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Effect of concentrating egg white on desirability of angel cake

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EFFECT OF CONCENTRATING EGG WHITE ON

DESIRABILITY OF ANGEL CAKE

by

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INTRODUCTION

The problem of concentrating egg whites was studied in an effort to obtain an egg white product which combined small volume and good keeping qualities with all of the desirable characteristics of fresh egg whites. Present commercial methods of producing dried egg white are such that the finished product does not perform in all respects in a manner comparable to the performance of fresh egg white. This deficiency in the product is particularly apparent when dried egg whites are used in angel cakes. In baked products the extensibility and coagulability of the proteins of the egg white are important in addition to their foaming ability. Commercially dried whites used in food preparation seem to retain their foaming properties but lose some of the properties essential in baked products.

Among other things, this study was planned to show whether the degree of concentration of the egg white was in any way related to the performance of the product in angel cake. It was considered possible that a certain amount of the water in the egg white might be removed without significantly damaging the product. In that event the deficiency of commercially dried whites might be partially explainable by the fact that they are dried to a low moisture content. If the degree of concentration were responsible for the unsatisfactory performance of dried whites in angel cakes, the cake quality should show a progressive decline as the degree of concentration of the egg white was increased.

Since the method used in dehydrating egg whites might very well be the cause of the damage to the product, this problem was planned so that two methods could be compared. One of these was a modification of the present commercial method known as pan drying. In that method the water is removed from the pans of egg white by the passage of heated air over the product. The other method used is known as vacuum drying from the frozen state or "lyophilizing". In that method the water is removed from the egg white while it is in a frozen condition.

In order that the results of the problem might be of value to industry, it was planned that the data compiled should include results on the time of processing of the eggs, temperature of processing, and a description of the appearance of the egg white at the various stages of concentration between the fresh control and the dried product. These data would give an indication of how far the egg white should be concentrated in order to have the physical properties desired by industry. Angel cake was chosen as the vehicle for testing the concentrated egg whites prepared by the two different methods, since differences in the quality of the egg white preparations would be reflected in changes in cake volume, tensile strength, and palatability. A study of the effect of storage on the concentrated product at room temperature (21.1°C.), refrigerator temperature (1.7°C.), and frozen storage temperature (-17.8°C.) was planned in order to compare the keeping qualities of fresh and concentrated egg white.

Preliminary experiments with the modified pan drying method of concentration were complicated by difficulties relating to some of the physical properties of the mucin fraction of the egg white proteins. It was found that when the mucin was removed before the egg white was concentrated, the concentration could be accomplished more easily. However, the angel cakes made from these mucin-free eggs were unacceptable. For this reason, the study of the role of mucin in angel cake was included in the problem.

REVIEW OF LITERATURE

A. Dehydration Methods

Present commercial methods for the dehydration of egg products include the spray method, the tray or pan method, and the belt method (43). In the spray method, used mainly for yolks and whole eggs, the liquid egg is sprayed under pressure into the top of a chamber heated to 71.1°C. to 76.6°C. (160°F. to 170°F.). In the belt method a thin film of liquid egg flows onto an endless aluminum belt where it is dried for one and one half to two hours in a warm chamber at 60°C. (140°F.). Heated, filtered air circulates above the egg on the belt. The partially dried egg is then spread on trays and dried further at 37.7°C. to 43.3°C. (100°F. to 110°F.) for two to three hours (43). The finished product contains 3% to 8% moisture (27). Egg albumen is usually dried commercially in trays or pans at 45°C. to 50°C. (113°F. to 122°F.). The trays are placed on shelves in a cabinet through which hot air is forced. After a thick skin forms on the product, drying is completed at 22°C. to 30°C. (71.6°F. to 86°F.) (40). Drying by this method is usually completed in 18 to 24 hours. The industrial preparation of egg white also usually involves a thinning process. The thinning process is brought about by fermentation in open vats for four to six days, by the addition of tryptic enzymes, or by treatment of the whites with acid before drying. Watts and Elliott (46) have reported that the foaming ability of the egg is increased by the thinning process but the baking quality of the egg white is adversely affected.

A method of vacuum drying from the frozen state was first described by Flosdorf and Mudd (14), who used it for preserving the lyophilic properties of serum. They described the procedure as "essentially one of rapid freezing at a very low temperature and rapid dehydration from the frozen state under high vacuum". In their original article these authors reported that the method had been successfully used for preserving protein solutions, bacterial cultures, and viruses. The name by which the process is now known, "lyophilizing", was selected because the dehydrated products redissolved so easily and completely on the addition of distilled water. They retained their "lyophile" or "solvent-loving" properties. Flosdorf and Mudd stated that the solubility of serum dehydrated by this method was the result of the unchanged properties of the proteins and the physical structure of the dehydrated material. The dehydrated product was in the form of a porous solid which occupied approximately the same volume as that of the original liquid.

The process described by Flosdorf and Mudd involved sublimation of water vapor from the surface of the frozen product. This occurred when the vapor pressure of the solid became greater than the external pressure before the melting point of the material was reached. Best (8) has described the application of the process to the drying of eggs. The liquid egg was frozen in a layer on the inside of a flask, and the flask was then attached to a system which was evacuated by vacuum pump to a pressure less than the vapor pressure of ice (4.58 mm. of mercury at the melting point of ice). When the ice from the layer of egg sublimed, it passed to a condenser submerged in an alcohol bath at -45°C. and was again frozen. Heat was supplied to the flask from the external air equal in amount to that which was removed by sublimation. The heat which was liberated when the vapor was frozen in the condenser passed through the condenser to the alcohol bath. According to Flosdorf and Mudd (14), as the drying proceeded, the rate of sublimation decreased and the temperature of the material gradually rose. The higher aqueous tension helped in driving out the remainder of the water and shortened the drying time. The rate of evaporation was dependent upon the difference between the vapor pressure at the freezing point of the liquid which was being dried and the vapor pressure of water at the temperature of the bath surrounding the condenser. Therefore, a lower temperature in the condenser would speed the rate of evaporation.

Flosdorf (13) reported that drying by sublimation prevented bacteriological action and reduced the loss of volatile components. He declared that in general, "drying from the frozen state produces less change in physical, chemical and nutritional characteristics than any other method of dehydration". Raw meat, milk, orange juice, pineapple juice, tomato products, and oysters have all been dried successfully by this method (13,22). Vitamin C was maintained practically without loss during the process. The bacterial count was neither increased nor decreased during the dehydration of milk (13), and there was no increase in the count during subsequent storage of the dry products.

Dehydration with infra-red radiation has been reported successfully used on meats, fish, and vegetables (11,45). Higher rates of heat transfer were obtained with radiant heat than with the usual hot-air ovens. According to Tiller et al. (45), the main factors in the net rate of heat transfer are the intensity of radiation, the absorptivity of the material, the surrounding air temperature, and the air circulation. Experimental work with vegetables showed that the time for dehydration depended upon the thickness of the vegetables. The rate of dehydration was found to increase to a maximum and then decrease as the material approached dryness.

B. Microbiology

Eggs which have been removed from the shell are readily susceptible to bacterial spoilage. Sharp and Stewart (38) have reported that an off odor or flavor in eggs may be caused by bacterial growth, absorption of odors or flavors from the surroundings, or chemical changes in the egg contents. The increasing demand for frozen and dried eggs has led to several studies on the effect of various methods of processing and storage of eggs on their microbiological quality. Most of the research reported has been done on whole eggs rather than on egg white, but the methods used are equally applicable to the egg white products.

According to McFarlane (30), the direct microscopic count is superior to the plate count for determining the presence of microorganisms in eggs. The former is a more rapid method, since it can be completed within an hour and does not require the three-day incubation period of the plate method. Both living and dead microorganisms are included in the microscopic count, and for that reason it is believed to present a truer picture of the quality of the egg. Breed and Brew (9) using the direct count on samples of milk reported that errors in the count might be caused by several factors. If the original sample was incorrectly measured or if bacteria grew on the slide while the sample was drying, an error would be introduced. Inaccurate counting could be the result of carelessness, poor preparations, or mistaking objects for bacteria which were not bacteria. Irregular distribution of bacteria in clumps might also lead to error. These authors reported that with samples of milk it was possible to determine with a small degree of error from the direct count whether the milk would give a plate count of less than 60,000, less than 200,000, or less than 1,500,000.

Johns and Berard (24) reported that the direct microscopic count was more accurate in giving a history of the egg sample than was the plate count. The plate count was affected by the kind of drier, temperature of drying, speed of removal from the drier, rate of cooling and storage conditions. Low plate counts were often obtained from samples which had a high original bacterial count.

Hartsell (19) found that the bacteria present in fresh dried egg powder depended upon the number and kind of organisms present in liquid whole egg, the temperature of processing and storage, the activity of lysozyme, pasteurization, evenness and method of drying, and amount of moisture in the finished product. He also found that dehydration of whole eggs was responsible for a sharp reduction in total bacterial count in the first few days of storage. When the temperature of storage of the dried egg product was increased there was a decrease in total bacterial count. There was a great reduction in total numbers of bacteria in samples stored at 37°C. after three months, but storage at 0°C. caused little difference in total count. Spore-formers withstood storage conditions better than non spore-formers. Organisms of the genus Bacillus predominated after three months' storage of the spray-dried egg powder. Higher counts were obtained if the plating media were incubated at 32°C. than at 37°C.

Thistle, Pearce, and Gibbons (44) found that grinding the egg powder in a mortar with sand and water gave a homogeneous emulsion. Their counts were made after three days' incubation at 37°C.

Lepper, Bartram, and Hillig (28) studied both bacteriological and chemical criteria for decomposition of liquid, frozen, and dried eggs. They stated that with liquid or frozen eggs a microscopic count of over 5,000,000 per gram and with dried eggs a count of over 100,000,000 per gram together with certain chemical tests indicated decomposition. They also stated that in the absence of other criteria, decomposition could be detected by the odor of the product.

Some interesting results on the effect of temperature and moisture on the bacterial content of liquid and dried egg have been reported by Gibbons and Fulton (15). They found that the bacterial content of liquid egg increased rapidly after holding for 6 hours at 20°C., 12 hours at

15.6°C., 25 hours at 11.1°C., and 2 to 3 days at 7.2°C. At 3.3°C. they found little change for the first 5 to 6 days, followed by a very gradual increase. They reported that the bacterial content of dried egg powder was affected by the number of bacteria in the original liquid egg, the temperature of drying, the rate of cooling, the storage temperature, and the moisture content. Low temperatures of drying followed by rapid cooling of the powder favored survival of bacteria. Increasing time and temperature of storage favored increased bacterial mortality. They also found that above 30°C., the mortality rate was proportional to changes in temperature. The organisms survived eight months' storage at 7.2°C. and below. Moisture content of the powder up to 8.6% seemed to have little effect on bacterial growth, but above 5% moisture there was an increase in the number of molds, especially at 23.9°C. and 32.2°C.

C. Ovomucin

Egg white has been found to contain at least five different protein fractions: ovoglobulin, ovomucin, ovalbumin, conalbumin, and ovomucoid (39). Of these proteins ovomucin is the only one which is a gel in its normal condition within the egg (32). It is now believed that the main difference between thick and thin egg white is due to the greater proportion of ovomucin in the thick white. According to Moran (34) the highly swollen mucin fibres form a framework which gives to thick egg white its characteristic appearance. There is not enough mucin present in the thin portion of the egg white to form such a framework. Moran reported the mucin content of thick and thin egg white as follows:

Outer thin white:	0.21-0.56 g. per 100 g. dry matter
Middle thick white:	1.49-2.45 g. per 100 g. dry matter
Inner thin white:	--- -0.33 g. per 100 g. dry matter

During storage of egg white there is a decrease in the amount of thick white present and a decrease in its gel strength, but the ovomucin does not disappear during this change. The change may be caused partly by a chemical breakdown and partly by shrinkage or partial collapse of the framework of mucin fibers (34). Almquist and Lorenz (1) reported that liquefaction could be caused by two different processes. When an excess of CO_2 was present the mucin fibers were believed to contract and squeeze out the liquid material which had been held in the framework. When there was insufficient CO_2 present the thinning was caused by a breaking up of the fibers. The effect of CO_2 probably depends mainly on the maintenance of the hydrogen-ion concentration within a certain range (31). Breaking up of the mucin fibers may be retarded by maintaining the pH of the egg white around 8 (4).

Ovomucin is a glucoprotein. It is soluble in dilute alkali and is precipitated by dilute acids. It is soluble in strong mineral acids but not in acetic acid (32). It has been found to have a low nitrogen content (12.9%) (31). It may be precipitated by dilution with two or three volumes of water or by acidification to pH 5. It may be salted out by 0.3 saturation with ammonium sulfate (4, 47).

If egg white is frozen and thawed, the material separates into two portions. The viscous portion contains fibers of mucin which have precipitated and separated from the fluid portion during the freezing

(12). Epstein (12) has reported that if the mucin became denatured by freezing or other means, the foaming value of the egg white would be impaired. He considered the function of mucin in a foam to be as follows: (12, p.75,76)

> The egg white contains a protein material known as mucin which has a characteristic unique property of becoming coagulated when shaken, beaten or whipped. When air is whipped into the egg white, the mucin which is absorbed in the form of films at the surface of the air bubbles coagulates, forming a rigid network in which the air cells are embedded, resulting in the characteristic whipped egg white foam.

Balls and Hoover (4) reported that removal of the mucin left a product which still contained about 95% of the original protein. The material remaining, however, was a "watery solution of low viscosity". According to Sorenson (39), 1.9% of the total protein of egg white is mucin.

D. Angel Cake

Angel cake was selected as the medium for testing the quality of the egg white products because it can be a very critical index of any changes in the performance ability of the eggs. In order to be satisfactory for use in angel cake, the egg white must retain not only its foaming properties but also its baking properties. A change in either of these qualities will invariably result in poor volume, increased tensile strength and a decrease in the palatability of the angel cake. Although it is very sensitive to egg quality, angel cake is equally sensitive to any mishandling in its preparation or baking. Even a slight variation in the temperature of the ingredients, in the method or time of mixing, or the time or temperature of baking will result in measurable differences in cake quality. Therefore, it is of the greatest importance that all conditions which can be controlled should be standardized so that any variation in the resulting cakes can be ascribed to a variation in the quality of the eggs.

