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THE EFFECT OF HOMOGENIZATION ON THE
GELATION AND PALATABILITY OF BAKED CUSTARDS
PREPARED WITH DRIED WHOLE EGG SOLIDS

By

Marjorie Eleanor Mastic

AN ABSTRACT

Submitted to the College of Home Economics
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Approved Evelyn M. Jones

Marjorie Eleanor Mastic

ABSTRACT

The effect of homogenization on the firmness of gel structure and palatability of baked custards prepared with 2 concentrations of spray-dried whole egg solids (DWES) were studied.

In the preparation of the custards from a standard recipe, dried egg solids were substituted for fresh eggs on a weight basis. Custards with a low concentration of egg contained an additional amount of milk equivalent in weight to the water necessary to reconstitute the dried egg solids. In custards with the high concentration of egg, the additional milk was omitted.

The dried egg custards were baked to the end internal temperature of 88, 90 and 92° C. in a 177° C. oven. Fresh egg control custards were baked to 88° C.

A taste panel of 7 persons from the Foods and Nutrition Department evaluated the following palatability characteristics on a 7-point scale: color and texture of the crust, color, aroma, flavor, texture, and consistency of the body of the custard.

Homogenization favorably affected the palatability of DWES custards. The non-homogenized variables were

significantly different in crust texture from the fresh egg custards. The homogenized DWES custards, often described as tough and "skin-like" on the surfaces, were not different from the control (1% level of probability). The crust color of the homogenized DWES custards was scored much higher than that of the non-homogenized DWES custards and slightly higher than that of the control which, in some cases, was noted as "pale" and "anemic." The flavor and aroma of the homogenized DWES custards, though not as desirable as the flavor and aroma of the fresh egg custards, were more acceptable than those of the non-homogenized DWES custards. The texture of the body of DWES custards was improved by homogenization. Particles of incompletely rehydrated dried egg were not present in the homogenized DWES custards but were evident in the non-homogenized DWES custards. The homogenized DWES custards were not significantly different from the controls. The fresh egg custard ranked highest in consistency. The firmness of the gel structure increased as the end internal baking temperature was raised from 88 to 90 to 92° C. The homogenized DWES custard baked to 92° C. was more firm while the homogenized DWES custard baked to 88° C. was less firm than the unhomogenized DWES custards baked to the same temperature. The color of the body of the DWES custards was not significantly different from the fresh egg custards.

Objective measurements indicated that the gel structure of the custards was greater when the high concentration of egg was used. Of the custards baked to 92° C., those receiving the homogenization treatment were usually more firm than those not undergoing the treatment. Homogenized custards baked to 88° C. were less firm than the non-homogenized custards. Significant correlations were found between the consistency scores and all of the objective readings.

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INTRODUCTION

In recent years, the demand for dried whole egg, yolk, and white increased sharply for use in commercial food products and in large quantity cooking. Work with the dried eggs, however, indicated that flavor and certain functional properties were altered during processing and storage. These changes limited the use of dried egg solids, as the quality of the foods in which they were incorporated was affected.

One of the changes in functional properties was the decrease in dispersibility upon reconstitution. An objectionable characteristic observed in custards made with dried whole egg of decreased dispersibility was the formation of a thick, tannish-orange surface crust and a weakened gel structure (3).

At Michigan State University, preliminary experimental work in the preparation of custards made with dried whole egg solids indicated that homogenization of the custard mix gave a product acceptable in appearance and comparable to custards prepared with fresh shell eggs.

The purpose of this study, therefore, was to determine the effect of homogenization on gelation and to compare the quality of baked custards made with 2

concentrations of dried whole egg solids and baked to 3 different end internal temperatures.

REVIEW OF LITERATURE

History

The egg-drying industry began in the United States shortly after the turn of the century; but because a cheaper product was obtained from China, the industry did not grow. With the Japanese invasion of China and the enforcement of a new tariff in the 1930's, importations were cut; and the drying of eggs was stimulated in the United States (24).

Only a small fraction of the total volume of eggs processed in the United States was dried before World War II. The amount varied from year to year, with the larger part being dried whites and dried yolks which were used in candies, noodles, and doughnut mixes (10). With the advent of war in Europe, the demand for dried whole eggs increased as it was realized that the concentrated product was a widely used and a highly nutritious protective food. In addition, the dried eggs were easier and less expensive to handle since they took less storage space and weighed considerably less than packaged shell eggs (19).

With the increased number of prepared mixes marketed in recent years, the demand for dried eggs became still greater. Rolfes, Clements, and Winter (26) stated that this demand would be even greater if various other food manufacturers could obtain equally good results. Extensive research was effective in extending the storage life of dried eggs and improving their palatability and functional performance by advances in methods of processing, facilities, equipment, and production standards (36).

General Method of Processing

A number of operations are involved in the preparation of dried whole egg, yolk, and white. The general procedure for the production of these products is summarized from several sources (10, 14, 29, 37).

(a) Candling

The fresh eggs are examined in a dark room for the presence of meat and blood spots. If spots are detected, the eggs are rejected.

(b) Washing

After candling, the shells of the eggs are washed when necessary with a detergent solution, followed by rinsing in a solution containing chlorine and then by fan-drying.

(c) Breaking and separating

The eggs are broken and yolks separated from whites if such treatment is planned. At this time any eggs having an off-odor are eliminated. Strict sanitation standards are of utmost importance in the breaking process.

(d) Blending and homogenizing

With blending or churning, smooth uniform products of yolks or whole eggs are obtained. Egg whites are not blended. Homogenizing completes the process of blending. The eggs are screened to remove any shell particles or membranes.

(e) Glucose removal

In this process the whole eggs, yolks, and whites are desugared by enzyme action or fermentation.

(f) Pasteurizing

Flash pasteurizing of the desugared whole eggs and yolks aids in checking the bacterial growth. Desugared whites are not pasteurized.

(g) Acidification

After pasteurization, dried whole egg solids are acidified to a pH of 5.5 by the addition of hydrochloric acid.

(h) Drying

Dried whole egg and dried yolk are prepared by pumping the liquid egg into the spray drier under high pressure. Whites are pan-dried and occasionally spray-dried.

(i) Packing

Packing of dried egg in an atmosphere of 20% carbon dioxide and 80% nitrogen is recommended.

Methods of Drying Eggs

Three commercial methods of drying eggs have been used in the United States. They include belt-drying, pan-drying, and spray-drying. The last 2 methods are much more important at the present time (24).

Belt-drying

This commercial method, developed early in the industry, was one in which the egg was poured onto metal belts about 4 feet wide and run through tunnels at low speed. Within the tunnels, heated air was circulated over the belt at 160° F. Mulvany (24) indicated that this method of drying was used to produce flaked yolk and flaked dried whole egg.

Pan-drying

Pan-drying is the method most used for the preparation of dried egg whites (19). In this method, a thin layer of stabilized liquid egg is placed on a tray or a shallow pan coated with wax or mineral oil. The pan is placed in a cabinet and warm air circulated over the eggs. The drying process takes 6 to 24 hours. The time is dependent on the temperature and air control in the cabinet. The dried egg white is flake-like and is referred to as crystalline albumen. Powdered albumen is prepared by grinding and screening the flakes.

Spray-drying

Spray driers have been divided into 2 groups (10, 24).

1) The tunnel or chamber type drier in which heated air passes through a chamber containing nozzles from which the liquid egg is sprayed.
2) The cyclone type drier in which the egg is sprayed into a whirling current of air in a tower or similar structure.

The operations involved in the processing of spray-dried eggs begin with a thorough mixing and straining of the broken liquid egg. This is followed by heating to 140° F. to improve the drying operation (19). The warm liquid egg, under a pressure of 2,000 to 6,000 pounds per square inch is sprayed from nozzles into a large drier chamber, through which a stream of air is passed at 250° to 300° F. The air picks up the moisture from the egg and leaves the chamber at 140° to 180° F. The temperature of the inlet air and the rate of flow of the liquid egg are adjusted to maintain the desired air outlet temperature. The egg powder settles in the bottom of the chamber from which it is withdrawn continuously (chamber or tunnel type drier), or it is in the exhaust air stream from which it is strained out (cyclone type drier) (10, 19, 24).

The powder contains 4% to 5% moisture. If 3% or less moisture content is desired, the powder is brought in contact again with dry air at 140° F. to 220° F. until the proper level of moisture is reached (19).

The spray-drying method has been used in the preparation of dried whole egg solids and dried egg yolk. Dried egg white has been prepared only to a limited extent by the spray-drying method. Lineweaver and Feeney

(19) pointed out that because of the character of the white, lower temperatures and pressures are required.

Stability of Dried Whole Egg Solids

Eggs have been widely used in foods because of the many important functional properties they possess. As a result of the drying process and storage, an alteration of some of these qualities occurred. This instability was one of the chief disadvantages of dried eggs. Decrease in dispersibility, the browning reaction, and flavor changes were properties of dried eggs which affected baked custards. A discussion of the functional properties affected by the processing and storage procedures, the causes of these changes, and methods of prevention follow.

Decrease in dispersibility

The quality of dried whole egg solids deteriorated with improper processing and poor storage conditions. This physical deterioration was measured in terms of dispersibility (3). Both increases in temperature of storage and water content influenced the rate of decrease of dispersibility (3, 20).

A freshly prepared and carefully dried sample of dried egg remained homogeneous when reconstituted and all

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allowed to stand (3). Dried egg which underwent decrease in dispersibility due to overheating during drying or high temperature storage creamed on reconstitution and standing. Microscopic examination of the layer which rose to the top and was referred to as "cream" showed that some of the small fat globules from the yolk of the egg fused together and some of the larger globules contained air bubbles. An objectionable characteristic of custards prepared from dried eggs of decreased dispersibility was the formation of a tannish-orange surface crust, 1/8 to 1/4 inch thick, which was the result of the creaming of the egg solids on reconstitution (11, 23). Lowe (20) described this crust as a rubbery egg layer which could be lifted off practically intact from the custards prepared with dried eggs.

