8
7	6.5		5.5			5.5
8		6.0		4.8		4.2
9	6.2	5.2		4.5		
10		5.8	5.5		4.0	
Series II						
1			5.0	6.0		4.3
2		5.2			3.5	5.2
3	6.5		4.5			4.2
4		5.3	5.2		3.5	
5		5.2		5.2		4.8
6	5.8			5.2	3.8	
7	6.0				3.8	5.2
8	6.3	5.0	5.8			
9	6.2	5.5		5.0		
10			5.2	5.5	3.8	

Table 29

SCORE SHEET FOR BAKED CUSTARD

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 - semi-glossy bubbly crust, light yellow in color
Crust - tender
Color, inside - light yellow color, even
Flavor - bland
Firmness - holds shape when cut, no leakage, not too firm
Smoothness - homogeneous texture, smooth, not granular or separated
Sweetness - degree (indicate)
Remarks

Firmness

Normal ________
Not firm enough ________
Slightly too firm ________
Much too firm ________