It is obvious that control of the ingredients and equipment used in the making of the cakes is fundamental in obtaining reproducible results. Any variable which could be caused by variable ingredients can be eliminated by purchasing at the beginning of the problem large enough quantities of flour, sugar, cream of tartar and salt of the same brand to last for the duration of the experiment. The use of eggs of similar quality and storage history will aid in standardizing conditions. Whenever possible enough eggs should be obtained at one time to fill the requirements of any one experiment. They can then be held under similar conditions and thoroughly mixed before being used. A well-mixed sample is essential in order to avoid inconsistencies caused when the relative proportion of thick and thin white varies in the eggs. Numerous studies have indicated that thick and thin white differ in their beating and baking qualities. St. John and Flor (42) found that under the conditions which they used, thin white gave a larger beating volume than thick white. Hunt and St. John (23) reported that angel cakes made from thin white had larger volumes than those made from thick whites. Henry and Barbour (21) found the initial beating properties of thin white to be superior to those of thick white but that thin white tended to lose volume on continued beating.

Bailey (3) reported a greater volume of foam was obtained with thick white and suggested that the discrepancies in the results reported by the various investigators could be traced to the type of beater used. Pyke and Johnson (37) reported that poor quality eggs whipped more rapidly than high quality eggs, but when the specific gravity of sponge cake batters from both kinds of eggs was standardized, the cakes made from the high quality eggs were superior in volume, texture, and quality. They felt that the difference in performance between eggs of varying quality could be traced to a loss of certain factors which were responsible for the structural strength of the cake during the baking process. Deterioration in the eggs was accompanied by an increased temperature of coagulation. Therefore, the time during which the cake was held at the coagulation temperature of the eggs was decreased, and the resulting product had less strength. Hedstrom (20) found that cake volume decreased with increased age of eggs. Bennion, Hawthorne, and Bate-Smith (7) reported that the volume of foam was correlated to the quality of test sponge cakes.

Since controlling the time of beating gives egg white foams of definitely different properties, some other criterion must be used for determining the end-point for standardizing the foams. It has been found that specific gravity is a satisfactory measurement to use for this purpose. Pyke and Johnson (37) found that it was necessary to beat foams or meringues to a constant specific gravity to compensate for the different resistance offered by different quality eggs to the mechanical manipulation of the beater. Barmore (5) reported that with foams beaten to the same specific gravity, the foams from thick white were stiffer than those from thin white. The foams from the thin white appeared to have much larger bubbles. However, the structure of the completed batter appeared to be identical, whether thin or thick white was used, and the resulting cakes were also identical. Henry and Barbour (21) and King et al. (25) listed specific gravity as one of the factors which should be controlled in the beating of eggs for experimental purposes. Glabau (17) found that a specific gravity of the meringue of 0.176 produced the most ideal cakes under the conditions which he used. He found that with such a specific gravity of the meringue, the specific gravity of the batter varied from 0.312 to 0.340. Barmore (5) recommended a specific gravity of the egg white foams of between 0.150 and 0.170. His measurements were made before addition of sugar. The optimum specific gravity found for one type of beater will not necessarily be the optimum specific gravity if a different beater is used (29).

Control of the temperature at which the ingredients are stored and the temperature of the room in which the cakes are mixed is highly advisable. There have been numerous studies made of the optimum temperature for beating egg white foams. Henry and Barbour (21) recommended 20°C. St. John and Flor (42) found 18°C. to 21°C. to be the most desirable range, and they stated that chilling the eggs gave poorer texture and volume. In a comparison of 40°F., 50°F., 60°F., and 70°F., Miller and Vail (33) found that best results were obtained when the eggs were beaten at 70°F. Burke and Niles (10) used 25°C. as the original temperature of the eggs in making angel cake. Glabau (17, 18) found that the best cakes were obtained when the eggs were whipped at either 50°F. or 70°F. Cakes at those temperatures were superior in cellular structure and texture to the cakes baked at other temperatures.

A similar range of values has been recommended by different authors for the time and temperature of baking angel cake. Miller and Vail (33) found that caked baked at 400°F. for 35 minutes or at 425°F. for 30 minutes gave the most desirable products when fresh, thin frozen, or thick frozen egg whites were used. Burke and Niles (10) used 325°F. for 1 hour and 350°F. for 45 minutes. They found that the moisture loss was less for cakes baked at 350°F., the volume was usually larger, and the general appearance was better although the crust usually had more cracks. Using 350 grams of batter per cake, Glabau (18) baked angel cakes for 23 minutes at 350°F. Barmore (5) recommended baking at 180°C. (350°F.) for 30 to 40 minutes depending on the size of the cake. He found there was less evaporation, greater cake volume, and decreased tensile strength when the high oven temperature was used. The variation in tensile strength was found to be indirectly dependent on the oven temperature and directly dependent on the cake volume. Using 135 grams of batter in small rectangular pans, Kraatz (26) found that the optimum baking times for the cakes baked at 150°C., 160°C., and 170°C. were 45, 30, and 25 minutes, respectively. The correct baking time will vary with the temperature used and with the size and shape of the pan. Acceptable cakes can be made over a range of baking times and temperatures, and when other factors are of primary interest the main concern in baking conditions is that they be kept constant.

Henry and Barbour (21) found that defrosted storage whites gave inferior results to fresh whites in volume increase. However, they stated that freezing and frozen storage exerted a negligible effect on beating properties for a period of one month at -3°C.

Watts and Elliott (46) compared the baking properties of various kinds of dried whites in angel cake and found that commercial dried whites were inferior to dried whites prepared in their laboratory. Their laboratory-dried whites were prepared by drying the fresh whites on porcelain plates at 45°C. in a vacuum oven. The dried material had a porous texture because of frothing under vacuum. The process required 6 to 10 hours for completion under their conditions. They also found that commercial samples of dried egg white whipped better and were more suitable for use in meringues than were the fresh or the laboratory dried samples. They recommended that egg whites which were to be dried and used for baking purposes should be handled differently from the usual methods and should be tested to see that they retained their baking properties. Balls and Swenson (6) also suggested that dried egg white be manufactured by different processes depending on the use which was to be made of the product.

Various tests have been devised for measuring the characteristics of cakes. In measurements of sponge cakes Platt and Kratz (35) used cake volume, tensile strength, shape and grain, and flavor as indices of desirability of the cake. They used a planimeter to determine the area of a cross section of the cake and calculated an "index of volume" from this measurement. Shape and grain of the cakes were recorded photographically, and flavor was determined by judges. King, Morris, and Whiteman (25) measured cake volume, tensile strength, and compressibility. They felt that measurement of volume by seed displacement was more rapid and reproducible than the planimeter method. Compressibility was measured by a penetrometer.

EXPERIMENTAL

A. Removal of Mucin

Two dozen fresh eggs were obtained from the poultry farm on three different days for this phase of the experiment. The eggs were broken, yolks and whites were separated, and the chalazae were removed from the whites. The whites were mixed briefly on the Waring Blendor to break up the thick white enough that uniform samples could be obtained. The pH of the sample was then determined, and the sample was divided into four equal portions of 150 c.c. each. The first portion served as a control and received no further treatment.

From the second portion the mucin was precipitated by acidification with 4% HCl to approximately pH 5.2 and shaken vigorously. To facilitate the removal of the layer of mucin which floated to the surface, the product was centrifuged. The mucin then formed a small clot, and the clear solution could be easily separated from it. After removal of the mucin, the remainder of the egg white was brought back to its original pH with 4% NaOH.

From the third portion the mucin was precipitated in the same manner as has been described in the previous paragraph. The mucin was not centrifuged and removed, but the whole egg white was brought back to its original pH using NaOH.

To the fourth portion of the egg white, an amount of distilled water was added equal to the combined volume of HCl and NaOH which had been used in the mucin treatment. This portion served as control for the effect of dilution.

B. Concentration of Egg White

1. Vacuum drying from the frozen state.

a. Normal egg white. Enough eggs to complete each of the studies on vacuum drying were obtained from the poultry farm as each section of the experiment was begun. They were stored for one week at approximately 21°C. (70°F.) in order to duplicate as closely as possible conditions as they would exist commercially. After this storage period the eggs were broken, yolks and whites were separated, and the chalazae were removed from the whites. The whites were mixed briefly on the Waring Blendor to break up the thick white enough that uniform samples could be obtained. The whites were then thoroughly mixed. The pH of the whites was recorded and moisture was determined by placing the weighed sample in a vacuum oven at 100°C., and 1 cm. of mercury or less, for five hours.

The egg whites were frozen in a thin film on the inside of a round bottom flask by twirling the flask in a bath of alcohol at -40°C. to -45°C. (-40°F. to -49°F.). They were then concentrated under vacuum from the frozen state. The flasks were attached by means of standard taper joints to an iron condenser immersed in the alcohol bath. The system was evacuated with a Kinney VSD556 vacuum pump. A diagram of the apparatus used by Best (8) is shown in Figure 1. The apparatus used in this study was modified so that four flasks instead of one could be attached. In Figure 1, A represents the round bottom Pyrex flask. B indicates the standard taper joint. C indicates the condenser, and D the opening leading to the vacuum pump.

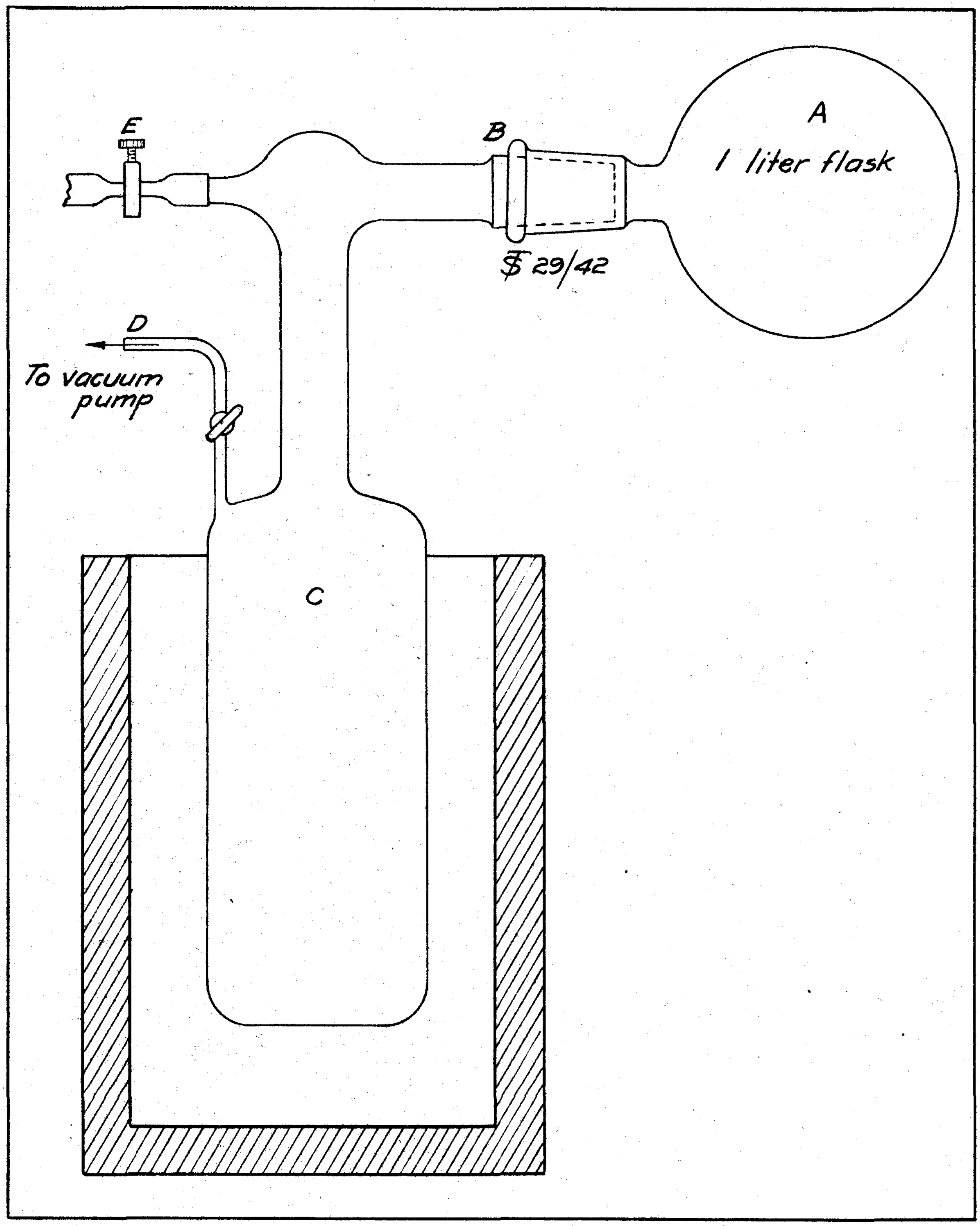

FIG. 1. APPARATUS FOR VACUUM DRYING IN THE FROZEN STATE.

For the first part of this experiment, 600 grams of egg white were frozen and concentrated to four different levels. Four 1-liter round flasks were used for each concentration, each flask containing 150 grams of egg white. The concentration of all of the whites was completed within two days after the eggs were broken from the shell. After concentration, the whites were stored in a refrigerator over night. In this time the whites at the lowest concentration (31.6% solids) came to equilibrium and could be poured from the flasks. The samples at the next two higher concentrations contained too much dried material to come to equilibrium in that length of time. In order that the egg might be removed from these flasks more easily, 50 c.c. of distilled water were added to the samples at 52.7% solids, and 70 c.c. of water were added to those at 78.6% solids before they were refrigerated over night. The whites concentrated to an average of 92.3% solids appeared completely dry and could be removed from the flasks without the addition of water. After the samples were refrigerated over night and removed from the flasks, the four samples at each concentration level (the four samples which averaged 31.6%, etc.) were combined and an amount of distilled water was added equal to that which had been removed during the concentration process. The samples at this time were ready for use in making cakes.

Similar procedures were used in concentrating the egg white samples for the other experiments on egg white dried under vacuum from the frozen state.

b. Mucin-free egg white. In order to compare the time required for concentration of normal egg white with mucin-free egg white, mucin was precipitated and removed from four 150-gram samples of egg white as has been previously described. The percentage solids after removal of the mucin was determined and recorded.

c. Storage of normal egg white, vacuum dried from the frozen state.

(1). Storage at -17.8°C. (0°F.) for angel cake study. Egg whites were prepared and concentrated by the methods previously outlined. Four hundred gram samples were used for each of the following concentrations: 12.4% solids (control), 34.4% solids, 55.6% solids, 74.0% solids, 95.4% solids. The fresh control sample was frozen and stored in metal cans. The other samples were stored in stoppered flasks at -17.8°C. (0°F.) for 80 days. At the end of the storage period, an amount of distilled water was added to the samples equivalent to that which had been removed in the concentrating process, and the samples were tested for their performance in angel cakes.