Conrad et al.(10) stated that acidification of liquid egg to a pH of 5.5 before drying favored the retention of dispersibility of a dried egg powder in storage.

Browning reaction

The browning or Maillard reaction in dried eggs was another undesirable change which took place in storage, and its occurrence was reported by several investigators (11, 25). This reaction involved the aldehyde group of glucose, naturally present in the eggs, and the free amino group of proteins (25, 28, 36).

The rate of browning was influenced greatly by the temperature and length of storage, the pH, and the moisture content (20). As the temperature and length of time of storage were increased, the browning was greater. In addition, an increase in alkalinity speeded the browning reaction. Browning occurred more rapidly in a moist product than in a dry product.

Lineweaver and Feeney (19) indicated that glucose removal and acidification were 2 methods by which the stability of dried whole egg solids and dried egg whites was increased.

Flavor Changes

Flavor changes were reported by several experimenters (3, 4, 11) in their work with dried egg solids which made them unsatisfactory for use in straight egg dishes.

Hawthorne (15) stated that samples with high-moisture content tended to deteriorate in flavor more rapidly during storage than those with low-moisture content. In a later study, Bate-Smith, Brooks, and Hawthorne (3) pointed out that the rate of flavor deterioration was a function of the storage temperature and water content.

The deterioration of dried eggs was rapid at high temperatures and as water content increased, flavor changes were detectable at lower storage temperatures.

Palatability was also affected by an increase in the length of storage time as reported by Paul et al. (25).

The different types of off-flavors have been described as follows (3):

Storage - This was the flavor developed at moderate temperatures of storage (15° C.). It has often been described as "cardboard".

"Burnt" - This flavor resulted from high-temperature storage or overheating during drying. The burnt or carmelized flavor has been described as "biscuit".

"Fishy" - Low moisture content samples stored at 15° C. for long periods developed a "fishy" flavor.

"Acid" or "Cheesy" - This flavor was developed in samples which had a low pH after reconstitution. The texture of the product was grainy.

Other - The development of other flavors was due to storage in non-air tight containers near strong smelling materials.

These flavor changes were generally due to high-temperature deterioration or non-oxidative changes and to oxidative changes in the phospholipid fraction of the eggs (3).

The preparation of dried eggs of low-moisture content, the packaging of the dried eggs in containers from which all oxygen has been excluded, and storage at low temperatures were recommended as ways to control flavor changes (10).

Methods of Stabilizing

Acidification

The browning or Maillard reaction in dried eggs was minimized by the acidification process prior to drying. After pasteurization, liquid whole egg was acidified with hydrochloric acid to a pH of 5.5 and dried to a low level of moisture content. Sodium bicarbonate, approximately 1.5 pounds per 100 pounds dried egg solids, was mixed in with the dried product so that upon reconstitution, the acid was neutralized (28, 36).

Glucose removal

By the removal of the naturally occurring glucose from the egg, a more stable product was produced.

Fermentation and enzyme treatment were 2 methods of desugaring used.

Fermentation

Formerly egg whites were desugared by spontaneous fermentation. This was an uncontrolled type of fermentation with the length of time of fermentation dependent on the temperature and the type of organism at work. (24). Odors and the proteolysis evident in the later stages of fermentation and the presence of the Salmonella organism made this method objectionable (2). Baker's yeast and various micro-organisms were employed in the desugaring process of egg whites and whole eggs, also.

Enzyme treatment

Approximately 10 years ago enzyme treatment was introduced. It was found to speed up the desugaring process considerably (25, 27). Snyder (27) reported that glucose oxidase was one enzyme accepted unanimously by egg dryers. This enzyme catalyzed the reaction by which glucose was converted to gluconic acid in the presence of excess oxygen. The source of the oxygen was hydrogen peroxide, from which it was released by the enzyme, catalase, present in the commercial preparation of glucose oxidase. After adjustment of the pH to 7.0 - 7.5 by the addition of hydrochloric acid, the egg white was heated to 85° to 90° F. While held at that temperature, the enzyme preparation was added, followed by the continuous addition of hydrogen peroxide over a period of 7 hours. When all the glucose was converted, the egg white was dried. Enzyme activity was terminated by the drying process.

The same process, with minor adaptions, was used for the desugaring of whole eggs and yolks. Adjustment of the pH was not required. The egg was heated to a slightly higher temperature (100° F.), and a larger amount of the enzyme was used.

Inert gas packing

To prevent or lessen deterioration in storage due to oxidation, the egg solids were cooled immediately and put into cans. The cans were vacuumized and gased with a mixture of 20% carbon dioxide and 80% nitrogen. The carbon dioxide aided the stabilization of the flavor of the eggs while the nitrogen minimized the vacuum damage to the cans.

Low-moisture content

Another method of retarding deterioration of dried eggs was by low-moisture content, but this has not been completely effective in itself (30). Hawthorne (5) stated that there was no critical moisture content below

which deterioration would not occur. Since low-moisture dried egg powders have a longer shelf-life, the trend today has been to produce powders with a moisture content of 2 to 4%.

Low-temperature storage

Dried whole eggs became less "soluble" at the higher storage temperatures; and consequently, dispersibility was decreased (22). Jacobs (16) indicated that 50° F. was the maximum temperature at which whole egg should be stored for any length of time, even when the dried egg had a moisture content of 5% or less. Below 40° F. the changes were slowed; and at 0° F., they were practically eliminated. Thistle, White, Reid, and Woodcock (30) reported objective tests of quality indicated that even at temperatures as low as -40° C. egg powder deteriorated slowly.

Heat Coagulation of Protein

Although protein may be coagulated by many means, heat has been one of the more important methods. Weiser (33) stated that heat coagulation of protein occurred in 3 distinct processes. The first reaction, denaturation, was an intramolecular rearrangement (33) or an opening up of the protein molecule (20), whereby certain chemical groups not detectable in the native protein became evident in the modified product. The second process was the flocculation of the denatured molecules, followed by the formation of an insoluble coagulum from the flocculated mass, the third process.

In custards, the largest amount of heat coagulable protein is furnished by the egg. Only 0.75% of the heat coagulable protein is provided by the milk. Many factors affect the coagulation of protein and the gelation temperature of the custards. These factors include the pH of the mixture, the proportion of ingredients, and the rate of cooking. As a result, no one end baking temperature can be recommended as the optimum temperature to which a custard should be baked.

Effect of Acid

Weiser (33) indicated that certain protein sols coagulated at a definite temperature which was fairly constant for each protein. With the lowering of the pH by the addition of acid, the coagulation temperature was raised. Chick and Martin (8) pointed out that denaturation, the first part of the heat coagulation process, was not hastened by acid solution, but the clotting or coagulation process was speeded.

Effect of Alkali

Chick and Martin (9) found that the second part of the coagulation process, the clotting or coagulation, did not occur in alkaline solution. They pointed out that if, after heating, the alkali was neutralized with acid, the coagulation process occurred.

Effect of Sugar

The addition of sugar to egg protein raised the gelation temperature due to the peptization of the protein by the sugar. Lowe (20) concluded that this effect was directly proportional to the amount of sugar added.

Effect of Salt

Salts or electrolytes greatly influenced the behavior of protein. Coagulation was brought about by adsorption of an ion having a charge opposite that of the protein to which it was attracted (20, 33). The amount of ion needed was dependent on the concentration of the colloid, the concentration of the salt, and the valence of that ion. The effect of the concentration of the salt and the valence of the ion on the coagulation temperature was demonstrated in baked custards (20). In general, the amount of salt necessary to produce flocculation varied with the valence of the ion. The greater the valence of of an ion, the more effective was its coagulation power; and the more effective an ion was in its coagulating power, the less amount of that ion needed to bring about flocculation.

Effect of the Concentration of Protein

Lowe (20) stated that as the amount of protein increased, the temperature of gelation decreased. The lowering of the temperature was inversely proportional to the quantity of egg added.

Effect of the Rate of Cooking and Temperature

Lowe (20) reported that the rate of coagulation increased as the temperature was raised. In addition, a firmer custard was obtained as the temperature increased until at a specific temperature, dependent on the rate of cooking, optimum gelation occurred. Further heating to a higher temperature caused porosity and finally syneresis.

Experimentation showed that the rate at which custard was cooked affected the gelation temperature (20). With a slow rate of cooking, gelation of custard occurred at a lower temperature, while gelation took place at a higher temperature with a fast rate of cooking. A slower rate of cooking was considered most desirable because optimum gelation was more easily perceptible.

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Custards as a Medium for the Use of Dried Whole Egg Solids

The use of dried eggs depends on how well they retain the properties that make fresh eggs useful in cookery. Thickening power is one of the important functional properties of the egg and is closely associated with the dispersibility of the dried egg. Since the baked custard represents a type of cooked product in which egg is a principal ingredient and one in which the thickening property of the egg protein is used, it can be used to compare the gelation properties of dried and fresh eggs. Color, flavor, and odor are also detected easily in the custards as they are made of relatively few essential ingredients.

The quality of the dried eggs greatly affects the product in which they are used. Bate-Smith, Brooks, and Hawthorne (3) indicated that dispersibility could be used as a measure of quality. With deterioration, there is a decrease in the dispersibility of the dried egg which in turn affects the product.

Ary and Jordan (1) found a slower rate of heat penetration in baked custards prepared with dried eggs of low dispersibility than in those in which fresh eggs or dried eggs known to have a higher degree of dispersibility were used. The rate of rise in temperature was similar in custards prepared with fresh and dried egg until the temperature was reached at which the coagulation of egg protein began (68° to 70° C.). A possible factor responsible for the slowing down of heat penetration in the custards prepared with dried eggs of decreased dispersibility was the interference contributed by many small particles of incompletely rehydrated egg present in the gel structure.

The firmness of the gel structure is dependent in part on the quality of the dried eggs. Dawson, Shank, Lynn, and Wood (11) observed that freshly dehydrated eggs produced custards which were smooth and firm, while dried eggs which had rapidly deteriorated due to adverse storage conditions gave custards which were soft and watery in consistency. Jordan and Sisson (18) reported dried egg custards were firm enough to be of a desirable consistency but not as firm as fresh egg custards. Ary and Jordan (1) stressed that a less firm custard may be associated with a powder of reduced dispersibility.

The firmness of the gel structure also depends on the end internal baking temperature. No one specific temperature has been recommended due to variations in proportions of ingredients and the rate of cooking. Lowe (20) stated that custards have a serving consistency between

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82° to 84° C. if cooked at ordinary rates. Curdling may occur at 85° to 87° C. under similar cooking conditions. With a more rapid rate of heating, the custard may be heated to a higher temperature of 89° C. before curdling may be evident.

Carr and Trout (7) found that the rate of heat penetration was slower in custards made with homogenized milk than in those made with unhomogenized milk. The firmness of the custards indicated that the custards prepared with homogenized milk could be baked to a higher end internal temperature without seriously affecting the stability of the gel. Miller, Jones, and Aldrich (23) observed that the optimum gelation temperature of custards prepared from fresh shell, homogenized frozen, and blended frozen eggs with homogenized milk was 86° to 88° C., while custards prepared with dried whole egg solids and baked to the same temperatures were less firm. Their study indicated that a higher end internal baking temperature was desirable for custards made with dried whole egg solids.

Several experimenters (11, 23) reported the formation of a thick, tannish-orange surface crust of undesirable texture in custards prepared with dried eggs. This crust formation was directly related to the decrease in dispersibility of the dried egg solids. Miller, Jones, and Aldrich (23) suggested that a longer period of rehydration might reduce the thickness of the crust and, consequently, improve the texture.

Unpleasant changes in flavor became evident as the dried egg powder underwent deterioration. Bennion, Hawthorne, and Bate-Smith (4) reported that the unpleasant flavor made dried eggs undesirable for straight egg dishes, which included baked custards, but could be used satisfactorily in sponge cakes. Ary and Jordan (1) similarly found that the undesirable flavor of dried egg powders of decreased dispersibility was more objectionable in baked custards than in plain cakes. Dawson, Shank, Lynn, and Wood (11) pointed out that storage temperature was very important in the retention of flavor. Even after 1 year of storage at temperatures below 60° F., good flavor was retained. Jordan and Sisson (18) reported that custards made from dried eggs reconstituted by contact with water for 18 hours were nearly comparable in flavor to fresh egg custards. The study by Miller, Jones, and Aldrich (23) indicated that off-flavor was quite evident in custards prepared with dried egg solids.

Nutritive Value of Dried Whole Eggs

Since dried eggs completely replaced fresh shell

eggs in certain foods, the nutritive value of the dried eggs was of concern.

Good quality dried whole eggs were found to have about the same food value as shell eggs if properly stored (31). They contained iron and the protein was of good quality.

Several experimenters (5, 10, 35) studied the stability of the important vitamins in dried eggs. During the dehydration process, Whitford et al. (35) reported no destruction of vitamin A, thiamin, or riboflavin. With storage there was an appreciable decrease in vitamin A content, with the amount lost dependent on the length and the temperature of storage. Conrad et al. (10) pointed out that the loss of vitamin A was probably due to oxidation which could be prevented by storing in an inert gas atmosphere. Work by Bohren and Hauge (5) tended to confirm this theory. Considerable thiamine was destroyed upon storage but to a lesser degree than vitamin A. It was shown that reduction of the moisture content or acidification increased the stability of thiamine (10). Riboflavin and pantothenic acid were very stable in storage (12).

In view of these findings, dried eggs were considered a good source of riboflavin and pantothenic acid.

If properly handled, they also supplied thiamine and vitamin A in appreciable quantities (35).

EXPERIMENTAL PROCEDURE

Design of Experiment

Subjective and objective evaluations were conducted on baked custards prepared with spray-dried whole egg solids and with fresh shell eggs which served as the control. Two concentrations of dried egg solids were used.

The dried egg custards were baked to the end internal temperatures of 88° C., 90° C., and 92° C. in a 177° C. oven. The fresh egg custard was baked to an end internal temperature of 88° C.

The variables of dried egg custard mix received 2 treatments: homogenization and non-homogenization.

Four variables and a control were prepared each baking day. Six replications of each dried egg variable were baked. An entire replication of each variable, consisting of 20 custards, was baked at one time and included 7 custards for the subjective tests and 8 for the objective tests and 1 for the temperature reading.

Ingredients

Dried whole egg solids (DWES) from a common lot were used in the preparation of the custards. The whole egg solids were prepared commercially. They were enzymatically desugared by glucose oxidase with hydrogen peroxide and spray-dried to a moisture content of 2 to 4% in a Gray-Jensen dryer with air outlet temperature of 74° C. The DWES were cooled immediately to 46° C., packed in drums (July 19, 1957), and held at 7° C. After overnight shipment from the processing plant, the egg solids were stored again at 7° C., hermetically sealed in a nitrogen atmosphere in 3-pound tin cans, and shipped to Michigan State University (November 4, 1957) where they were refrigerated immediately at 5° C. The DWES were 18 to 20 months old when used in this study.

Fresh eggs for the control custards were obtained from a specific flock of White Leghorn hens at the Michigan State University Poultry Farm. The eggs were stored under refrigeration at the Poultry Building and were 2 days old when used.

Freshly processed homogenized milk was obtained in a large lot from the Michigan State University Dairy on the day preceding each baking day and was stored at 5° C. in a walk-in refrigerator.

The granulated sugar was from a common lot of beet sugar.

Formula

The weights of ingredients used in the preparation of the control custards and the custards prepared from the 2 concentrations of DWES are found in Table 1.

The formula for the fresh egg custard was based on the recipe in Lowe's text (20) with one change; namely, the amount of sugar was increased to 2½ tablespoons per cup of milk.

The weight of DWES substituted for the shell eggs was based on the fact that the raw whole egg contained 74% water and 26% solids (32). One concentration of DWES used in the preparation of custards was equal to the weight of the solids content of the fresh eggs in the formula for control custard. The weights of sugar and milk remained the same as those used in the control custard. For the purpose of simplification, the concentration of dried egg in these custards was designated as a high concentration. In the custards made with the second concentration of DWES, the milk was increased by an amount equivalent in weight to the water necessary for reconstitution of the egg solids. The weights of the dried egg and the sugar remained the same. This concentration of egg solids was designated as a low concentration.

TABLE 1

Formulas Used in the Preparation of Baked Custards

Ingredients	Fresh Egg Custard	Dried Egg Custards	
		High Egg Concentration*	Low Egg Concentration
	gm.	gm.	gm.
Milk	2440	2440	2791
Egg - Fresh	480	--	--
- Dried	--	129	129
Sugar	312	312	312
Salt	2	2	2

* Amounts of ingredients were increased one-tenth when mix was homogenized.

Preparation

The day preceding the preparation of the custards, the sugar, salt, and DWES were weighed into containers on a Toledo direct reading scale and tightly covered with Saran wrap. The DWES were refrigerated at 6° C.

The homogenized milk was weighed out as needed for preparation and heated to 27° C. in the top of a large double boiler. In the preparation of the DWES custards, 1 cup of milk was removed from the double boiler. The entire amount of sugar was added to the remaining milk and dissolved by an initial stirring for $1\frac{1}{2}$ minutes and five 15-second stirrings at intervals. Meanwhile, the cup of milk was added to the dried eggs and blended for 15 minutes by a Kitchen Aid mixer, model K5-A, with a whip attachment on speed 1 to form a paste. After 2 and 4 minutes, the mixer was stopped and the unmoistened DWES were scraped from the sides and bottom of the mixing bowl with a rubber scraper. At the end of the 15-minute blending period, the sugar-milk mixture was added in 2 equal portions. Each was blended with the dried egg-milk mixture at speed 1 for 5 minutes. The custard was poured through a #18 mesh strainer to separate out any large particles of dried egg.

Homogenization of the custard mix was done at the Michigan State University Dairy Plant in Anthony Hall in a laboratory homogenizer with a single stage process at a pressure of 2,000 to 2,500 pounds per square inch. The custard mixes were transported in large glass jars, transferred to stainless steel containers at the Dairy Plant, and warmed to 54.4° C. (130° F.) in a running hot water bath. After homogenization, the mix was cooled to 26.7° C. (80° F.) in a running cold water bath and returned to the Food's laboratory and baked immediately. The homogenized DWES custards were the first 2 variables baked on any given day.

For the fresh egg custards, the sugar was added to the entire quantity of milk and similarly dissolved by an initial stirring for 1½ minutes and five 15-second periodic stirrings. During this time 11 shell eggs were broken out and blended on a Kitchen Aid Mixer, model K3-C, for 6 minutes at speed 1 with a whip attachment. The eggs were weighed into a mixing bowl and the milk-sugar mixture added and blended on the Kitchen Aid mixer, model K5-A, for 6 minutes at speed 1. The custard mix was then strained.

The custards were baked in 5-ounce pyrex custard cups. Each cup was filled with custard mix to a measured depth of 1 3/4 inches. The cups, divided into

5 coded groups and numbered from 1 through 20, were placed in numerical order in a large stainless steel baking pan which contained a layer of screening to hold the cups off the bottom of the pan.

The baking pan was placed on a rack 3 inches from the bottom of a gas oven preheated to 177° C. Water at room temperature (25° - 27° C.) was poured into the baking pan until it came up to the level of the custard mix in the cups. Three lead wires from a Brown Electronik Potentiometer High Speed Multiple Point Recorder were suspended by means of clamps from the upper rack of the oven. The tip of one of these lead wires was centered in a custard in a central position in the baking pan. A second wire was placed in the water bath while the third wire was suspended freely in the oven. Time-temperature readings were obtained from the recordings made by the potentiometer during the baking of the custards. Readings were taken every 5 minutes for the first 50 minutes of baking, every 2 minutes for the next 10 minutes of baking, and every minute thereafter until the custards reached the desired internal temperature.

Upon completion of baking, the custards were removed from the water bath, placed on a wire rack, and allowed to cool at room temperature for at least 1½ hours before covering with aluminum foil for refrigerator storage.