(2). Storage at 1.7°C. and 21.1°C. (35°F. and 70°F.) for microbiological study. The egg whites for the microbiological study were prepared and concentrated by the methods previously described. They were stored at refrigerator (1.7°C.) and room (21.1°C.) temperatures for one month, during which time microbiological counts were made at intervals. Samples for analysis were taken on the day before plating. They were diluted 1:10 with sterile distilled water and allowed to stand in a refrigerator overnight in order that the dried samples might become rehydrated. Glass beads were used in the test tubes containing the samples to facilitate thorough mixing. All plates were incubated for 72 hours at 32°C. (89.6°F.). Nutrient agar was used for the standard plate count. Potato dextrose agar was the medium for the yeast and mold count.

The method of McFarlane (30) was used for the direct microscopic count. The count was made from a 1:10 dilution of the egg white. A 0.01 ml. portion of the sample was discharged onto a clean slide using a capillary pipette calibrated to deliver exactly that amount. The material was spread over a 2 square centimeter area (1 cm. by 2 cm.) with the aid of a bent inoculating needle and a 2 square centimeter guide. The film was dried in a horizontal position in a 37°C. (98.6°F.) incubator. It was then defatted for two to five minutes in xylol and fixed for two to five minutes in 95% alcohol. It was then stained one minute in North's analine oil-methylene blue, washed in a beaker of water, drained and dried. The following formula for the stain was used:

Analine oil	3.0 ml.
Alcohol, ethyl, 95%	10.0 ml.
Hydrochloric acid concentrated (add with stirring)	1.5 ml.
Methylene blue, saturated alcoholic solution	30.5 ml.
Distilled water	55.5 ml.

The method used for adjusting the microscope and calculating the count is described in <u>Standard Methods for the Examination of Dairy Products (1941)</u> (2). Thirty to sixty fields were counted on each slide. The average count per field was obtained and this number was multiplied by the microscope factor to obtain the direct microscopic count per gram.

2. Air film concentration.

Eggs obtained from the poultry farm were stored varying lengths of time at refrigerator and room temperature for the different parts of this experiment. The yolks and whites were separated, and the chalazae were removed from the whites. The whites were mixed briefly on the Waring Blendor. The pH of the whites and the average solids content were determined and recorded. Varying amounts of whites were weighed into glass pie plates, whose internal dimensions were 7 5/8 inches in diameter at the bottom, 9 3/8 inches at the top, and 1 inch in depth. The pie plates were placed in a row beneath a double row of infra-red lights (General Electric Reflector Drying).

The lights were approximately 13 inches from the bottom of the pie plates. A fan placed at one end of the plates was turned on high speed in order to blow a constant stream of air across the surface of the eggs. The lights were turned on or off as needed to control the temperature range of the drying egg white. The temperature of the egg whites was read by a thermometer which was immersed in the liquid as long as possible and which was placed on top of the egg white when it had been dried to a solid condition. The temperature of concentration was varied from 35°C. to 45°C. (95°F. to 113°F.) for the first experiment and from 25°C. to 35°C. (77°F. to 95°F.) for the second experiment.

C. Angel Cakes

1. Ingredients.

The angel cake formula used (29) was as follows:

		Full recipe	1/4 recipe
Egg white	1 c.	244 g.	61 g.
Sugar	1 1/4 c.	250 g.	62.5 g.
Cake flour	9/10 c.	90 g.	22.5 g.
Cream of tartar	1 t.	3.6 g.	0.9 g.
Salt	1/4 t.	1.5 g.	0.3 g.

Enough sugar for the entire problem was obtained at the beginning of the experiment. It was thoroughly mixed and stored in a large can. Enough cake flour of the same brand and shipment was also obtained for the whole experiment. Cream of tartar and salt were obtained in sufficient quantities to last throughout the experiment.

2. Method of mixing.

Flour and sugar for each day's baking were weighed and stored in an incubator whose temperature varied from 23°C. to 26°C. (73.4°F. to 78.8°F.). One-fourth of the full recipe was used in all of the cakes except for the one series of vacuum-dried whites where the full recipe was used to make large cakes. Before the ingredients for each cake were combined, one fourth of the sugar was sifted four times with the flour. The remaining sugar was then sifted four times. The temperature of the egg whites was brought to 21°C. (70°F.) before heating. In making the small size cakes (1/4 of the full recipe), the eggs were beaten until frothy on the third speed of a Hobart "Kitchen Aid", Model 4, electric mixer. Cream of tartar and salt were added after 10 seconds of beating. Sugar was added in fourths after 20 seconds, 30 seconds, 37 seconds, and 45 seconds of beating. In making the large size cakes, a larger electric mixer, "Kitchen Aid", Model G, was used because preliminary work had shown that the smaller mixer was inadequate for producing a foam of the desired specific gravity with the larger volume of ingredients. Second speed of the mixer was used. Cream of tartar and salt were added after 20 seconds of beating. Sugar was added, approximately one tablespoonful at a time, starting after 25 seconds of beating and continuing the additions at intervals of 7.5 seconds. All of the sugar was added after one and one-half minutes of mixing. The meringue was beaten until peaks of foam turned down slightly when the beater was removed. The total time of beating of the meringue was recorded. The specific gravity of the meringue was determined by weighing a level one-fourth cup of meringue and dividing that weight by the weight of an equal volume of water. The flour and sugar mixture was sifted, one fourth at a time, over the top of the meringue. It was combined with the meringue using ten strokes of a French balloon whip for each fourth added. The temperature of the batter was determined, and the specific gravity of the batter was obtained in the same manner as that of the meringue.

The order of preparation and judging of the cakes was randomized in an attempt to prevent any error caused by fatigue in making or judging of the cakes. The cakes for the mucin-treated series were always made within two days after treatment of the mucin. Previous experience had shown that with longer standing, the mucin in the sample in which it was precipitated but not removed tended to form large clumps which could not be broken up with ordinary beating. Under such conditions these large pieces of mucin then appeared in this undispersed state in the cakes.

3. Baking.

The rectangular pans used in baking the small cakes measured approximately 2.75 inches in height, 3.5 inches in width, and 5.5 inches in length. Their volume ranged from 750 to 760 c.c. A layer of wax paper was cut to fit the bottom of the pans. For each cake, 120 grams of batter were weighed into the pans. Cakes were baked one at a time in the center of the lower rack of a Clark Jewel gas oven maintained at 175°C. (347°F.) for 27 minutes. After baking they were inverted until cool. They were then covered with thin wax paper and stored until the following morning, at which time they were weighed and tested.

The large size pans were standard angel cake pans measuring 8 3/4 inches in diameter across the top, 7 1/4 inches across the bottom, and 3 1/4 inches in height. The volume of the large pans varied from 2485 to 2515 c.c. The large cakes were baked for 38 minutes at 175°C. (347°F.). A large cake (430 grams of batter) and a small cake (120 grams of batter) were baked at the same time from the same batter.

4. Testing.

Cake volume was determined by seed displacement while the cakes were still in the pans. Rape seeds were dropped onto the cakes from a constant height, and the volume of seeds was subtracted from the volume of the pan to give the volume of the cake. Tensile strength was determined on a tensile strength machine which was similar in principle to the one described by Platt and Kratz (35).

Two slices of each cake were tested and the results averaged. The reading obtained was divided by two to obtain the tensile strength measurement in grams. Palatability scores were determined by three judges. Each judge was given a slice from the same relative position in each cake. Slices were cut with a saw-edged knife, using a wooden miter box, so that each slice was the same thickness.

RESULTS

A. Removal of mucin

1. Appearance of egg white after treatment of mucin.

After removal of the mucin the egg white had the appearance of a clear liquid with a viscosity approximating that of water. When this liquid was beaten on the electric mixer, there was a pronounced spattering of the sides of the bowl, a condition which was not present in any of the other treatments.

When the mucin was precipitated but not removed, it floated on the surface in small clumps which gradually coalesced on standing. When these samples were beaten on the electric mixer they had the appearance of normal egg white.

2. Effect on angel cake.

a. Specific gravity of meringue and batter. The specific gravity of the batter ranged from 0.247 to 0.277. The average values obtained for the specific gravity of the meringue and batter for each of the four treatments are shown in Table 1.

Table 1

Effect of Treatment of Mucin on Average Specific Gravity of Meringue and Batter and Time of Beatings of Meringue

Treatment	Specific gravity of meringue	Specific gravity of batter	Time of beatings meringue (seconds) Av.	Diff.
Fresh control	0.180	0.250	70.5	---
Fresh control, water added	0.176	0.262	60.8	- 9.7
Mucin precipitated and removed	0.173	0.265	188.3	117.8**
Mucin precipitated and not removed	0.179	0.263	123.3	52.5**

** Highly significant

b. Total beating time of meringue. The total beating time of the meringue varied from 55 seconds to 3 minutes and 20 seconds for the four treatments. An analysis of variance showed that there was no significant difference between replications but that there was a highly significant difference between treatments. There was a non-significant difference between the average beating time of the cakes made from the fresh control eggs and those made from the eggs with water added. There was a highly significant difference between the means from those two samples and the means of both of the mucin-treated samples. There was also a highly significant difference between the means of the two mucin-treated samples. The sample in which the mucin was removed required a longer time for beating to the same specific gravity than did the sample in which the mucin was precipitated but not removed. The average beating times for the four treatments are shown in Table 1. Tables of analysis of variance for all sections of this experiment are recorded in the appendix.

c. Temperature of batter. The final temperature of the batter, at completion of mixing, ranged from 21°C. to 23°C.

d. Loss of weight of cakes during baking. The loss of weight of the cakes during baking ranged from 10.9% to 15.1%. The average values for the four treatments are recorded in Table 2.

e. Shrinkage during baking of cakes. In preliminary tests it was noted that the cakes without mucin had a decided tendency to pull away from the sides of the pan during baking. This characteristic was measured, and the results are recorded in Table 2.

Table 2

Effect of Treatment of Mucin on Loss of Weight and Shrinkage During Baking of Angel Cake

Treatment	Loss of weight during baking(%)	Shrinkage during baking (cm.)
Fresh control	12.0	0.0
Fresh control, water added	13.7	0.25
Mucin precipitated and removed	12.0	1.15
Mucin precipitated and not removed	12.5	0.50

f. Volume of cakes. The volume of the cakes ranged from 535 to 725 c.c. An analysis of variance showed that there was a significant difference in the volumes of the cakes made from the four treatments of egg whites. There was a non-significant difference between the mean scores for volume of the cakes made from the fresh control eggs and the cakes made from the fresh control eggs with water added. The mean volumes of both of those samples were greater than the mean volumes of the cakes made from either of the mucin-treated samples. The difference was highly significant. The mean volume of the cakes made from the eggs with the mucin removed was significantly higher than that of the cakes made from the eggs with the mucin precipitated but not removed. The average volume of the cakes of the four different treatments is recorded in Table 3.

Table 3

Effect of Treatment of Mucin on Volume and Tensile Strength of Angel Cake

Treatment	Volume c.c. Av.	Volume c.c. Diff.	Tensile Strength Av.	Tensile Strength Diff.
Fresh control	691.5	---	35.15	---
Fresh control water added	687.7	-3.8	27.95	-7.2*
Mucin precipitated and removed	599.0	-92.5**	45.05	9.9**
Mucin precipitated and not removed	557.5	-134.0**	42.1	6.95

* Significant
** Highly significant

g. Tensile strength of cakes. The tensile strength of the cakes ranged from 20 to 53. An analysis of variance of tensile strength showed that there was a non-significant difference in replications and a highly significant difference in treatments. An analysis of the difference between the means of the four treatments showed that the fresh control had a significantly greater tensile strength than the cakes made from the fresh control eggs with water added. The average tensile strength of the cakes made from the fresh control eggs was lower than that of the samples from which the mucin was removed. The difference was highly significant. The mean tensile strength of the samples in which the mucin was precipitated but not removed did not differ significantly from that of the fresh control samples. The average tensile strength of the cakes made from the four different samples of eggs is recorded in Table 3.

h. Palatability of cakes. In each of the factors of palatability there was a non-significant difference between the scores for the cakes made from the fresh control eggs and the scores for those made from the fresh control eggs with water added. In each case, however, there was a highly significant difference between the scores for the two treatments in which the mucin was treated and the two treatments in which the mucin was not treated. In addition, the judges found the cakes made from the eggs with the mucin removed to be significantly more tender than those in which the mucin was precipitated but not removed. The tensile strength scores for this factor gave opposite results. The judges also found that in total palatability, the cakes with the mucin removed were significantly superior to those in which the mucin was precipitated but not removed. The two chief criticisms of both series of cakes in which the mucin had been treated were that they were compact in texture and gummy. The palatability scores given the cakes by the three judges are shown in Table 4.

Table 4

Effect of Treatment of Mucin on Palatability of Angel Cake

Treatment	Texture (25%) Av.	Diff.	Tenderness (25%) Av.	Diff.	Moistness (15%) Av.	Diff.	Eating Quality (35%) Av.	Diff.	Total (100%) Av.	Diff.
Fresh control	21.5	---	22.2	---	13.2	---	31.3	---	88.1	---
Fresh control, water added	21.0	- 0.5	22.5	0.3	13.4	0.2	31.3	0.0	88.2	0.1
Mucin precipitated and removed	13.3	-8.2**	20.2	2.0**	9.7	-3.5**	23.1	-8.2**	66.3	-21.8**
Mucinprecipitated and not removed	11.3	-10.2**	18.5	-3.7**	8.7	-4.5**	20.9	-10.4**	59.6	-28.5**

** Highly significant

Photographs of slices of cake from a fresh control egg and from the two mucin treatments show the effect of mucin treatment on the volume and texture of the angel cakes. (Figures 2, 3, and 4).