Subjective Tests

All custards were randomized with regard to baking position for the subjective tests. The custards were covered individually with aluminum foil to prevent any intermingling of odors and were refrigerated at 6° C. until evaluated during the morning following the baking. The panel, composed of 7 judges from the Foods and Nutrition Department of Michigan State University, evaluated the cold custards on the following characteristics: color and texture of the crust, color, aroma, flavor, texture, and consistency of the body of the custard. A 7-point scale was used in the evaluation with 7 as the highest score. The judges were asked to record comments with regard to any outstanding features noted. A sample of the score card used in the subjection evaluation is in Table 24 of the appendix.

Objective Tests

All samples were randomized for the objective tests and were stored 19 to 22 hours at a refrigerator temperature of 5° C. before the tests were made on the cold custards.

Micrometer Adjustment Penetrometer

The firmness of the baked custards was determined by use of the Micrometer Adjustment Penetrometer. The custard cup was placed on a level platform directly beneath the cone attachment, with the point of the cone just touching the surface of the custard. The cone was released and a reading taken at the end of 5 seconds. The depth in millimeters to which the cone and rod (150 gram weight) penetrated the baked custard was considered a measurement of the firmness. Duplicate readings were taken on samples of all variables from which the crust was carefully removed and those from which the crust was not removed but loosened from the edges of the cup. As the reading increased, the amount of penetration was greater. This indicated a decrease in the firmness of the gel structure of the custard.

Curd Tension Meter

The Raytheon Curd Tension Meter (model number 2-505) was used to measure the firmness of the custards. Duplicate readings were taken on samples of all variables from which the crust was removed. The custard cup was placed on the platform of the instrument, directly beneath the cutting blade. The motor-driven blade was then lowered into the custard. The resistance offered the blade in passing through the custard was determined by the amount the float was raised out of the column of mercury. The measurements were obtained directly from a scale calibrated in grams.

Per cent Sag

The firmness of custards was also determined by measurements for the calculation of per cent sag. The height of the baked custard was measured to the nearest 1/32 inch by means of a depth gauge inserted into the center of the custard while it remained in the cup. The custard was then loosened carefully with a metal spatula and inverted on a glassplate. After 15 minutes the height was determined again by inserting the depth gauge into the center of the custard. The difference between the 2 readings divided by the original measured height and multiplied by 100 gave the per cent sag.

Statistical Methods

The data obtained from the subjective and objective tests on the baked custard variables were evaluated

by F tests for the analysis of variance. When significant differences due to the treatments were found, the mean scores for the variables on which the tests were made were compared using the studentized multiple ranges.

Correlation coefficients were calculated on the following pairs of items: consistency vs. curd tension meter readings (crust off); consistency vs. penetrometer readings (crust on); consistency vs. penetrometer readings (crust off); and consistency vs. per cent sag (inverted).

RESULTS AND DISCUSSION

The quality of baked custards prepared from homogenized and non-homogenized custard mix containing 2 concentrations of DWES, baked to the end internal temperature of 88° C., 90° C., and 92° C. were evaluated by subjective and objective tests. The scores obtained from these tests were analyzed by an analysis of variance and by the studentized multiple range (13) when significant differences were found. The mean taste panel scores and objective test readings for each replication of the baked custards variables and 2-way tables listing the mean scores of the custard under experimental conditions of treatments, temperatures, and concentrations ofegg solids are given in tables accompanying the discussion of the results obtained for each of the quality factors. An illustration of the analysis of variance and studentized range calculations for one of the quality factors are found in the appendix, on pages 86 to 90. The formula used in the correction for the 1 missing value in the per cent sag calculations is shown in Table 29 on page 91 of the appendix.

Subjective Tests

Color of the Crust

The mean scores for the color of the crust are listed in Table 2. The source of variation among the scores as indicated by the analysis of variance from which the scores of the control were excluded was the homogenization treatments.

In the 2-way tables in Table 3 are given the mean scores of the experimental treatments, temperatures, and concentrations of egg for the samples of baked custards. Comparison of the treatments by the studentized multiple range method showed that the homogenized DWES custards and the non-homogenized DWES custards were significantly different from the fresh egg custard and from each other.

Baked custards made from the homogenized mixes received higher mean scores than custards prepared from the non-homogenized mixes, irrespective of the concentration of the dried egg. Fresh egg custards had a mean score between those of the homogenized and non-homogenized samples.

The crusts of the non-homogenized DWES custards were an off-color (bright yellow to orange). This

Key:

Variable	
1	Homogenized DWES custards, high egg concentration, baked to 88° C.
2	Homogenized DWES custards, high egg concentration, baked to 90° C.
3	Homogenized DWES custards, high egg concentration, baked to 92° C.
4	Homogenized DWES custards, low egg concentration, baked to 88° C.
5	Homogenized DWES custards, low egg concentration, baked to 90° C.
6	Homogenized DWES custards, low egg concentration, baked to 92° C.
7	Non-homogenized DWES custards, high egg concentration, baked to 88° C.
8	Non-homogenized DWES custards, high egg concentration, baked to 90° C.
9	Non-homogenized DWES custards, high egg concentration, baked to 92° C.
10	Non-homogenized DWES custards, low egg concentration, baked to 88° C.
11	Non-homogenized DWES custards, low egg concentration, baked to 90° C.
12	Non-homogenized DWES custards, low egg concentration, baked to 92° C.
13	Fresh egg custard (control), baked to 88° C.

TABLE 2

Mean Scores for the Color of the Crust

Variable	Replications						Mean
	1	2	3	4	5	6	
1[1]	5.7[2]	5.4	5.4	5.3	5.3	5.9	5.50
2	5.6	6.0	5.3	5.1	5.4	5.3	5.45
3	5.4	5.4	5.3	5.6	5.6	5.2	5.42
4	5.6	5.7	5.7	5.3	5.6	5.3	5.53
5	4.7	5.3	5.6	5.6	5.4	5.3	5.32
6	5.9	5.7	5.3	5.0	5.4	5.6	5.48
7	3.6	3.6	3.9	3.4	4.0	3.9	3.73
8	3.7	3.9	2.4	3.7	3.4	3.1	3.37
9	3.7	3.9	3.3	3.3	3.6	4.0	3.63
10	3.3	4.0	3.7	3.4	3.3	3.9	3.60
11	2.9	3.9	4.0	3.9	3.3	3.3	3.55
12	4.4	3.1	3.0	3.6	3.1	3.4	3.43
13	4.2	4.3	4.7	5.0	4.8	5.0	4.67

1 Refer to the key for variables on page 39.
2 Mean score of 7 judges' evaluations of 1 replication of each variable.

TABLE 3

2-Way Tables for the Color of the Crust of Baked Custards under Specific Experimental Conditions

Treatments	Temperatures			Treatment Means**
	88° C.	90° C.	92° C.	
Homogenization	66.2	64.6	65.4	5.5
Non-homogenization	44.0	41.5	42.4	3.6

** The homogenization and non-homogenization treatments of DWES custards were significantly different from each other at the 1% level of probability.

Temperatures	DWES Concentrations		Temperature Means
	High Egg Conc.	Low Egg Conc.	
88° C.	55.4	54.8	4.6
90° C.	52.9	53.2	4.4
92° C.	54.3	53.5	4.5

Concentrations	Treatments		Concentration Means
	Homogenization	Non-homogenization	
High Egg Concentration	98.2	64.4	4.5
Low Egg Concentration	98.0	63.5	4.5

objectionable, intense color accounted for the low scores assigned the custards. The homogenized DWES custards had crusts of a lighter yellow. A slight gray cast was evident in the color of these samples also. The taste panel considered the crust of the fresh egg custard "pale" and "anemic" in some cases.

Browning was apparent frequently on the custards baked to 92° C. and occasionally on those baked to 90° C.

<u>Texture of the Crust</u>

The mean scores for the texture of the crust of the custards are presented in Table 4. The analysis of variance of the scores from which those of the control were excluded and the studentized multiple range showed significant differences in the joint effect of the treatments and concentrations on the crust texture. Variation due to replications was not significant. Table 5 includes the mean scores for this quality factor under the experimental conditions.

The fresh egg custards had the highest mean score for the texture of the crust and were considered the most acceptable. The scores for the texture of the crust of all the non-homogenized DWES custards were significant from the control at the 5% and 1% levels of probability. At the 1% level, all the non-homogenized DWES

TABLE 4

Mean Scores for the Texture of the Crust

Variable	Replications						Mean
	1	2	3	4	5	6	
1[1]	4.0[2]	4.0	4.7	4.3	5.3	4.9	4.53
2	5.0	4.3	4.6	5.1	4.4	4.4	4.63
3	4.0	4.7	4.9	4.7	5.0	4.0	4.55
4	4.1	4.4	3.4	4.6	4.6	4.7	4.30
5	4.0	3.4	4.9	4.7	4.7	4.1	4.30
6	4.6	4.3	4.7	3.7	4.6	4.6	4.42
7	3.9	2.9	4.0	3.0	3.6	3.4	3.47
8	4.0	3.4	1.9	3.7	3.0	3.3	3.22
9	3.1	3.0	2.3	3.4	3.6	3.3	3.12
10	3.6	3.3	3.4	3.0	3.1	4.0	3.40
11	3.1	3.1	3.1	3.3	3.4	3.4	3.23
12	4.6	3.4	2.9	3.9	3.9	3.9	3.77
13	4.1	4.6	4.4	5.1	4.9	4.9	4.67

1 Refer to the key for variables on page 39.
2 Mean score of 7 judges' evaluations of 1 replication of each variable.

TABLE 5

2-Way Tables for the Texture of the Crust of Baked Custards under Specific Experimental Conditions

Treatments	Temperatures			Treatment Means
	88° C.	90° C.	92° C.	
Homogenization	53.0	53.6	53.8	4.5
Non-homogenization	41.2	38.7	41.3	3.4

Temperatures	DWES Concentrations		Temperature Means
	High Egg Conc.	Low Egg Conc.	
88° C.	48.0	46.2	3.9
90° C.	47.1	45.2	3.8
92° C.	46.0	49.1	4.0

Concentrations	Treatments		Concentration Means
	Homogenization	Non-homogenization	
High Egg Concentration	82.3	58.8	3.9
Low Egg Concentration	78.1	62.4	3.9

custards except that variable containing the low concentration of dried egg and baked to 92° C. were significantly different from all samples of homogenized DWES custards with regard to the texture of the crust. The homogenized DWES custards and the fresh egg custards were not significantly different from each other.

The fresh egg custard was scored the highest in texture of the crust. The 3 homogenized DWES custard variables of high egg concentration were judged next highest, followed by the 3 homogenized DWES custard variables of low egg concentration. The judges indicated that the crusts of the homogenized DWES custards were tough and formed "skin-like" surfaces.

The crust of the non-homogenized DWES custards did not have a desirable texture. The taste panel noted that the crusts of these custards were thick, grainy, and porous. It was evident that incompletely rehydrated egg suspended in the custard mix contributed to the thickness and intensity of the color of the crust. These particles of egg rose slowly to the surface until the gelation temperature of the custard was reached. Variation in the texture of the crust was apparent within any one replication of the non-homogenized DWES custards. This variation was due to the differences in the amounts of creamed egg solids each cup held. The first custard cups filled from a container of the DWES custard mix tended to have a considerable amount of the creamed egg solids; and as a result, the crusts had a thick, moist, and extremely porous appearance. Later custards poured from the same container of custard mix had a thick, grainy, and smoother crust as less "cream" was present.

The homogenization process was a successful method whereby the texture of the crust of the DWES custards was altered to give an acceptable product. Possibly, the toughness associated with the crusts of the homogenized DWES custards may be explained in part by the greater dispersion of the fat globules in the DWES custard as a result of homogenization.

<u>Color of the Body of the Custard</u>

In Table 6 the mean scores for the color of the body of the custard are listed. An analysis of variance indicated no significant differences in the color of the body of the fresh egg custards and the custards prepared with whole dried egg solids. This fact was attributed to the attempt made to use fresh eggs which gave a product comparable in body color to that of the dried egg custards in order to eliminate any bias in scoring by the taste panel. Variation due to replications was not significant.

TABLE 6

Mean Scores for the Color of the Body of the Custard

Variable	Replications						Mean
	1	2	3	4	5	6	
1[1]	5.7[2]	5.9	5.0	5.1	5.7	5.4	5.47
2	5.7	5.6	5.6	5.6	5.0	5.3	5.47
3	5.7	5.7	5.6	5.4	5.3	5.4	5.52
4	5.3	5.6	6.0	5.3	5.0	5.1	5.38
5	5.1	5.3	5.7	5.4	5.4	5.4	5.38
6	5.6	5.7	5.0	5.7	5.7	5.6	5.55
7	5.6	4.9	5.4	5.4	5.6	5.4	5.38
8	5.7	5.4	5.4	5.1	5.1	5.4	5.35
9	5.7	5.3	5.1	5.4	5.4	5.9	5.47
10	5.1	5.3	5.1	5.0	5.1	5.4	5.17
11	5.1	5.7	5.1	5.4	5.3	5.4	5.33
12	5.9	4.7	5.4	4.9	5.3	5.4	5.27
13	5.3	5.0	5.1	5.4	5.3	5.3	5.23

1 Refer to the key for variables on page 39.
2 Mean score of 7 judges' evaluations of 1 replication of each variable.

<u>Aroma</u>

Table 7 shows the mean scores for the aroma of the baked custards. The source of variation among the scores for aroma shown by the analysis of variance which included the scores of the control was due to the treatments at the 5% level of probability. Further analysis of the individual factors which comprised the treatments indicated no differences in aroma between the DWES custards. The difference existed between the 2 types of egg used. Table 8 lists the mean scores for the aroma of the baked custards under the different experimental conditions. There were no significant differences between replications.

The fresh egg custard received the highest mean score and was considered typical in aroma. By the studentized multiple range method, the fresh egg custard scores were significantly higher than all other scores for the DWES custards except the homogenized DWES custards of both egg solid concentrations baked to 92° C.

Aroma was a quality factor which was sometimes hard to evaluate. This difficulty was expressed by several members of the taste panel.

<u>Flavor</u>

Table 9 gives the mean scores for the flavor of the baked custards. Treatments accounted for the

TABLE 7

Mean Scores for the Aroma

Variable	Replications						Mean
	1	2	3	4	5	6	
1[1]	4.9[2]	5.0	4.7	5.1	5.3	5.1	5.02
2	4.9	5.1	4.9	5.4	5.1	4.7	5.02
3	5.0	4.9	5.4	5.0	5.1	5.3	5.12
4	5.0	4.9	5.3	4.9	4.9	5.1	5.02
5	5.1	4.6	5.1	4.9	5.0	4.4	4.85
6	5.3	5.3	5.1	5.1	5.0	5.1	5.15
7	4.9	4.6	5.0	5.0	5.1	5.1	4.95
8	4.9	4.9	5.0	4.9	5.1	4.9	4.95
9	4.7	4.9	4.3	4.7	5.1	5.3	4.83
10	4.7	4.7	5.0	5.1	4.9	5.1	4.92
11	4.4	5.0	4.9	5.1	5.1	4.9	4.90
12	5.0	5.1	4.7	5.3	4.9	4.9	4.98
13	5.1	5.3	5.3	5.3	5.3	5.3	5.27

1 Refer to the key for variables on page 39.
2 Mean score of 7 judges' evaluations of 1 replication of each variable.

TABLE 8

2-Way Tables for the Aroma of Baked Custards under Specific Experimental Conditions

Treatments	Temperatures			Treatment Means
	88° C.	90° C.	92° C.	
Homogenization	60.2	59.2	61.6	5.0
Non-homogenization	59.2	59.1	58.9	4.9

Temperatures	DWES Concentrations		Temperature Means
	High Egg Conc.	Low Egg Conc.	
88° C.	59.8	59.6	5.0
90° C.	59.8	58.5	4.9
92° C.	59.7	60.8	5.0

Concentrations	Treatments		Concentration Means
	Homogenization	Non-homogenization	
High Egg Concentration	90.9	88.4	5.0
Low Egg Concentration	90.1	88.8	5.0

TABLE 9

Mean Scores for the Flavor

Variable	Replications						Mean
	1	2	3	4	5	6	
1[1]	4.4[2]	4.1	4.0	3.7	3.4	4.4	4.00
2	5.0	4.4	4.9	4.7	3.9	4.6	4.58
3	4.9	5.4	4.9	4.3	5.1	4.6	4.87
4	4.6	4.3	5.0	4.0	3.1	4.6	4.27
5	3.9	4.3	4.6	4.4	4.1	3.7	4.17
6	5.3	4.7	4.0	4.0	5.0	5.3	4.72
7	5.0	4.3	5.1	4.4	4.9	4.4	4.68
8	4.6	4.9	4.0	4.4	4.7	4.9	4.58
9	4.9	4.3	4.9	4.4	4.7	5.3	4.75
10	4.0	4.9	4.3	4.6	4.7	4.6	4.52
11	4.9	4.7	4.6	4.9	4.3	4.6	4.67
12	4.7	4.9	4.3	5.0	4.6	4.6	4.68
13	5.4	5.4	5.3	5.4	5.6	5.7	5.47

1 Refer to the key for variables on page 39.
2 Mean score of 7 judges' evaluations of 1 replication of each variable.

variation in flavor as indicated by the analysis of variance of the scores in which those of the control were included. Analysis of the individual factors involved in treatments to the DWES custards showed that the homogenization and non-homogenization treatments and the temperatures to which the dried egg custards were baked were statistically different. Variation due to replications was not significant. Table 10 shows the mean scores of the baked custard variables in relation to treatments, temperatures, and concentrations of egg.

The fresh egg custard was the most acceptable and had the highest mean score for flavor. It was considered typical in flavor. All DWES custards were scored significantly lower than the control (studentized multiple range methods of comparison). At the 1% level, only one sample, the homogenized DWES custard of high egg concentration baked to 92° C., did not vary significantly from the control. Nevertheless, this variable was not considered typical by the taste panel. The "eggy" flavor evident in the custards made with DWES was noted less frequently by the taste panel in those custards which had received the homogenization treatment.

Those custards baked to the end internal temperature of 92° C. were rated the highest of all the DWES

TABLE 10

2-Way Tables for the Flavor of Baked Custards under Specific Experimental Conditions

Treatments	Temperatures			Treatment Means*
	88° C.	90° C.	92° C.	
Homogenization	49.6	52.5	57.5	4.4
Non-homogenization	55.2	55.5	56.6	4.6

* The homogenization and non-homogenization treatments of DWES custards were significantly different from each other at the 5% level of probability.

Temperatures	DWES Concentrations		Temperature Means**
	High Egg Conc.	Low Egg Conc.	
88° C.	52.1	52.7	4.4
90° C.	55.0	53.0	4.5
92° C.	57.7	56.4	4.8

** All temperatures were significantly different from each other at the 1% level of probability.

Concentrations	Treatments		Concentration Means
	Homogenization	Non-homogenization	
High Egg Concentration	80.7	84.1	4.6
Low Egg Concentration	78.9	83.2	4.5

custards and were considered the most desirable in flavor. All of the custards contained the same amounts of sugar, but those baked to 88° C. appeared more sweet than those baked to 90° C. and 92° C.

Texture of the Body of the Custard

The mean scores for the texture of the body of the custard are given in Table 11. As determined by the analysis of variance, the variation of the scores from which the control was excluded was due to the interaction between the treatments and the end internal temperatures to which the DWES custards were baked. Variation due to replications was significant at the 5% level of probability. Possibly this was due to the differences in the amounts of incompletely rehydrated particles of dried egg which became trapped in the gel structure as it formed during the baking process. In addition, the taste panel's reaction to this effect on texture may be another source of the variation in replications. Mean scores of the experimental treatments, temperatures, and concentrations of egg protein for the custards are included in Table 12.

As indicated by the mean scores, the homogenized DWES custards with high concentrations of egg solids baked to 90° C. and 92° C. were judged the smoothest in texture.