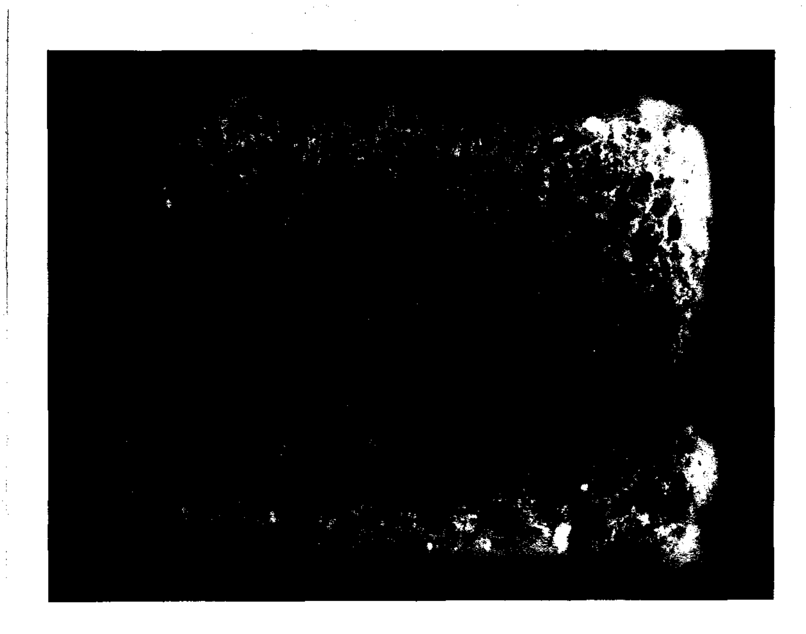

Figure 2: Slice of Angel Cake Made from Fresh Control Egg

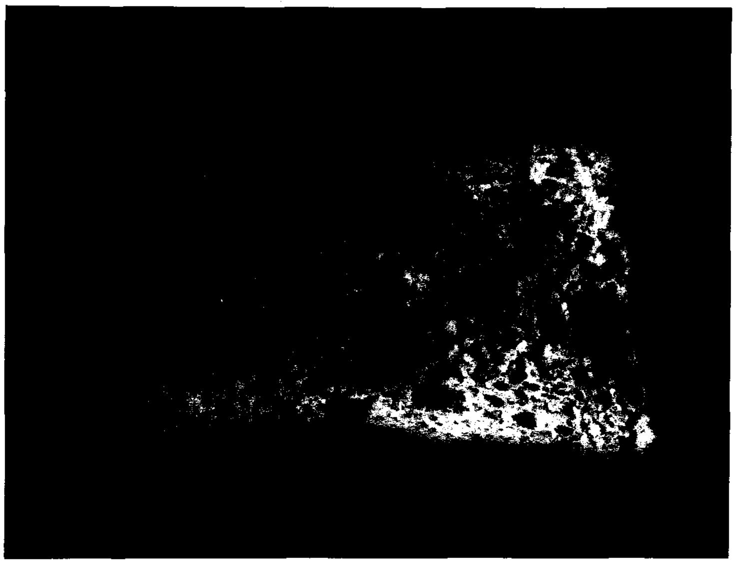

Figure 3: Slice of Angel Cake Made from Egg White After Precipitation and Removal of Mucin

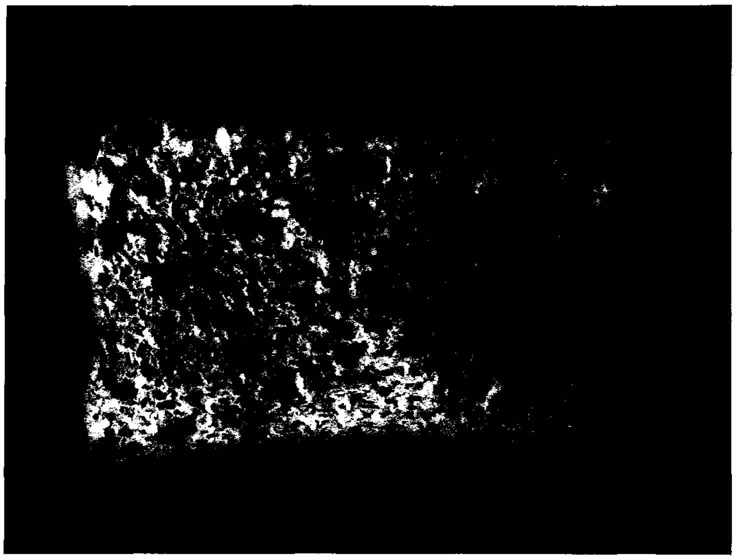

Figure 4: Slice of Angel Cake Made from Egg White After Precipitation of Mucin

B. Concentration of the Egg White

1. Vacuum drying from the frozen state.

a. Appearance of concentrated egg white.

(1). Normal egg white. The general appearance of the egg white at the various concentrations was as follows:

24% solids: After coming to equilibrium, approximately half of the material appeared to be a clear solution and half appeared to be a thick mass similar to the thick white of fresh egg.

37% solids: After coming to equilibrium, the product appeared to be mainly a thick mass with very little clear liquid present.

42% solids: After coming to equilibrium, the product appeared to be a thick mass with no thin liquid present.

53% solids: About half of the product appeared to be dry, and the remainder was a thick layer which stuck to the sides of the flask.

63% solids: About three-fourths of the product appeared to be completely dry.

78% solids: About ninety per cent of the product appeared to be completely dry.

92% solids: The product appeared completely dry.

The reconstituted egg whites were held in the refrigerator for an eight-day period while baking was in progress. On the first two days of this holding period, translucent, flaky material was noted floating in the clear solution of the samples which had been concentrated. On the third day the samples had become practically homogeneous throughout and resembled the fresh egg white very closely. On the last two days of baking a slight-off-odor was noted, and sediment had settled to the bottom of the flasks. The change in pH of the egg whites from the time of concentrating to the last day of baking is shown in Table 5.

Table 5

pH of Vacuum-Dried (Lyophilized) Egg White Used in Angel Cake

Date	Days	pH of egg white concentrations				
		12.47% solids	31.6% solids	51.9% solids	78.6% solids	92.3% solids
2/1/45	0	9.16				
2/3/45	2	9.26				
2/6/45	5	9.45	9.45	9.46	9.48	9.60
2/14/45	13	9.25	9.22	9.25	9.27	9.37

(2) Mucin-free egg white. The general appearance of the mucin-free egg white at the various concentrations was as follows:

30.3% solids: After coming to equilibium the product was a viscous liquid which poured readily and flowed freely around the flask without sticking. It seemed to be of the same consistency throughout, with no separation into a thick and thin portion.

40.2% solids: After coming to equilibrium, the product was a thick, viscous liquid which poured readily. However, it tended to stick to the flask and appeared to be approaching a gel condition.

67.3% solids: About three-fourths of the product appeared completely dry. The remainder was very thick and stuck to the sides of the flask. It did not come to equilibrium after standing in a stoppered flask at refrigerator temperature for two and one-half months.

94.3% solids: The product appeared to be completely dry.

b. Time of concentration.

(1). Normal egg white. The concentration of solids obtained in each flask and the corresponding processing times are shown in Table 6.

Table 6

Time Required for Concentration of Fresh Egg White by Vacuum-Drying from the Frozen State

Percentage of solids of egg white in each flask	Average percentage of solids in the four flasks	Time of processing (150 g. of egg white in each flask)
	12.47 (Control)	----
29.9, 32.2, 33.0, 31.4	31.6	2 hours, 55 minutes
48.6, 53.4, 53.0, 52.7	51.9	3 hours, 40 minutes
83.1, 83.1, 79.6, 70.6	78.6	4 hours, 30 minutes
93.5, 95.4, 91.2, 89.0	92.3	5 hours, 30 minutes

(2). Mucin-free egg white. Egg white with mucin removed took approximately the same length of time to concentrate as did the fresh control egg white. This is shown in Table 7.

Table 7

Time Required for Concentration of Mucin-free Egg White by Vacuum-Drying from the Frozen State

Percentage of solids of egg white in each flask	Time of processing (150 g. of egg white in each flask)
10.67	----
30.3	2 hours, 55 minutes
40.2	3 hours, 30 minutes
67.3	4 hours
94.3	6 hours, 30 minutes

It has been found that the percentage of solids and the time of processing have a linear relationship between approximately 30% and 80% solids. (Figure 6)

c. Effect of vacuum-drying of egg white on small angel cakes.

(1). Specific gravity of meringue and batter. The specific gravity of the meringue ranged from 0.171 to 0.195. An analysis of variance of the results showed that there was a non-significant difference in specific gravity of meringue between the five replications and a significant difference between the treatments (concentrations of the egg white). The sample which had been concentrated to 92.3% solids and the control (12.4% solids) differed significantly from the other three samples in that the former had a higher specific gravity.

The specific gravity of the batter ranged from 0.257 to 0.276. An analysis of variance of the results showed that there was a non-significant difference between replications and between treatments.

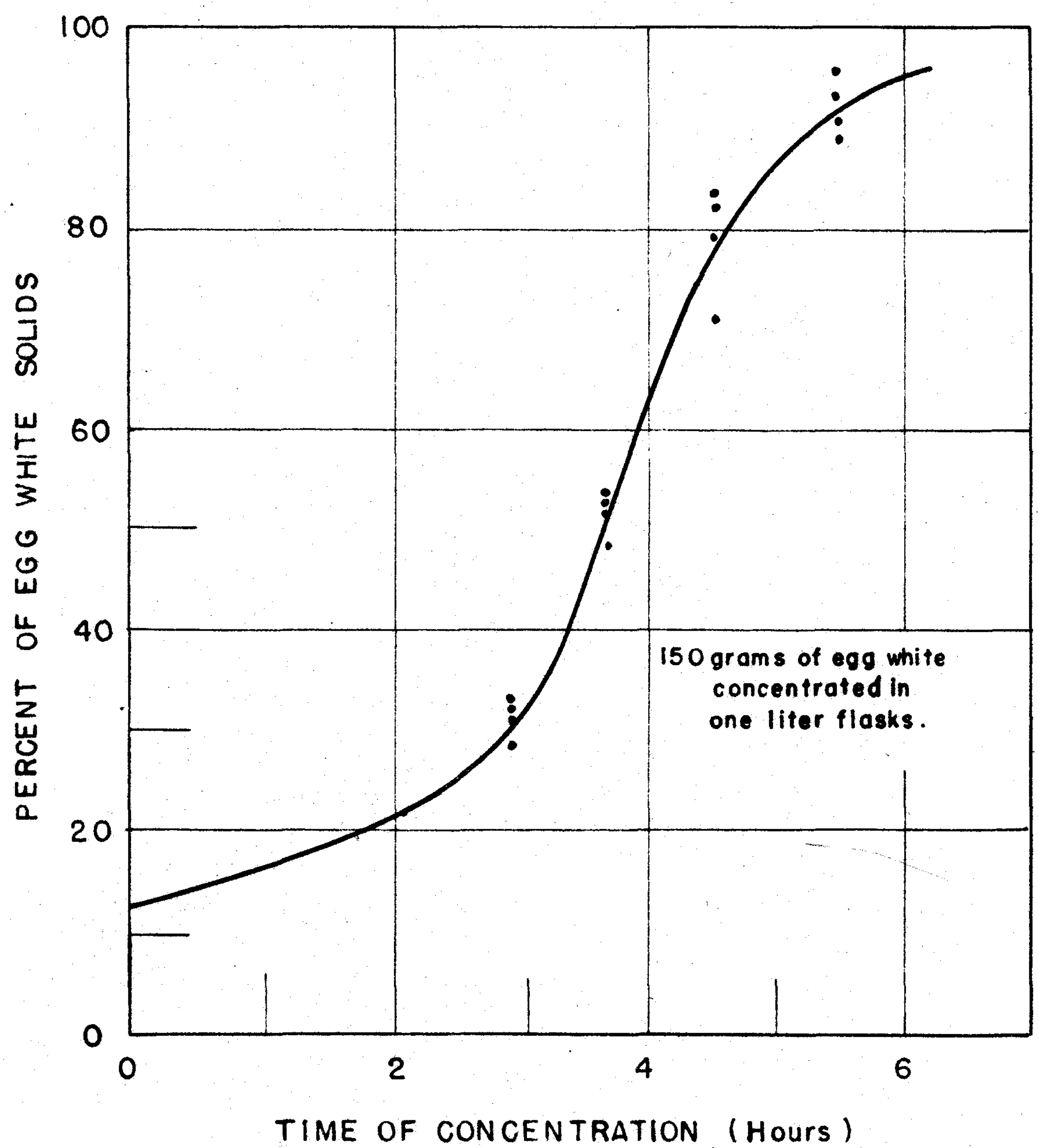

Figure 5. Time Required for Concentration of Egg White by Vacuum-Drying from the Frozen State.

The average values obtained for the specific gravity of meringue and batter at the various concentrations of egg white solids are shown in Table 8.

(2). Total beating time of meringue. The total time of beating of the meringue ranged from 50 to 70 seconds. An analysis of variance showed that there was no significant difference between replications but a highly significant difference between treatments. There was a highly significant difference between the means of concentrations 12.47% and 92.3% and of the three other concentrations. Yet it will be noted that those concentrations in which the meringue was beaten for the longest time had the highest specific gravity, indicating that a still longer beating time would have been needed to bring the specific gravity of those two samples down to that of the other three samples. The average beating times for the meringues of the various concentrations of egg whites are shown in Table 8.

Table 8

Effect of Concentration of Egg White by Vacuum Drying from the Frozen State on Average Specific Gravity of Meringue and Batter and Time of Beating of Meringue

Percentage of solids after concentration	Specific gravity of meringue		Specific gravity of batter		Time of beating of meringue (seconds)	
	Av.	Diff.	Av.	Diff.	Av.	Diff.
12.47	0.188	----	0.267	----	64.6	----
31.6	0.177	-0.011**	0.263	-0.004	52.4	-12.0
51.9	0.182	-0.006**	0.267	0.000	53.6	-10.8**
78.6	0.182	-0.006**	0.267	0.000	52.8	-11.6**
92.3	0.186	-0.002	0.267	0.000	62.8	-1.6

** Highly significant

(3). Temperature of batter. The final temperature of the batter, at completion of mixing, ranged from 21.5°C. to 23°C. (70.7°F. to 73.4°F.).

(4). pH of batter. The pH of the batter ranged from 5.27 to 5.64 and averaged 5.45. The average values for pH of the batters made from the egg whites at the five different concentrations are shown in Table 9.

(5). Loss of weight of cakes during baking. The loss of weight of the cakes during baking ranged from 11.0% to 13.5% and averaged 12.26%. The average loss of weight during baking of the cakes made from the various concentrations of egg white is shown in Table 9.

Table 9

Effect of Concentration of Egg White by Vacuum-Drying from the Frozen State on pH of Batter and Loss of Weight during Baking of Angel Cake

Percentage of solids after concentration	pH of batter	Loss of weight during baking (%)
12.47	5.48	12.3
31.6	5.46	12.0
51.9	5.43	12.5
78.6	5.50	12.4
92.3	5.46	12.0

(6). Volume of cakes. The volume of the cakes ranged from 659 to 729 c.c. An analysis of variance showed that there was no significant difference in cake volumes related to the different days on which the cakes were baked (replications). However, there was a significant difference in volume among the different concentrations of eggs used. There was a slight difference between the mean values for volume between the cakes made from the eggs which had been vacuum-dried (lyophilized) to the highest concentration and the other three concentrated samples. The cakes made from the highest concentration of egg whites were significantly smaller than all but the cakes made from the fresh controls. One cake made from the fresh control egg had an unusually small volume, because the meringue was not beaten to as light a specific gravity as it should have been. If this one cake were disregarded, there would have been a significant difference in the volume of cakes made from the fresh control egg and those made from egg white concentrated to 92.3% solids. On the other hand, the volume of the cakes made from the egg white concentrated to 92.3% solids compared favorably with the volume of cakes made from fresh egg white in a different section of this experiment. The average volumes of cakes made from the five different concentrations of egg white are shown in Table 10.

Table 10

Effect of Concentration of Egg White
by Vacuum-Drying from the Frozen State
on Volume and Tensile Strength
of Angel Cakes

Percentage of solids after concentration	Volume of cakes (c.c.) Av.	Diff.	Tensile strength of cakes Av.	Diff.
12.47 (control)	699.4	---	39.75	----
31.6	714.8	15.4	34.85	- 4.9
51.9	713.2	13.8	37.7	- 2.05
78.6	711.6	12.2	36.15	- 3.6
92.3	686.8	- 12.6	43.75	4.0

When the analysis of variance for volume was based on a comparison of the cakes made from the fresh control eggs and each of the other treatments, there was a non-significant difference between the means.

(7). Tensile strength of cakes. The tensile strength of the cakes ranged from 30.5 to 47. An analysis of variance showed that there was no significant difference in the tensile strength of cakes made from the eggs at any of the five different percentages of solids or from the cakes made on the five different days. The average tensile strengths for the cakes made from the various concentrations of egg white are shown in Table 10.

(8). Palatability of cakes. The palatability scores given the cakes by the three judges are shown in Table 11. The average total scores for the cakes made from the different concentrations of egg white ranged from 86.5 to 88.5. An analysis of variance showed that there was a non-significant difference in palatability of cakes between the five treatments. However, the judges' scores showed a highly significant difference between replications. Since the objective tests showed no significant difference between replications, it would appear that the judges were not consistent from day to day. Since tenderness was the only characteristic measured both objectively and subjectively, a comparison of the two methods of grading is of interest. The objective measurement (tensile strength) showed no significant difference between treatments or between replications. The subjective measurement showed no significant difference between replications.

An analysis of variance of each of the judges' scores separately for palatability showed that all three found no significant difference between treatments. However, in the scores of two of the three judges there was a highly significant difference between replications, while the third showed a non-significant difference.

An analysis of variance using the scores of the three judges as treatments and the twenty-five cakes as replications showed that there was a non-significant difference between replications but a highly significant difference between treatments. In other words, the three judges differed significantly from each other in the total scores which they gave the cakes.

Table 11

Effect of Concentration of Egg White by Vacuum-Drying from the Frozen State on Palatability of Angel Cake

Percentage of solids after concentration	Palatability scores of judges									
	Texture (25%)		Tenderness (25%)		Moistness (15%)		Eating Quality (35%)		Total (100%)	
	Av.	Diff.	Av.	Diff.	Av.	Diff.	Av.	Diff.	Av.	Diff.
12.47 (control)	19.9	---	21.8	---	13.5	---	31.7	---	86.5	---
31.6	19.7	-0.2	22.7	0.9	13.6	0.1	32.4	0.7	88.4	1.9
51.9	20.2	0.3	22.5	0.7	13.6	0.1	32.1	0.4	88.5	2.0
78.6	20.3	0.4	21.9	0.1	13.3	-0.2	31.6	-0.1	87.1	0.6
92.3	20.2	0.3	22.1	0.3	13.7	0.2	32.1	0.4	88.1	1.6

d. Effect of vacuum-drying of egg white on large angel cakes.

(1). Specific gravity of meringue and batter. The specific gravity of the meringue ranged from 0.172 to 0.178. The specific gravity of the batter ranged from 0.237 to 0.255. The average values obtained for the specific gravity of meringue and batter at the various concentrations of egg white are shown in Table 12.

(2) Time of beating of meringue. The total time of beating of the meringue ranged from 1 minute and 55 seconds to 2 minutes and 20 seconds. An analysis of variance showed that there was no significant difference between replications but a highly significant difference between treatments. There was a highly significant difference between the means for each concentration and the means for each of the other concentrations. The average values obtained for beating time of each of the three treatments is shown in Table 12.

Table 12

Effect of Concentration of Egg White by Vacuum-Drying from the Frozen State on Average Specific Gravity of Meringue and Batter and Time of Beating of Meringue of Large Angel Cake

Percentage of solids after concentration	Specific gravity of meringue	Specific gravity of batter	Time of beating of meringue (seconds)	
			Av.	Diff.
12.1	0.177	0.246	137.5	---
46.5	0.177	0.245	115.0	- 22.5**
97.5	0.177	0.238	129.8	- 7.7**

** Highly significant

(3). Temperature of the batter. The final temperature of the batter, at completion of mixing, ranged from 21.5°C. to 23°C.

(4). Loss of weight of cakes during baking. The loss of weight of the large cakes during baking ranged from 9.7% to 11.9%. The loss of weight of the small cakes ranged from 10.1% to 13.4%. The average values for loss of weight of the cakes during baking are shown in Table 13.

Table 13

Effect of Concentration of Egg White by Vacuum-Drying from the Frozen State on loss of Weight during Baking of Large and Small Angel Cakes

Percentage of solids after concentration	Loss of weight during baking (%)	
	Large cakes	Small cakes
12.1	10.6	11.9
46.5	11.1	11.4
97.5	10.9	12.1

(5). Volume of cakes. The volume of the large cakes ranged from 2049 to 2413 c.c. The volume of the small cakes ranged from 651 to 724 c. c. An analysis of variance of the volume of the large cakes showed that there was a non-significant difference in treatments and a non-significant difference in replications. The same was true of the analysis of variance of the volume of the small cakes. The average values for volume of large and small cakes made from the egg whites of the three different treatments are shown in Table 14.

(6). Tensile strength of cakes. The tensile strength of the large cakes ranged from 18.75 to 39.5; that of the small cakes ranged from 26.75 to 42.25. An analysis of variance of the tensile strength of the large cakes vs. the tensile strength of the small cakes also showed a non-significant difference between replications and between treatments. The average values for tensile strength of the large and small cakes made from the different concentrations of egg whites are shown in Table 15.

Table 14

Effect of Concentration of Egg White by Vacuum-Drying from the Frozen State on Volume of Large and Small Angel Cakes Baked from the Same Batter

Percentage of solids after concentration	Volume c. c. Large cakes Av.	Large cakes Diff.	Small cakes Av.	Small cakes Diff.
12.1	2130.5	----	678.5	----
46.5	2263.8	133.3	704.2	25.7
97.5	2165.3	34.8	673.0	- 5.5

Table 15

Effect of Concentration of Egg White by Vacuum-Drying from the Frozen State on Tensile Strength of Large and Small Angel Cakes Baked from the Same Batter

Percentage of solids after concentration	Tensile strength Large cakes Av.	Large cakes Diff.	Small cakes Av.	Small cakes Diff.
12.1	27.5	---	31.25	---
46.5	22.0	- 5.5	25.35	- 5.9
97.5	22.2	- 5.3	32.9	1.65

(7). Palatability of cakes. The total palatability scores of the large cakes ranged from 83.7 to 91.3; those of the small cakes ranged from 69.7 to 85.7. An analysis of variance of palatability scores of the large cakes showed there was a non-significant difference between treatments and replications. The same was true for the small cakes. However, when the palatability scores of the large cakes were compared with those of the small cakes, it was found that there was a highly significant difference. The average values obtained for the palatability scores are recorded in Tables 16 and 17.

Table 16

Effect of Concentration of Egg White by Vacuum-Drying from the Frozen State on Palatability of Large Angel Cakes

Percentage of solids after concentration	Palatability of cakes					
	Texture (25%)	Tenderness (25%)	Moistness (15%)	Eating Quality (35%)	Total (100%) Av.	Diff.
12.1	20.7	21.8	13.4	30.9	86.7	---
46.5	20.4	22.3	13.4	30.5	85.8	-0.9
97.5	21.2	22.2	13.8	31.3	88.4	1.7

Table 17

Effect of Concentration of Egg White by Vacuum-Drying from the Frozen State on Palatability of Small Angel Cakes

Percentage of solids after concentration	Palatability of cakes					
	Texture (25%)	Tenderness (25%)	Moistness (15%)	Eating Quality (35%)	Total (100%) Av.	Diff.
12.1	18.4	21.6	12.2	28.6	80.9	---
46.5	17.2	22.1	12.4	29.0	80.8	-0.1
97.5	18.1	20.7	12.2	28.6	79.6	-1.3

e. <u>Effect of vacuum-drying and storage at -17.8°C. (0°F.) of egg white on small angel cakes.</u>

The egg whites for this storage study were concentrated by vacuum-drying from the frozen state, and they were stored for eighty days at -17.8°C. (0°F.). The control sample (12.4% solids) was frozen and stored without concentrating. The other samples were concentrated to 34.4%, 55.6%, 74.0% and 95.4% solids and then stored.

(1). <u>pH of reconstituted egg white.</u> The pH of the sample which was frozen and stored in the normal, unconcentrated condition was 9.5. The pH of the concentrated samples after storage for eighty days and reconstitution with distilled water ranged from pH 9.4 to pH 9.65.

(2). <u>Specific gravity of meringue and batter.</u> The meringues for the twenty-five cakes were beaten until the specific gravity fell within a range of 0.167 to 0.187. They averaged a specific gravity of 0.179. The specific gravity of the batter ranged from 0.240 to 0.273 and averaged 0.261. The specific gravity of meringue and batter are recorded in Table 18.

(3). <u>Time of beating of meringue.</u> In this series of cakes it was noted that after the second replication there were still undispersed particles of the dried product floating in the clear liquid of the sample which had been concentrated. Since the samples which had been concentrated were not producing superior cakes, it was considered possible that a more thorough blending of the samples might produce more acceptable cakes. Accordingly, all of the samples except the control were processed briefly on the Waring Blendor. The blending caused a decrease in quality of the cakes in most respects. Therefore, the results of this experiment are reported in two parts to show the effect of additional blending.

The average time of beating of the meringue of the control sample was 60 seconds. Before blending on the Waring Blendor the average time of beating of the concentrated samples ranged from 68 to 80 seconds. After blending the average time of beating was increased to 83 to 92 seconds. The concentrated samples which were stored for 80 days required longer beating times than did the unconcentrated sample. (Table 18).

Table 18

Effect of Concentration of Egg White by Vacuum-Drying from the Frozen State and Storage at -17.8°C. (0°F.) on Average Specific Gravity of Meringue and Batter and Time of Beating of Meringue

Per cent of egg white solids	Specific gravity of meringue		Specific gravity of batter		Time of beating of meringue (seconds)	
	Before blending*	After blending**	Before blending*	After blending**	Before blending*	After blending*
12.4(Control)	0.171	----	0.251	----	60	----
34.4	0.173	0.180	0.259	0.256	68	85
55.6	0.177	0.184	0.261	0.268	68	83
74.0	0.185	0.186	0.265	0.264	80	92
95.4	0.177	0.185	0.262	0.267	80	83

* Average of 5 cakes of control samples, 2 cakes of concentrated samples
**Average of 3 cakes of concentrated samples

(4). <u>Temperature of batter</u>. The final temperature of the batter, at completion of mixing, ranged from 21.5°C. to 23°C. (70.7°F. to 73.4°F.).

(5). Loss of weight of cakes during baking. The loss of weight of the cakes during baking ranged from 11.8% to 15.3% and averaged 13.1%.

(6). Shrinkage of cakes during baking. It was noted in this series of cakes as well as in the mucin-treated series that there was a characteristic shrinkage of the cakes from the sides of the pan during the latter part of baking and cooling of the cakes. For the control sample, the shrinkage averaged 0.45 cm., and for the concentrated samples the shrinkage ranged from 0.40 to 0.60 cm.

(7). Volume of cakes. The volume of the cakes made from the control egg white averaged 693 c.c., a volume which was within the range associated with superior cakes. Before treatment on the Waring Blender, the average cake volume of the concentrated samples ranged from 635 to 672 c.c.; and after blending the average volume dropped to 613 to 632 c.c. (Table 19). On the basis of these few results it cannot be stated that the degree of concentration had any effect on the cake volume. However, concentration to any of the levels used in this study followed by storage at 0°F. for eighty days resulted in a decrease in cake volume.

Table 19

Effect of Concentration of Egg White by Vacuum-Drying from the Frozen State and Storage at -17.8°C. (0°F.) on Volume and Tensile Strength of Angel Cake

Per cent of egg white solids	Volume of cakes(c.c.) Before blending*	After blending**	Tensile strength of cakes (grams) Before blending*	After blending**
12.4 (control)	693	---	32.1	---
34.4	658	613	38.7	36.7
55.6	672	632	34.0	43.8
74.0	635	617	42.7	47.2
95.4	643	618	35.0	46.0

*Average of 5 cakes of control sample, 2 cakes of concentrated samples
**Average of 3 cakes of concentrated samples.

(8). Tensile strength of cakes. The tensile strength of the cakes made from the control egg white averaged 32.1 grams. Before treatment on the Waring Blendor, the average tensile strength of the concentrated samples ranged from 34 to 42.7 grams, and after blending the tensile strength ranged from 36.7 to 47.2 grams. Neither concentration nor processing with the Waring Blendor had much effect on the tensile strength of the cakes. (Table 19).

(9). Palatability of cakes. The total palatability scores of the cakes are shown in Table 20. The average score for the cakes made from the control egg white was 83.9. Before blending the concentrated samples had scores ranging from 75.5 to 85.3, and after blending, from 77.7 to 79.9. The cakes made from the concentrated samples were somewhat more compact and slightly coarser in texture than those from the unconcentrated samples, but there appeared to be little difference in tenderness.