TABLE 11

Mean Scores for the Texture of the Body of the Custard

Variable	Replications						Mean
	1	2	3	4	5	6	
1[1]	5.9[2]	6.0	5.0	5.1	6.0	4.6	5.43
2	6.4	5.9	5.9	5.7	5.6	5.1	5.77
3	5.9	6.1	6.0	5.3	6.1	5.1	5.75
4	5.4	5.6	6.3	4.7	4.3	5.0	5.22
5	6.0	5.6	6.0	5.4	5.6	5.3	5.65
6	5.9	6.0	5.1	5.4	5.7	6.1	5.70
7	5.1	5.3	4.9	5.1	4.6	5.0	5.00
8	5.3	5.0	5.3	4.4	4.6	5.0	4.93
9	4.9	4.1	4.9	4.4	5.0	5.6	4.82
10	4.4	5.6	4.7	4.1	4.9	5.3	4.83
11	4.9	5.4	4.9	5.3	4.3	5.3	5.02
12	4.7	4.6	4.7	4.1	4.6	4.6	4.55
13	5.9	5.8	5.7	5.3	5.8	5.8	5.72

1 Refer to the key for variables on page 39.
2 Mean score of 7 judges' evaluations of 1 replication of each variable.

TABLE 12

2-Way Tables for the Texture of the Body of Baked Custards under Specific Experimental Conditions

Treatments	Temperatures			Treatment Means
	88° C.	90° C.	92° C.	
Homogenization	63.9	68.5	68.7	5.6
Non-homogenization	59.0	59.7	56.2	4.9

Temperatures	DWES Concentrations		Temperature Means
	High Egg Conc.	Low Egg Conc.	
88° C.	62.6	60.3	5.1
90° C.	64.2	64.0	5.3
92° C.	63.4	61.5	5.2

Concentrations	Treatments		Concentration Means
	Homogenization	Non-homogenization	
High Egg Concentration	101.7	88.5	5.3
Low Egg Concentration	99.4	86.4	5.2

The control ranked next in texture followed by the homogenized DWES custards with low egg concentration baked to 92° C. and 90° C. All non-homogenized DWES custards were scored much lower. The poorer scores received by these custards was attributed in part to the yellow particles of incompletely rehydrated dried egg noted by the taste panel. The 2 non-homogenized DWES custards baked to 92° C. were scored the lowest. The taste panel described these variables frequently as porous. These results substantiate the inter-relationship of treatments and temperatures in this study.

The extreme differences in texture scores for the non-homogenized and homogenized DWES custards is due to the homogenization treatment which resulted in a greater dispersion of the dried egg. It would appear that the homogenized custards could withstand a higher end internal baking temperature before porousness was evident than could the non-homogenized custards. This thesis is in accord with the findings of Carr and Trout (7) in their work with custards made with homogenized milk.

Consistency

Table 13 shows the mean scores for the consistency of the baked custards. An analysis of variance of the scores from which those of the control were

TABLE 13

Mean Scores for Consistency

Variable	Replications						Mean
	1	2	3	4	5	6	
1[1]	5.0[2]	5.0	3.3	3.6	4.9	2.7	4.08
2	5.7	5.0	5.6	5.0	5.3	5.9	5.42
3	5.6	5.4	5.7	5.1	5.6	5.6	5.50
4	5.4	4.3	5.4	2.4	3.7	3.3	4.08
5	4.4	5.6	4.9	4.1	5.0	5.3	4.88
6	5.9	5.9	3.3	5.3	5.6	5.7	5.28
7	5.4	4.0	5.6	5.1	5.3	4.9	5.05
8	5.6	5.1	5.1	5.3	5.3	5.1	5.25
9	5.3	4.7	5.1	5.1	5.0	5.4	5.10
10	3.4	4.9	4.0	4.0	4.6	5.4	4.38
11	5.4	5.1	5.1	4.7	5.0	5.4	5.12
12	5.1	5.4	5.4	5.4	5.6	5.1	5.33
13	5.4	5.6	6.0	5.9	6.0	6.0	5.82

1 Refer to the key for variables on page 39.
2 Mean score of 7 judges' evaluations of 1 replication of each variable.

excluded indicated that the source of variation was the end temperature to which the custards were baked. Variation due to replication was not significant. Table 14 gives in 2-way table form the mean scores for the custard variables as influenced by the experimental conditions.

Taste panel evaluation showed that the consistency of the fresh egg custard baked to 88° C. was most preferred in firmness. Of the DWES custards, those custards baked to 92° C. received mean scores higher than those baked to 88° C. and 90° C. with the exception of the non-homogenized custard containing the high concentration of dried egg baked to 92° C. In the latter case, the non-homogenized DWES custards baked to 90° C. was slightly preferred. Although the custards baked to 92° C. were occasionally described as too firm, their consistencies were more desirable than those of the custards baked to the lower end internal temperatures. Custards prepared with the low concentration of egg and baked to 88° C. and 90° C., were designated as being "too soft" more frequently than those custards containing the high concentration of egg and baked to the same end internal temperature. The concentration of egg protein gave no statistical difference in the firmness of the DWES custards.

The analysis of variance of the scores for all

TABLE 14

Mean Scores for the Consistency of Baked Custards under Specific Experimental Conditions

Treatments	Temperatures			Treatment Means
	88° C.	90° C.	92° C.	
Homogenization	49.0	61.8	64.7	4.9
Non-homogenization	56.6	62.2	62.6	5.0

Temperatures	DWES Concentrations		Temperature Means**
	High Egg Conc.	Low Egg Conc.	
88° C.	54.8	50.8	4.4
90° C.	64.0	60.0	5.2
92° C.	63.6	63.7	5.3

** The 88° C. temperature was significantly different at the 1% level of probability from the 90° C. and 92° C. temperatures. The 90° C. and 92° C. temperatures were not significantly different from each other.

Concentrations	Treatments		Concentration Means
	Homogenization	Non-homogenization	
High Egg Concentration	90.0	92.4	5.1
Low Egg Concentration	85.5	89.0	4.8

the variables of baked custards and the studentized multiple range comparison indicated that the fresh egg custard which was baked to 88° C. was significantly different in consistency at the 5% level from all DWES custards baked to 88° C. The comparison of the end internal temperatures showed that the 88° C. temperature was significantly different in its effect on consistency from the temperatures of 90° C. and 92° C. The latter 2 temperatures did not differ statistically from each other. This is confirmed by the fact that the DWES custards baked to 88° C. received the lowest mean scores.

Objective Tests

Micrometer Adjustment Penetrometer

The depth to which the cone of the Micrometer Adjustment Penetrometer penetrated the baked custards was used as a measurement of the firmness of the custards. The mean penetrometer readings on custards with the crust on and off are included in Tables 15 and 16. The mean readings of custards with the crust on as affected by treatments, temperatures, and concentrations are shown in the 2-way tables in Table 17. The mean readings of custards from which the crust was removed and under the experimental conditions are found in Table 18.

TABLE 15

Mean Penetrometer Readings on Baked Custards with the Crust On

Variable	Replications						Mean
	1	2	3	4	5	6	
1[1]	32.1[2]	32.2	32.1	31.1	29.4	31.1	31.33
2	31.0	30.4	30.3	31.2	28.9	29.5	30.22
3	30.3	29.4	30.4	27.8	29.0	28.6	29.25
4	32.1	31.9	32.1	32.5	31.8	32.6	32.17
5	31.7	30.6	31.0	30.8	30.4	29.8	30.72
6	31.2	30.9	30.3	28.5	28.9	29.0	29.80
7	30.9	31.4	29.5	30.6	29.7	30.0	30.35
8	31.8	31.1	30.2	28.7	28.0	30.1	29.98
9	30.9	29.2	29.3	29.7	29.8	29.4	29.72
10	32.7	31.2	32.1	31.0	29.6	30.4	31.17
11	32.5	30.2	31.3	30.7	30.1	30.2	30.83
12	32.7	30.7	30.6	29.8	28.7	30.8	30.55
13	30.8	31.1	30.7	31.0	29.7	30.3	30.60

1 Refer to the key for variables on page 39.
2 Mean score of 2 readings on 1 replication of each variable.

TABLE 16

Mean Penetrometer Readings on Baked Custards with the Crust Off

Variable	Replications						Mean
	1	2	3	4	5	6	
1[1]	33.0[2]	33.8	33.3	32.3	31.7	34.1	33.03
2	32.7	34.4	31.6	33.0	30.6	31.2	32.25
3	31.3	30.3	31.3	29.8	30.9	31.1	30.78
4	34.0	33.0	33.2	35.2	33.0	32.5	33.48
5	34.7	31.7	32.8	31.9	31.6	30.6	32.22
6	32.9	31.4	32.1	30.1	30.7	31.7	31.48
7	32.5	33.8	32.1	32.3	32.0	32.3	32.50
8	34.1	32.9	32.1	31.3	30.5	31.4	32.05
9	33.1	31.7	31.5	31.3	30.5	32.0	31.68
10	34.2	32.2	32.6	32.6	32.5	31.9	32.67
11	32.4	33.2	33.6	32.4	32.6	32.2	32.73
12	33.4	32.0	31.9	32.0	29.9	30.7	31.68
13	32.4	33.4	32.0	31.2	31.1	31.2	31.88

1 Refer to the key for variables on page 39.
2 Mean score of 2 readings on 1 replication of each variable.

TABLE 17

Mean Scores for the Penetrometer Readings on Baked Custards (Crust On) under Specific Experimental Conditions

Treatments	Temperatures			Treatment Means
	88° C.	90° C.	92° C.	
Homogenization	381.0	365.6	354.3	30.6
Non-homogenization	369.1	364.9	361.6	30.4

Temperatures	DWES Concentrations		Temperature Means
	High Egg Conc.	Low Egg Conc.	
88° C.	370.1	380.0	31.3
90° C.	361.2	369.3	30.4
92° C.	353.8	362.1	29.8

Concentrations	Treatments		Concentration Means**
	Homogenization	Non-homogenization	
High Egg Concentration	544.8	540.3	30.1
Low Egg Concentration	556.1	555.3	30.9

** The high egg concentrations and the low egg concentrations were significantly different from each other at the 1% level of probability.