Table 20

Effect of Concentration of Egg White by Vacuum-Drying from the Frozen State and Storage at -17.8°C. (0°F.) on Palatability of Angel Cake

Per cent of egg white solids	Palatability of angel cakes	
	Before blending*	After blending**
12.4 (control)	83.9	---
34.4	80.6	79.9
55.6	85.3	77.7
74.0	81.7	78.2
95.4	75.5	79.5

*Average of 5 cakes of control sample, 2 cakes of concentrated samples
**Average of 3 cakes of concentrated samples

f. Effect of vacuum drying and storage at 1.7°C. and 21.1°C. (35°F. and 70°F.) on microbiology of egg white.

(1). Standard plate count. There was a decrease in the standard plate count apparently caused by the concentrating process alone. In the concentrated and control samples stored at 1.7°C. (35°F.) there was relatively little change in the standard plate count over a storage period of one month. (Table 21) In the samples stored at 21.1°C. (70°F.) there was little change in the standard plate count of the two samples concentrated to the highest levels (74.8% and 97.2% solids). In the unconcentrated sample stored at 21.1°C. there was a rapid increase in the count. There was a definite, but slower, increase in the count of the samples concentrated to 34.3% and 45.4% solids stored at 21.1°C. (Table 22) After 10 days of storage at 21.1°C. an off-odor was noted in all of the samples except the one concentrated to 97.2% solids. The odor of the unconcentrated sample was described as resembling that present in incipient fermentation. The odors of the concentrated samples were variously described as musty, fruity and yeasty.

(2). <u>Direct microscopic count</u>. The direct microscopic count was made after approximately two and four weeks' storage. The count was higher than that obtained by the standard plate count in all but one instance. However, all counts lower than one million organisms per gram were believed to be unreliable because the average count in 60 fields had to be multiplied by a microscope factor of 1,062,000 to derive the count per gram. Therefore, only one organism per field would give a count of 1,062,000, and when so few organisms were present there was a large possibility of error. The direct count after storage of 31 days was higher in all but one case then the direct count after 17 days' storage. It was also evident that the samples were not thoroughly mixed, because the organisms were often present in clumps. It should be noted that the concentrated samples were not diluted to their original solids' content before dilutions for the bacteriological sampling were made. Therefore, the counts reported represent the organisms present per gram of concentrated egg white. The direct microscopic counts are recorded in Tables 23 and 24.

(3). <u>Yeast and mold count</u>. The yeast and mold counts obtained from the samples stored at 21.1°C. were relatively small, and these organisms were probably not the cause of deterioration of the samples. (Table 24).

Table 21

Effect of Concentration of Egg White by Vacuum-Drying from the Frozen State and Storage at 1.7°C. (35°F.) on Standard Plate Count

Per cent of egg white solids	Standard plate count per gram after varying storage periods					
	1 day	7 days	10 days	17 days	25 days	31 days
11.7	23,450	40,800	32,500	27,500	15,000	22,450
34.3	4,950	4,000	12,750	4,000	2,400	205
45.4	760	1,555	6,000	1,750	1,525	2,385
53.0	2,300	5,300	9,900	1,450	280	1,300
72.9	6,200	17,300	15,800	9,850	1,350	1,140
97.2	8,550	16,450	23,800	4,000	4,000	1,540

Table 22

Effect of Concentration of Egg White by Vacuum-Drying from the Frozen State and Storage at 21.1°C. (70°F.) on Standard Plate Count

per cent of egg white solids	Standard plate count per gram after varying storage periods					
	1 day	7 days	10 days	17 days	25 days	31 days
11.7	74,500	820,000	6,000,000	164,000,000	---	---
34.3	22,600	24,400	195,000	6,192,000	---	---
45.4	4,650	1,250	3,150	144,280	865,000	---
74.8	120	3,450	1,150	20	150	370
97.2	520	40	1,750	65	10	260

Table 23

Effect of Concentration of Egg White by Vacuum-Drying from the Frozen State and Storage at 1.7°C. (35°F.) on the Direct Microscopic Count

Per cent of egg white solids	Direct microscopic count per gram	
	17 days' storage	31 days' storage
11.7	70,800	987,660
34.3	35,400	902,700
45.4	17,700	885,000
53.0	88,500	354,000
72.9	17,700	456,660
97.2	35,400	1,062,000

Table 24

Effect of Concentration of Egg White by Vacuum-Drying from the Frozen State and Storage at 21.1°C. (70°F.) on the Direct Microscopic Count and Yeast and Mold count

Per cent of egg white solids	Yeast and mold count per gram after 10 days' storage	Direct microscopic count per gram	
		17 days' storage	31 days' storage
11.7	5	168,858,000	----
34.3	30	3,239,100	----
45.4	35	1,628,400	----
74.8	25	159,300	531,000
97.2	5	389,400	265,500

(4). pH of egg white. The only case in which there was a definite drop in pH during the storage period was in the unconcentrated sample held at 21.1°C. This sample dropped to pH 7.35, while all of the other samples were at pH 9.3 to 10.0.

2. Air film concentration.

a. Appearance of concentrated egg white. There were characteristic differences in the appearance of the egg white at the different levels of concentration. A thin skin formed on the top surface of the layer of egg white within a few minutes after the concentrating process was begun, before the concentration of solids had increased more than 1% over the amount originally present. When the material was stirred the skin disappeared, but it reformed more quickly as the concentration of solids increased. At approximately 15% solids a small amount of thick material tended to stick to the stirring rod and thermometer. At approximately 25% solids a large mass of material resembling thick white with entrapped air bubbles floated in a thin fluid portion. At about 35% solids the material all resembled thick white, and there was no longer any thin liquid present. At 40% solids the concentrated product seemed rubbery when it was stirred, and it started to stick to the bottom of the plate. At approximately 50% solids, the product was very rubbery and stretched into strands on stirring. It had a definitely whitish appearance from the increased number of entrapped air bubbles. After it had been concentrated beyond 60% solids it could no longer be stirred, and it formed a layer in the bottom of the plate. At approximately 75% solids this layer had a hard, glazed appearance, and cracks appeared with further drying.

b. Time and temperature of concentration. The temperature of the egg white during the concentrating process was varied in the two sections of this experiment. In the first section the temperature ranged from 35°C. to 45°C., and in the second section it ranged from 25°C. to 35°C. When the temperature was controlled, the time required for concentration could be varied by varying the size of the sample of egg white being concentrated. (Tables 25, 26 and Figures 6, 7) The thicker the layer of egg white in the plates, the longer the time required for concentration. The time required was also affected by the distance of the plates from the fan and by the humidity of the air. The plates which were closest to the fan were concentrated in a shorter time than those at a greater distance.

Table 25

Time Required for Concentration of Egg White by Air Film Process at 35°C.-45°C.

Time of concentration at 35°C.-45°C.	70-gram sample (0.2-cm. layer)*	150-gram sample (0.5-cm. layer)*	200-gram sample (0.7-cm. layer)*	400-gram sample (1.2-cm. layer)*
0	11.6	11.6	11.6	11.6
15 min.	17.8	-	13.2	12.5
30 min.	38.7	-	16.1	13.7
45 min.	77.3	-	19.9	15.2
1 hr.	85.5	58.0	26.6	16.8
15 min.	90.2	-	40.7	19.1
30 min.		80.9	67.2	21.5
45 min.		-	77.3	26.1
2 hr.		84.9		30.4
15 min.		87.0		38.8
30 min.				48.1
45 min.				60.7
3 hr.				63.1
15 min.				66.3
30 min.				67.2
45 min.				71.9
4 hr.				72.5
15 min.				73.7
30 min.				74.8
45 min.				76.1
5 hr.				76.7
15 min.				77.3
30 min.				78.6
45 min.				-
6 hr.				80.0
15 min.				80.7
30 min.				-
45 min.				81.4
9 hr.				84.4

* % of egg white solids

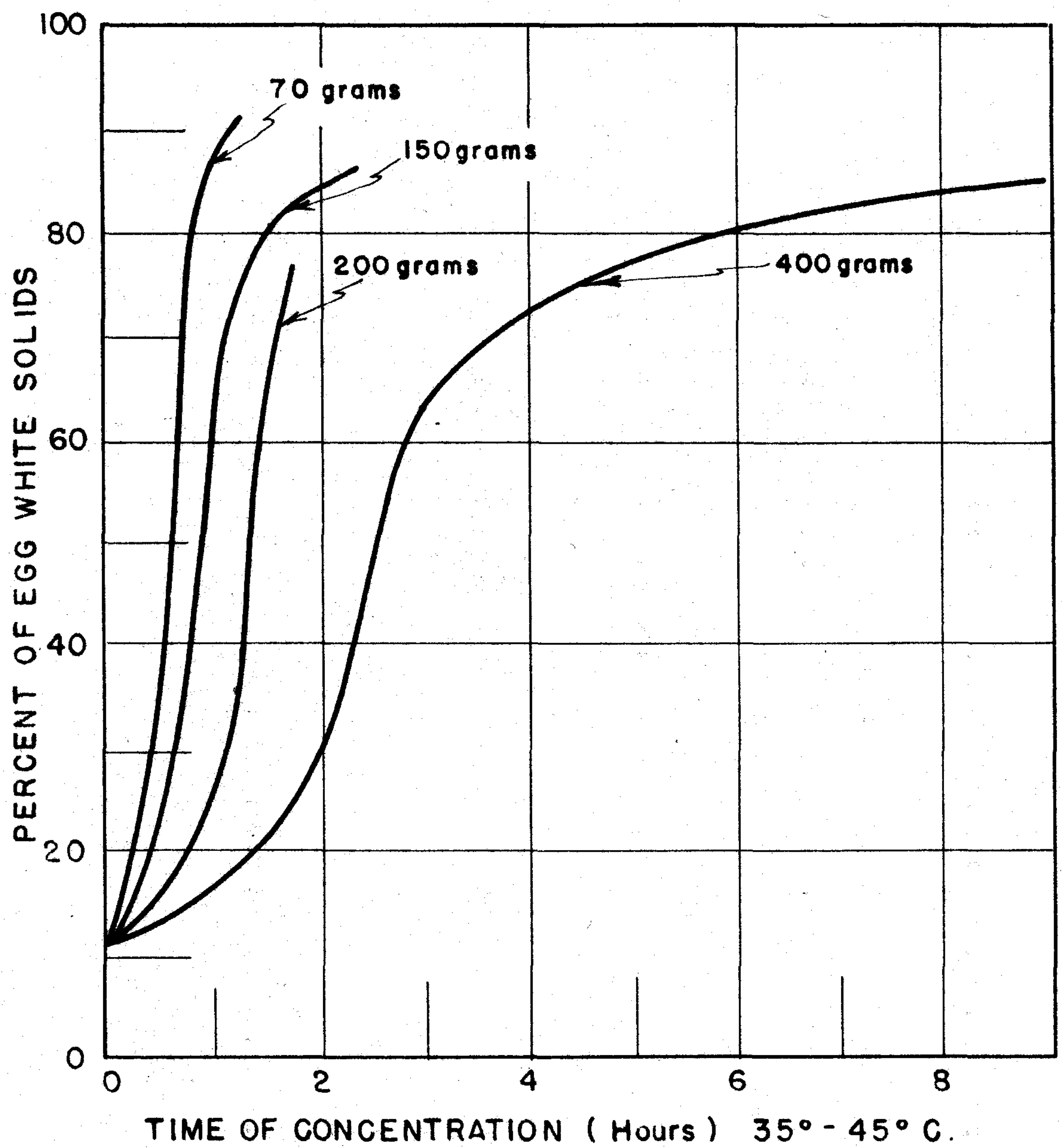

Figure 6. Time Required for Concentration of Egg White by Air Film Process at 35°C.-45°C.

Table 26

Time Required for Concentration of Egg White by Air Film Process at 25°C.-35°C.

Time of concentration at 25°C.-35°C.	70-gram sample (0.2-cm. layer)*	150-gram sample (0.5-cm. layer)*	200-gram sample (0.7-cm. layer)*	400-gram sample (1.2-cm. layer)*
0	11.2	11.2	11.2	11.2
15 min.	14.9	13.1	12.1	11.6
30 min.	22.1	17.3	13.2	12.3
45 min.	42.4	23.2	14.7	13.0
1 hr.	71.3	36.9	-	13.9
15 min.	78.4	62.2	19.5	14.7
30 min.	82.5	86.1	22.8	15.8
45 min.	87.1	88.4	28.0	16.8
2 hr.		90.8	36.4	18.6
15 min.		93.3	50.3	20.1
30 min.		93.3	64.0	22.3
45 min.		-	70.0	24.8
3 hr.		96.0	74.7	27.9
15 min.			75.9	32.0
30 min.			78.6	37.3
45 min.			-	43.3
4 hr.				53.3
15 min.				62.6
30 min.				64.4
45 min.				66.9
5 hr.				69.5
15 min.				70.6
45 min.				73.4
6 hr. 15 min.				75.1
45 min.				77.2
7 hr. 15 min.				78.6
45 min.				80.7
8 hr. 15 min.				80.7
45 min.				81.5
9 hr.				81.5

* % of egg white solids

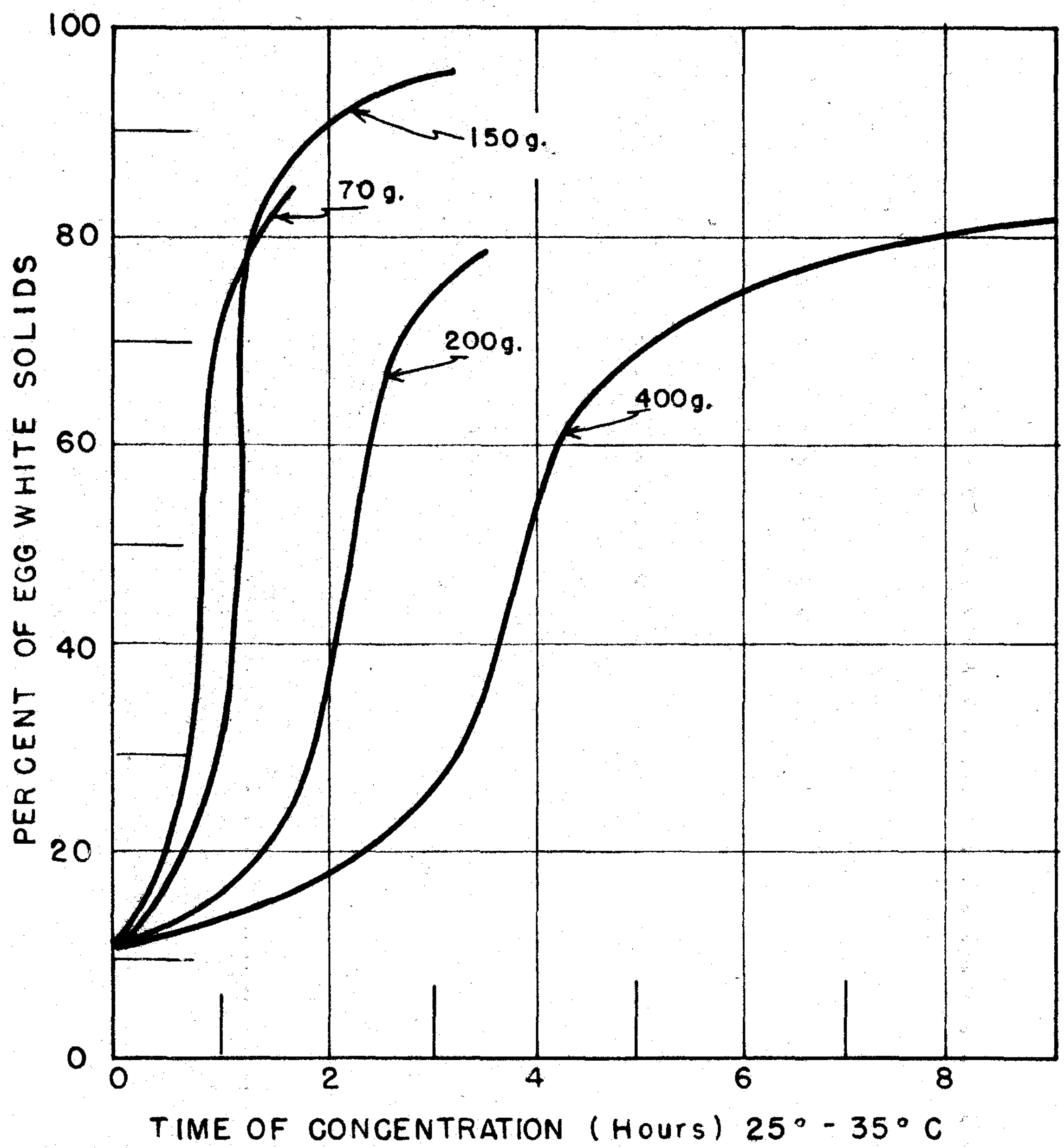

Figure 7. Time Required for Concentration of Egg White by Air Film Process at 25°C.-35°C.

c. <u>Effect of air film concentration of egg white at 35°C. to 45°C. (95°F. to 113°F.) on angel cakes.</u>

(1). <u>Specific gravity of meringue and batter.</u> The specific gravity of the meringues ranged from 0.167 to 0.187 and averaged 0.176. The specific gravity of the batters ranged from 0.250 to 0.275 and averaged 0.260. The meringues of all of the cakes in this series were beaten until they fell within a definite range (0.167 to 0.187) so that there would be no difference in the cakes caused by differences in specific gravity.

(2). <u>Total beating time of meringue.</u> The total beating time of the meringues ranged from 1 minute to 2 minutes and 20 seconds. Beating time was related to the time required to concentrate the eggs. When the time of concentration was approximately one and one-half hours or less, there was apparently no effect of time of concentration on beating time of the meringue. As the time of concentration was increased to approximately two and one-half hours, there was an increase in the time required for beating the meringue. From a concentration time of two and one-half hours to nine hours there was no further increase in beating time with increased time of concentration. (Table 27, Figure 8) Beating time was apparently not related to the degree of concentration of the egg white to approximately 90 per cent egg white solids. (Table 27, Figure 9)

(3). <u>Temperature of batter.</u> The temperature of the batter ranged from 21.5°C. to 23°C.

Table 27

Effect on Time and Degree of Concentration of Egg White by Air Film Process at 35°C.-45°C. on Time of Beating Meringue, Angel Cake Volume and Tensile Strength

Time of concentration at 35°C-45°C.	Per cent of egg white solids	Time of Beating meringue	Angel cake volume (c.c.)	Tensile strength of angel cakes (grams)
0	11.6	1 min. 15 sec.	690	37.0
0	11.6	1 min. 20 sec.	653	47.5
0	11.6	1 min.	719	30.5
0	11.6	1 min.	704	33.5
0	11.6	1 min.	700	24.0
0	11.6	1 min.	713	27.0
0	11.6	1 min. 25 sec.	676	33.5
0	11.6	1 min. 5 sec	710	26.5
40 min.	41.6	1 min. 15 sec.	698	37.0
45 min.	67.7	1 min. 30 sec.	646	48.5
55 min.	77.3	1 min. 15 sec	689	37.5
1 hr.	24.7	1 min. 5 sec.	703	27.5
1 hr.	24.7	-	688	35.5
1 hr. 15 min.	90.2	1 min. 5 sec.	722	36.0
1 hr. 20 min.	39.3	1 min.	704	27.5
1 hr. 20 min.	39.3	1 min.	721	24.0
1 hr. 20 min.	39.3	1 min.	700	25.0
1 hr. 25 min.	85.5	1 min. 30 sec.	686	38.0
1 hr. 25 min.	39.6	1 min. 20 sec.	691	31.0
1 hr. 25 min.	39.6	1 min. 20 sec.	718	32.0
1 hr. 35 min.	85.5	1 min. 40 sec.	678	31.5
1 hr. 35 min.	77.3	1 min. 15 sec.	696	32.5
1 hr. 40 min.	77.3	1 min. 45 sec.	652	42.5
1 hr. 40 min	77.3	1 min. 50 sec.	622	43.0
1 hr. 40 min.	69.2	2 min.	684	39.0
1 hr. 40 min.	69.2	2 min.	690	35.0
1 hr. 45 min.	85.5	1 min. 40 sec.	672	44.5
1 hr. 55 min.	85.5	2 min.	602	64.5
2 hr. 15 min.	87.0	1 min. 35 sec.	634	37.0
2 hr. 50 min.	39.1	2 min.	610	45.5
2 hr. 50 min.	39.1	2 min.	628	52.0
3 hr. 25 min.	59.3	2 min. 5 sec.	619	48.0
3 hr. 25 min.	59.3	2 min. 5 sec.	623	45.5
3 hr. 25 min.	59.3	2 min. 20 sec.	620	49.5
3 hr. 25 min.	59.3	2 min.	630	48.0
4 hr. 45 min.	77.7	2 min. 5 sec.	606	50.0
4 hr. 45 min.	77.7	2 min. 10 sec.	590	53.0
4 hr. 45 min.	77.7	2 min. 20 sec.	612	59.0
4 hr. 45 min.	77.7	2 min.	627	47.0
9 hr.	84.4	2 min.	602	59.0
9 hr.	84.4	2 min. 5 sec.	612	44.0
9 hr.	84.4	2 min. 10 sec.	622	54.0
9 hr.	84.4	2 min.	640	47.5

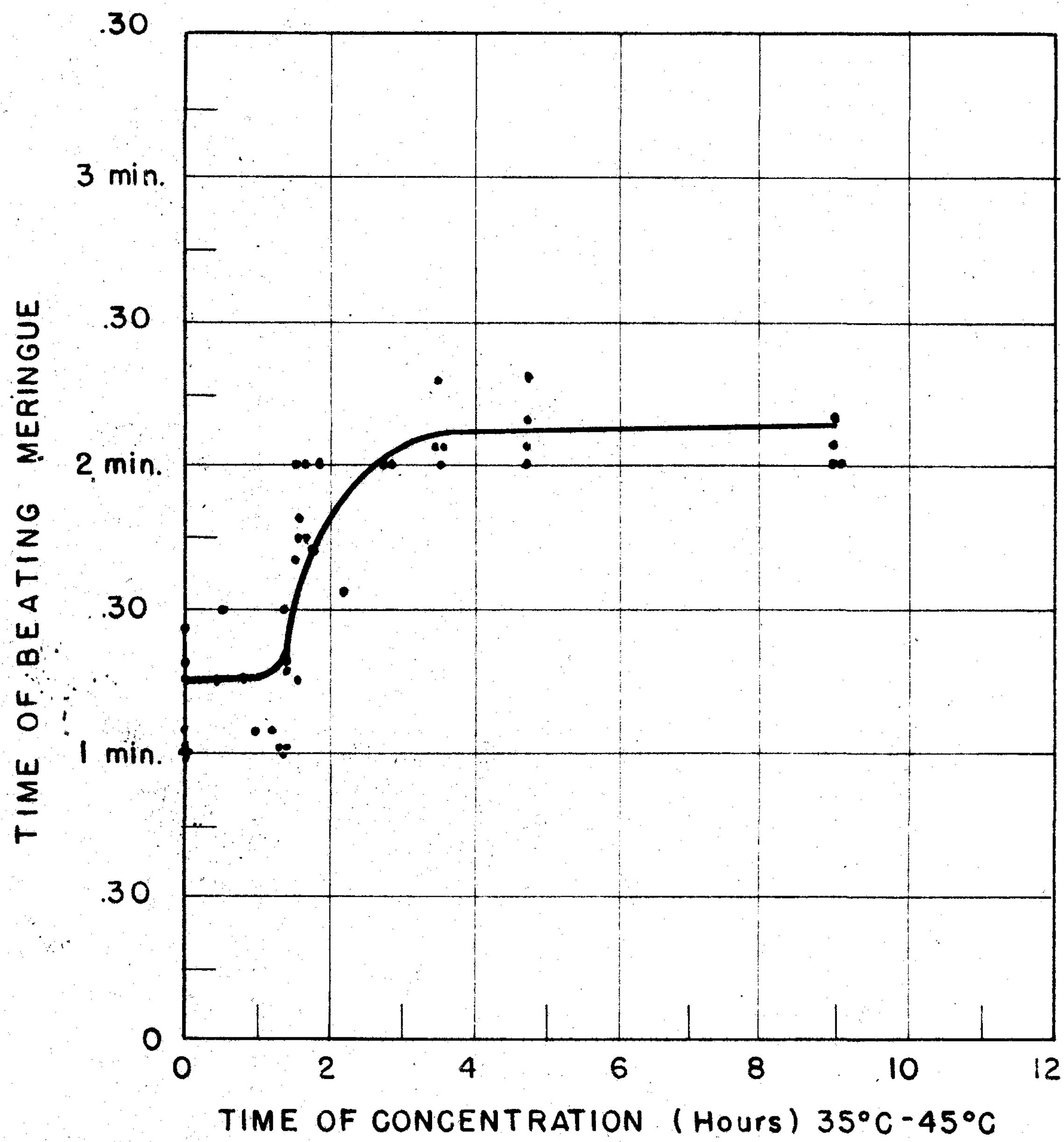

Figure 8. Effect of Time of Concentration of Egg White by Air Film Process at 35°C.-45°C. on Time of Beating Meringue

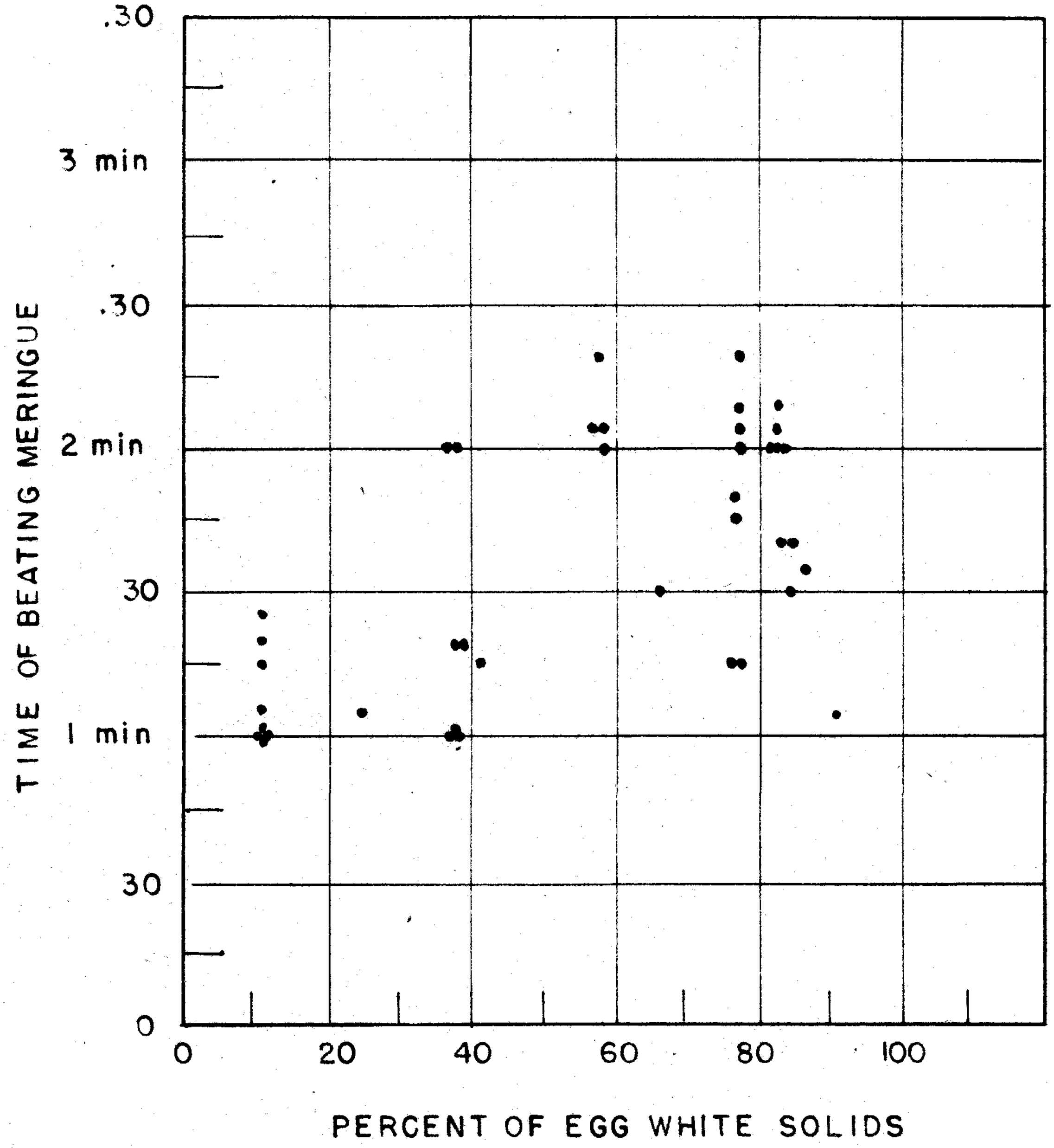

Figure 9. Effect of Degree of Concentration of Egg White by Air Film Process at 35°C.-45°C. on Time of Beating Meringue

(4). Loss of weight of cakes during baking. The loss of weight of the cakes during baking ranged from 11.5% to 16.5% and averaged 12.9%.