TABLE 18

Mean Scores for the Penetrometer Readings on Baked Custards (Crust Off) under Specific Experimental Conditions

Treatments	Temperatures			Treatment Means
	88° C.	90° C.	92° C.	
Homogenization	399.1	386.8	373.6	32.2
Non-homogenization	391.0	388.7	380.2	32.2

Temperatures	DWES Concentrations		Temperature Means
	High Egg Conc.	Low Egg Conc.	
88° C.	393.2	396.9	32.9
90° C.	385.8	389.7	32.3
92° C.	374.8	379.0	31.4

Concentrations	Treatments		Concentration Means
	Homogenization	Non-homogenization	
High Egg Concentration	576.4	577.4	32.1
Low Egg Concentration	583.1	582.5	32.4

An analysis of variance of the penetrometer readings from which the readings of the control were excluded indicated that the differences were due to the joint effect of treatments and temperatures at the 5% level of probability on custards with the crust off. The concentration of egg protein in the DWES custards and the interaction of temperatures and treatments were significant at the 1% level in samples tested with the crust on. Significant differences existed at the 1% level between the replications of the baked custards with respect to both penetrometer tests.

The rank of the mean readings of firmness of custards with the crust removed shows that all DWES custards baked to 92° C. were more firm than the control and that the homogenized variables were more firm than the non-homogenized samples. In general, the weakest gel structures were evident in the homogenized DWES custards baked to 88° C. This substantiates the slower rate of heat penetration into the custard due to the homogenization process reported by Carr and Trout (7).

In the custards in which the crusts were not removed, those baked to 88° C. ranked lowest in firmness. The mean readings indicated that dilution of the egg protein by the addition of extra milk produced a more delicate or weaker gel structure. The custards containing

the high egg solids concentration baked to 92° C. were equal or greater in firmness to those custards which contained the low concentration of egg protein baked to the same temperature.

Curd Tension Meter

The firmness of baked custards from which the crust was removed was measured by the curd tension meter. The mean curd tension meter readings of the baked custards are given in Table 19. Table 20 shows in 2-way table form the mean readings of the custards as affected by the treatments, temperatures, and concentrations of egg solids obtained from this test.

An analysis of variance of the readings on the custards from which the readings of the control were excluded showed that the concentration of egg protein affected the firmness of the gel structure. Variation due to replication was significant at the 1% level of probability. An interaction of the treatments and temperatures indicated significance at the 1% level.

It is evident from the mean readings that the resistance of the custard to cutting by the knife blades of the instrument was greater in custards containing the high egg concentration than in those custards made with the low egg concentration.

TABLE 19

Mean Curd Tension Meter Readings on Baked Custards

Variable	Replications						Mean
	1	2	3	4	5	6	
1[1]	24.5[2]	25.0	25.0	24.5	30.0	21.0	25.00
2	21.0	27.0	29.5	26.5	34.0	28.0	27.67
3	32.5	37.0	38.5	43.0	39.0	43.0	38.83
4	21.5	23.0	25.0	24.0	22.5	23.5	23.25
5	17.5	21.5	23.5	25.0	24.5	28.5	23.25
6	27.0	32.5	28.0	37.0	33.0	34.0	31.92
7	19.0	22.0	23.0	25.0	22.0	26.0	22.83
8	23.5	24.0	26.0	27.0	32.5	27.5	26.75
9	25.0	29.5	30.5	27.0	34.5	27.0	28.92
10	14.5	19.5	17.0	17.0	18.0	19.5	17.58
11	19.5	23.0	22.0	19.0	23.0	25.5	22.00
12	23.0	23.5	23.5	24.0	27.5	26.5	24.67
13	32.3	30.2	35.3	36.0	37.5	35.2	34.42

1 Refer to the key for variables on page 39.
2 Mean score of 2 readings on 1 replication of each variable.

TABLE 20

Mean Scores for the Curd Tension Meter Readings of Baked Custards (Crust Off) under Specific Experimental Conditions

Treatments	Temperatures			Treatment Means
	88° C.	90° C.	92° C.	
Homogenization	289.5	305.5	424.5	28.3
Non-homogenization	242.5	292.5	321.5	23.8

Temperatures	DWES Concentrations		Temperature Means
	High Egg Conc.	Low Egg Conc.	
88° C.	287.0	245.0	22.2
90° C.	326.5	271.5	24.9
92° C.	406.5	339.5	31.1

Concentrations	Treatments		Concentration Means**
	Homogenization	Non-homogenization	
High Egg Concentration	549.0	471.0	28.3
Low Egg Concentration	470.5	385.5	23.8

** The high egg concentrations and low egg concentrations were significantly different from each other at the 1% level of probability.

With a rise in the end internal temperature, the gel structure of the custards became firmer as determined by the greater resistance of the custard to cutting. No significant differences in firmness were indicated by an analysis of the variance of the readings as a result of an increase in the end baking temperature.

The mean scores show that the homogenized DWES custard of high egg concentration baked to 92° C. was the firmest. The control ranked second in firmness while the non-homogenized DWES custard baked to 92° C. was next.

Per cent Sag

The measurements for the calculations of per cent sag were used to determine firmness of baked custards. The mean per cent sag of the custards are listed in Table 21. Analysis of variance of the per cent sag calculations showed differences in concentrations significant at the 1% level of probability. The mean per cent sag for samples of the 2 concentrations are given in the 2-way tables in Table 22. Variation between replications was not evident.

The results showed that additional milk tended to weaken the gel structure of DWES custards. This accounts for the higher percentages of sag found in custards made with a low concentration of egg solids, baked to any given end internal temperature. The strongest gel structures

TABLE 21

Mean Per cent Sag of Baked Custards

Variable	Replications						Mean
	1	2	3	4	5	6	
1[1]	25.0[2]	28.4	38.6	31.3	27.1	28.9	29.88
2	23.7	24.5	24.2	26.6	21.8	22.7	23.92
3	17.4	14.6	21.1	17.9	21.3	18.8	18.52
4	27.4	34.0	32.7	32.9	31.3	31.6	31.65
5	28.5	25.0	26.8	31.9	24.2	25.3	26.95
6	24.5	22.9	32.6	22.9	26.1	26.3	25.88
7	27.2	26.7	25.5	26.2	26.8	23.3	25.95
8	24.5	25.0	24.0	26.8	24.2	25.0	24.92
9	26.0	18.4	18.5	26.5	21.7	23.1	22.37
10	37.0	28.9	19.6	30.2	24.8	28.4	28.15
11	27.5	23.4	28.3	26.5	28.1	27.8	26.93
12	23.5	28.5	24.5	27.1	22.9	24.5	25.17
13	26.4	28.4	27.8	26.0	23.4	24.5	26.08

1 Refer to the key for variables on page 39.
2 Mean score of 2 readings on 1 replication of each variable.

TABLE 22

Mean Per cent Sag of Baked Custards under Specific Experimental Conditions

Treatments	Temperatures 88° C.	90° C.	92° C.	Treatment Means
Homogenization	369.2	305.2	266.4	26.1
Non-homogenization	324.6	311.1	285.2	25.6

Temperatures	DWES Concentrations High Egg Conc.	Low Egg Conc.	Temperature Means
88° C.	335.0	358.8	28.9
90° C.	293.0	323.3	25.7
92° C.	245.3	306.3	23.0

Concentrations	Treatments Homogenization	Non-homogenization	Concentration Means**
High Egg Concentration	433.9	439.4	24.3
Low Egg Concentrations	506.9	481.5	27.5

** The high egg concentrations and the low egg concentrations were significantly different from each other at the 1% level of probability.

were evident in custards prepared with the high concentration of egg solids baked to 92° C. The homogenized variable ranked highest and the non-homogenized sample second. Next in firmness, and in the same order, was the homogenized custard with high egg concentration baked to 90° C. and the non-homogenized variable with high egg concentration baked to 90° C. These variables were followed by the non-homogenized sample with low egg concentration and baked to 92° C. which was slightly more firm than the homogenized custards having a low egg concentration and baked to 92° C. The fresh egg custard was comparable in firmness to the homogenized DWES custards of low egg concentration baked to 92° C. and the non-homogenized DWES custard of high egg concentration baked to 88° C. These findings indicated that an increase in egg protein contributed to a firmer gel structure as did the joint effect of treatments and temperatures which was found to be significant at the 5% level.

Correlation between Subjective Scores for Consistency and Objective Measurements

Correlation coefficients were calculated on the penetrometer and curd tension meter readings and the per cent sag values to determine the reliability with the taste panel's scores for consistency. The results

are shown in Table 23 and indicate close agreement between the subjective and objective evaluations of firmness. The formula used in the calculation of the correlation coefficients is found on page 92 of the appendix.

There was a significant negative correlation at the 1 per cent level of probability between the judges' scores for consistency and the penetrometer readings on the custards with the crusts on and on those custards with the crusts removed. This indicated that as the firmness of the custards increased, the taste panel's scores increased and the penetrometer readings decreased. A significant positive correlation existed between the taste panel's scores and the curd tension meter readings at the 1 per cent level. The resistance offered by the custard to the knife blades of the curd tension meter increased as the strength of the gel structure became greater. The judges' scores for firmness and the per cent sag calculations also gave a highly significant negative correlation.

TABLE 23

Correlation between Subjective Scores for Consistency and Objective Measurements of Baked Custards

	r Value
Consistency Score vs. Penetrometer Readings (Crust On)	- .428 **
Consistency Score vs. Penetrometer Readings (Crust Off)	- .482 **
Consistency Score vs. Curd Tension Meter Readings (Crust Off)	+ .448 **
Consistency Score vs. Per cent Sag (Inverted, Crust On)	- .560 **

* Significant at the 5 per cent level of probability

** Significant at the 1 per cent level of probability

SUMMARY AND CONCLUSIONS

The effects of homogenization of custard mix on the strength of the gel structure and the palatability of baked custards prepared with spray-dried whole egg solids (DWES) were compared. Fresh egg custards served as the controls in the study.

Two concentrations of DWES were used. One concentration of DWES, designated a high egg concentration, was equal to the weight of the solids content of the fresh egg used in the control custards. The weights of the milk and sugar were the same as those used in the fresh egg custards. In the custards containing the low concentration of DWES, an additional amount of milk, equivalent in weight to the water necessary to reconstitute the egg solids was used while the weights of the dried egg and sugar remained the same. The DWES custards received 2 treatments: homogenization and non-homogenization. The DWES custards were baked to the end internal temperatures of 88° C., 90° C., and 92° C. Custards made with fresh eggs were baked to 88° C. in a 177° C. oven.

The palatability of the custards was evaluated subjectively by a taste panel of 7 persons on the following characteristics: color and texture of the crust, color, aroma, flavor, texture, and consistency of the body of the custard. In rating the samples, a 7-point scale was used in which 7 was the highest possible score. Objective measurements of the gel strength of the custards included the penetrometer, curd tension meter, and per cent sag.

Analyses of variances of the fresh egg and DWES custards showed that the main source of variation among the subjective scores for palatability was the treatments received by the custards. These treatments included the homogenization process given to the DWES custard mixes and the end internal temperatures to which the custards were baked. The homogenization process gave favorable results in the DWES custards. The flavor and aroma of the homogenized DWES custards, though not as desirable as the flavor and aroma of the fresh egg custards, were more acceptable than those of the non-homogenized DWES custards. The color of the crusts of the homogenized DWES custards was scored much higher than that of the non-homogenized DWES custards and slightly higher than that of the control which, in some cases, was described as "pale" and "anemic." The texture of the body of the DWES custards was affected by an interaction which existed between treatments and temperatures. As the end internal baking temperature was raised to 90° C., the effectiveness of the homogenization process on the texture of the custards became greater. Irrespective of treatment, baking to an end internal temperature of 92° C. resulted more often in porosity in all variables but the homogenized custard of low dried egg concentration, as noted by the taste panel. The joint effect of treatments and concentrations affected the crust texture scores. The homogenized DWES custards containing the high concentration of dried egg received the highest scores. The end internal baking temperatures accounted for the source of variation in scores for consistency. With a rise in the end internal baking temperature, the firmness of the DWES custards became greater with the exception of the homogenized variable containing the high egg concentration baked to 92° C. The color of the body of the DWES custards was judged similar by the taste panel and was not significantly different from the control made with fresh eggs.

Objective measurements indicated that the gel strength of the custards was greatest when the high concentration of egg protein was used. The penetrometer (crust on) and curd tension meter and per cent sag readings showed that the additional milk used in the preparation of a DWES custard with the low egg concentration tended to weaken the gel structure of the body of the custard. The significance of the penetrometer (crust on) readings due to concentrations indicated that possibly the high egg protein concentration may have resulted in an increased resistance to cutting by the crust. An interaction of the temperatures and treatments also affected the firmness of the custards. The mean scores of the variables showed the custards of high egg concentration baked to 92° C. were more firm than those of low egg concentration baked to the same temperature. Of the custards baked to 92° C., those receiving the homogenization treatment were firmer than those custards not undergoing the treatment. The penetrometer (crust off) and per cent sag readings showed similar trends. Significant correlations were found between the consistency scores and all of the objective readings.

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APPENDIX

TABLE 24

SCORE CARD FOR BAKED CUSTARDS

CHARACTERISTICS	SAMPLES				
CRUST Color					
Texture					
BODY OF CUSTARD Color					
Aroma					
Flavor					
Texture					
Consistency					
General Comments					

Scoring Key:

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

Definitions of Characteristics:

Crust:	Color - Typical color	Off-color
	Texture - Tender, smooth, thin	Tough, grainy, thick
Body:	Color - Typical yellow	Off-color
	Aroma - Typical fresh	Off-odor
	Flavor - Natural, delicate	Strong, off-flavor
	Texture - Smooth, compact	Porous
	Consistency - Firm	Too firm, soft

TABLE 25

A Statistical Analysis of Consistency

Analysis of Variance with Control Included

Source of Variation	df	Sum of Squares	Mean Squares	F
Total	77	45.90	--	--
Replications	5	2.13	.43	1.10
Treatments	12	20.63	1.72	4.41**
Replications X Treatments	60	23.14	.39	--

* Significant at the 5% level of probability
** Significant at the 1% level of probability

Correction Term = CT = $\frac{(\Sigma X)^2}{N} = \frac{(391.8)^2}{78} = 1968.04$

Total Sum of Squares = $\Sigma X^2 - CT = 2013.94 - 1968.04 = 45.90$

Replication Sum of Squares = $\frac{\Sigma r^2}{13} - CT$

$= \frac{(67.6)^2 + (66.0)^2 + \ldots + (65.8)^2}{13} - 1968.04$

2.13

Treatment Sum of Squares = $\frac{\Sigma t^2}{6} - CT$

$= \frac{(24.5)^2 + (32.5)^2 + \ldots + (34.9)^2}{6} - 1968.04$

$= 20.63$

Replication X Treatment Sum of Squares = $45.90 - (2.13 + 20.63)$

$= 23.14$

TABLE 26

Studentized Multiple Range Comparison of Treatments at the 1% Level of Probability

$S_{\bar{Tr}} = \sqrt{\frac{.39}{6}} = .255$

Studentized Multiple Range Numbers:

2	3	4	5	6	7	8	9	10	11
3.76	3.92	4.03	4.12	4.17	4.23	4.27	4.31	4.34	4.37

12	13
4.39	4.42

Studentized Multiple Range Numbers X $S_{\bar{Tr}}$:

(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
.959	1.000	1.028	1.051	1.063	1.079	1.089	1.099	1.107

(11)	(12)	(13)
1.114	1.119	1.127

Consistency Mean Scores:

Variable #:								
13	3	2	12	6	8	11	9	7
Mean Score:								
5.817	5.500	5.417	5.333	5.283	5.250	5.117	5.100	5.050

Variable #:			
5	10	1	4
Mean Score:			
4.883	4.383	4.083	4.083

Illustration:

5.817 + .959 = 6.776   5.817 - .959 = 4.858

Conclusions:

Variable #13 is significantly different from variables #10, 1, and 4.
Variables #3 and 2 are significantly different from variables #10, 1, and 4.
Variables #12, 6, and 8 are significantly different from variables #1 and 4.
Variable #10 is significantly different from variable #13.
Variable #1 is significantly different from variables #13, 3, 2, 12, 6, and 8.

TABLE 27

A Further Statistical Analysis of Consistency

Analysis of Variance with Control Excluded

Source of Variation	df	Sum of Squares	Mean Squares	F
Total	71	41.48	--	--
Replications	5	2.55	.51	1.24*
Temperatures	2	11.40	5.70	13.90**
Treatments	1	.49	.49	1.20
Concentrations	1	.87	.87	2.12
Treatments X Temperatures	2	2.10	1.05	2.56
Treatments X Concentrations	1	.01	.01	.02
Temperatures X Concentrations	2	.46	.23	.56
Treatments X Temperatures X Concentrations	2	1.21	.61	1.49
Replications X Treatments	55	22.39	.41	--

* Significant at the 5% level of probability
** Significant at the 1% level of probability

Correction $\text{Term}_1 = CT_1 = \frac{\Sigma X^2}{N} = \frac{(356.9)^2}{72} = 1769.13$

Total Sum of Squares $= \Sigma X^2 - CT_1 = 1810.61 - 1769.13 = 41.48$

Replication Sum of Squares $= \frac{\Sigma r^2}{12} - CT_1 = \frac{(62.2)^2+(60.4)^2+..+(59.8)^2}{12} - 1769.13$
2.55

Treatment Sum of Squares $= \frac{\Sigma t^2}{6} - CT_1 = \frac{(24.5)^2+(32.5)^2+..+(32.0)^2}{6} - 1769.13$

$= 16.54$

Replication X Treatment Sum of Squares $= 41.48 - (2.55 + 16.54) = 22.39$

TABLE 28

Studentized Multiple Range Comparison of Temperatures

at the 1% Level of Probability

$$S_{\bar{x}\,\text{Temp}} = \sqrt{\frac{.41}{24}} = .131$$

Studentized Multiple Range Number:

2	3
3.76	3.92

Studentized Multiple Range Number X S_{Temp}:

(2)	(3)
.493	.514

Temperature Mean Scores:

Temperature °C.	92° C.	90° C.	88° C.
Mean Scores	5.304	5.167	4.400

Conclusions:

92° C. is significantly different from 88° C.
90° C. is significantly different from 88° C.

TABLE 29

Procedure for Correction for the Missing Value in Per cent Sag Calculations

One missing value was calculated by the following formula:

$$x = \frac{r.R + t.T - G}{(r-1)\ (t-1)}$$

$$x = \frac{6\ (31.99) + 13\ (157.0) - 1985.3}{5 \cdot 12} = \frac{1975.1}{60} = 32.92$$

Key:

x = missing value

r = number of replications

R = sum of scores in replication column in which missing value occurs

t = number of treatments

T = sum of scores in treatment row in which missing value occurs

G = grand total

TABLE 30

Procedure for Calculation of Correlation Coefficients (34)

Formula:

$$r_{xy} = \frac{\Sigma XY - \frac{(\Sigma X)\ (\Sigma Y)}{N}}{\sqrt{\left[\Sigma X^2 - \frac{(\Sigma X)^2}{N}\right]\left[\Sigma Y^2 - \frac{(\Sigma Y)^2}{N}\right]}}$$

Key:

r_{xy} = correlation coefficient

ΣXY = sum of the cross products or (X) (Y)

N = number of pairs of observations

ΣX = sum of the taste panel's scores for consistency

ΣY = sum of the values for the objective tests

ΣX^2 = sum of the squared scores for consistency

ΣY^2 = sum of the squared values for the objective tests

APR ~~11~~ 1960

~~JUL 10 1960~~

~~OCT 10 1960~~ pd.

OCT 2 8 1960

~~NOV 18 1960~~ pd.

~~DEC 5 1960~~

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