(5). Volume of cakes. The volume of cakes ranged from 602 c.c. to 722 c. c. There was a definite relation between cake volume and time required for concentrating the egg white. When the time of concentration was approximately one and one-half hours or less, there was apparently no effect of time of concentration on cake volume. As the time of concentration was increased to approximately two and one-half hours there was a decrease in the cake volume. From a concentration time of two and one-half hours to nine hours there was no further decrease in cake volume with increased time of concentration. (Table 27, Figure 10) Cake volume was apparently not related to the degree of concentration of the egg white to approximately 90 per cent egg white solids. (Table 27, Figure 11)

(6). Tensile strength of cakes. The tensile strength of the cakes ranged from 24 to 64.5 grams. There was a definite relation between tensile strength of the cakes and time required for concentrating the egg white. When the time of concentration was approximately one and one-half hours or less, there was apparently no effect of time of concentration on tensile strength of the cakes. As the time of concentration was increased to approximately two and one-half hours, there was an increase in tensile strength of the cakes. From a concentration

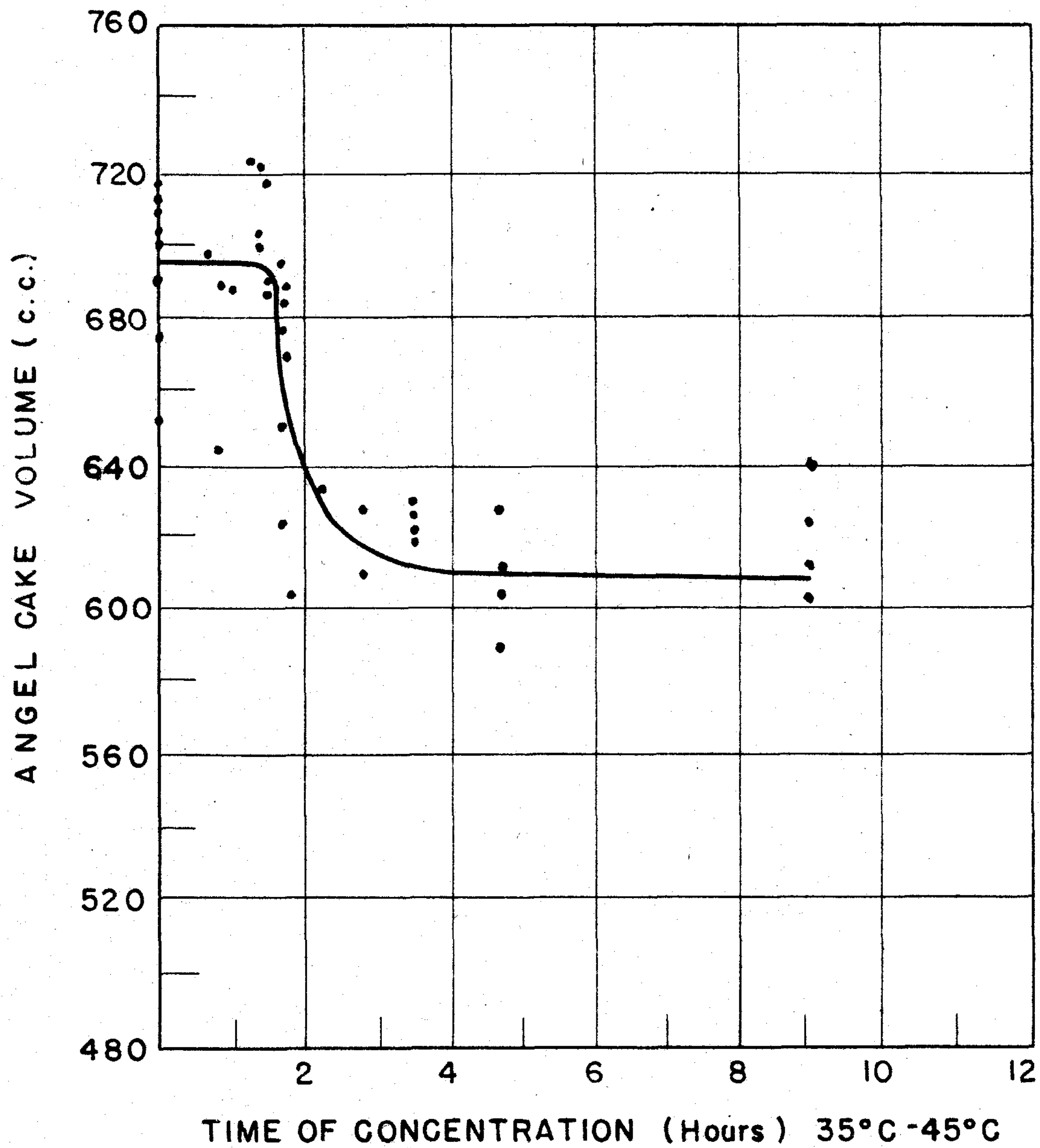

Figure 10. Effect of Time of Concentration of Egg White by Air Film Process at 35°C.-45°C. on Angel Cake Volume

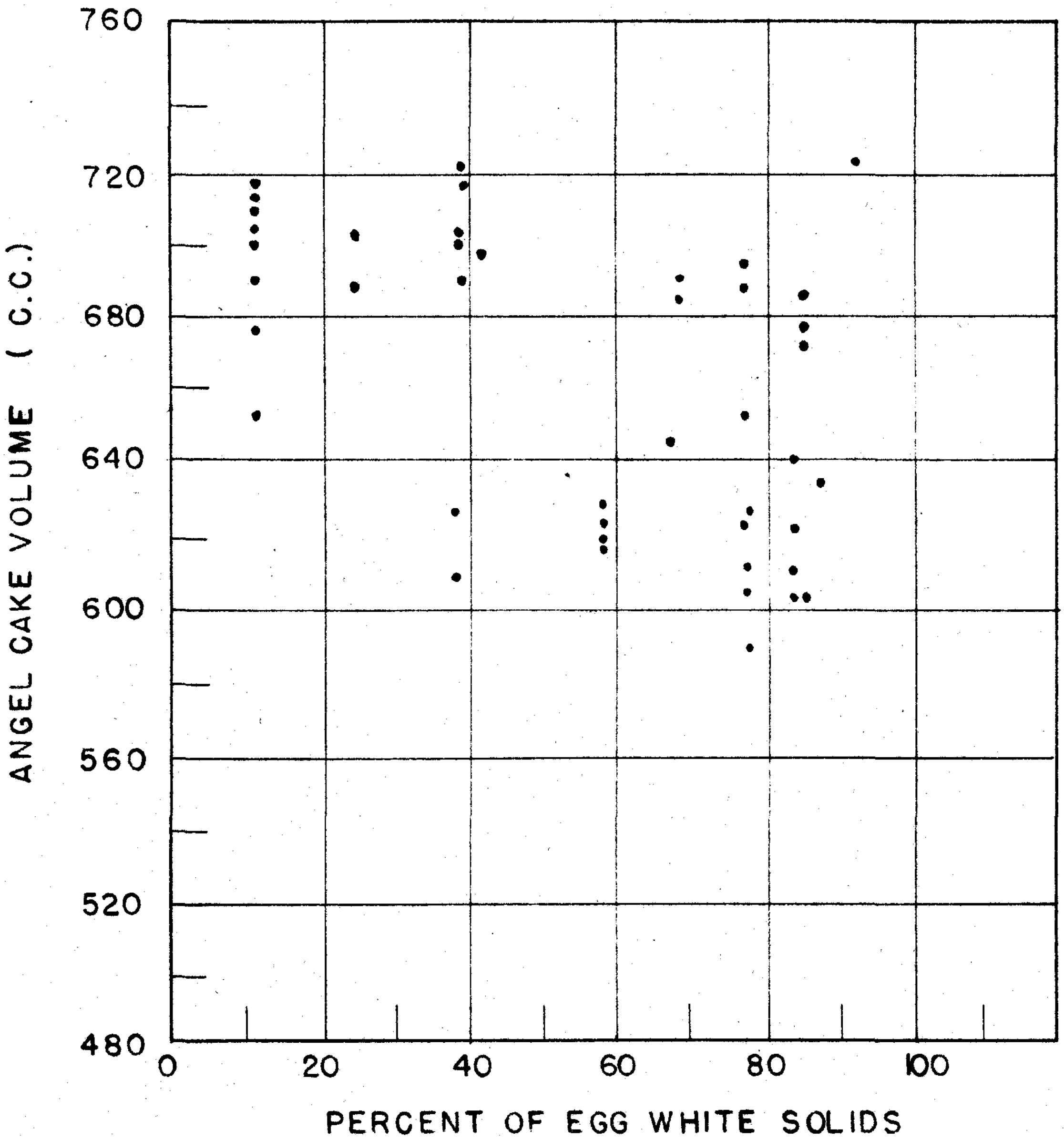

Figure 11. Effect of Degree of Concentration of Egg White by Air Film Process at 35°C.-45°C. on Angel Cake Volume

time of two and one-half hours to nine hours there was no further increase in tensile strength. (Table 27, Figure 12) Tensile strength was apparently not related to the degree of concentration of the egg white to approximately 90 per cent egg white solids. (Table 27, Figure 13)

(7). Palatability of cakes. The total palatability scores of the cakes ranged from 71.3 to 91.0 out of possible score of 100. Texture scores ranged from 15.7 to 22.7 out of a possible score of 25. Tenderness scores ranged from 17.3 to 23 out of a possible score of 25. Scores fór moistness ranged from 9.7 to 14 out of a possible score of 15. Scores for eating quality ranged from 25 to 32.7 out of a possible score of 35. The palatability of the cakes was related to the time required for concentration of the egg whites. When the time of concentration was approximately one and one-half hours or less, there was apparently no effect of time of concentration on palatability of the cakes. As the time of concentration was increased to approximately two and one-half hours there was a decrease in the palatability of the cakes. From a concentration time of two and one-half hours to nine hours there was no further decrease in palatability with increased time of concentration. (Table 28, Figure 14) The palatability of the cakes was apparently not related to the degree of concentration of the egg white to approximately 90 per cent egg white solids. (Table 28, Figure 15)

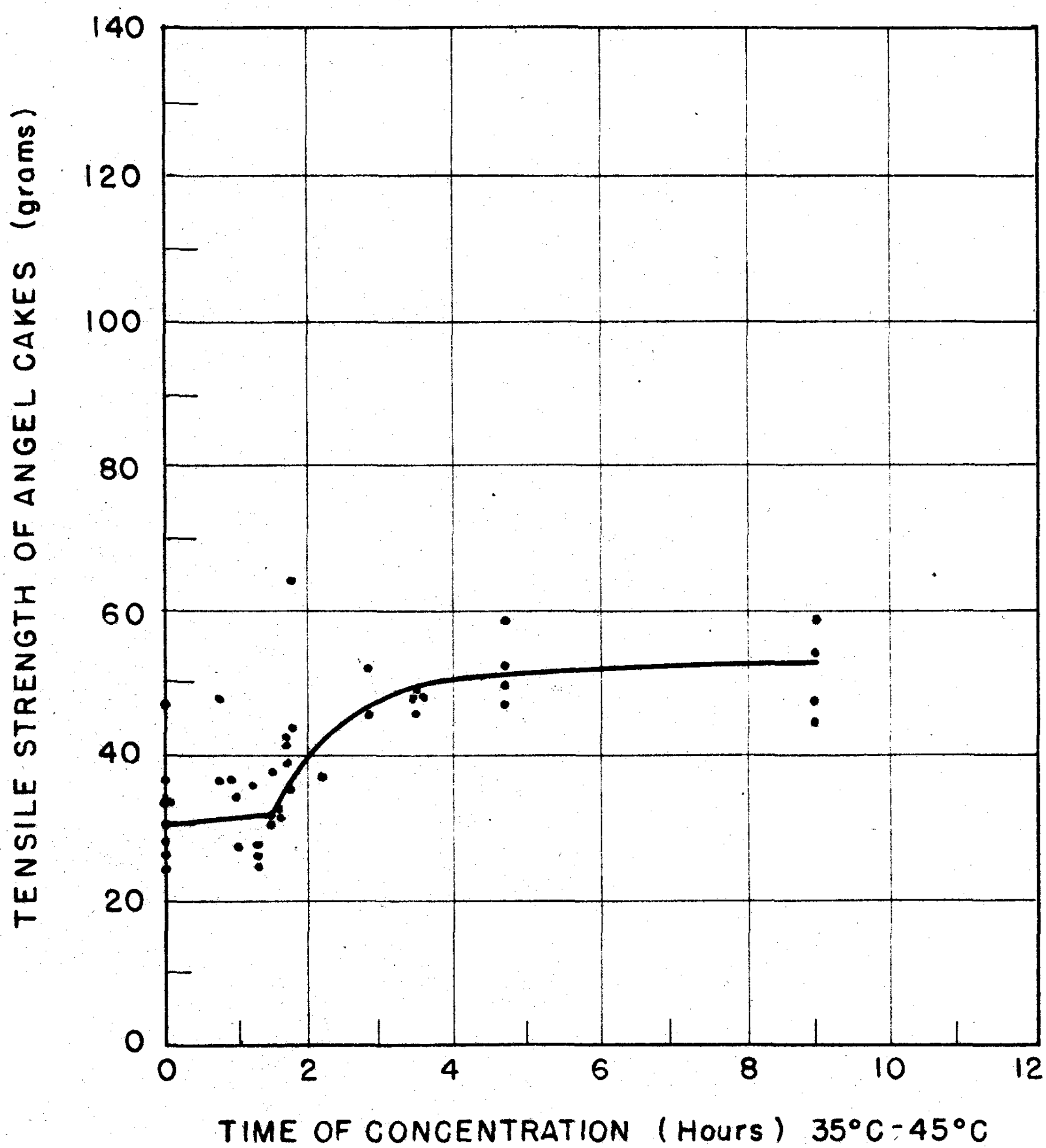

Figure 12. Effect of Time of Concentration of Egg White by Air Film Process at 35°C.-45°C. on Tensile Strength of Angel Cakes

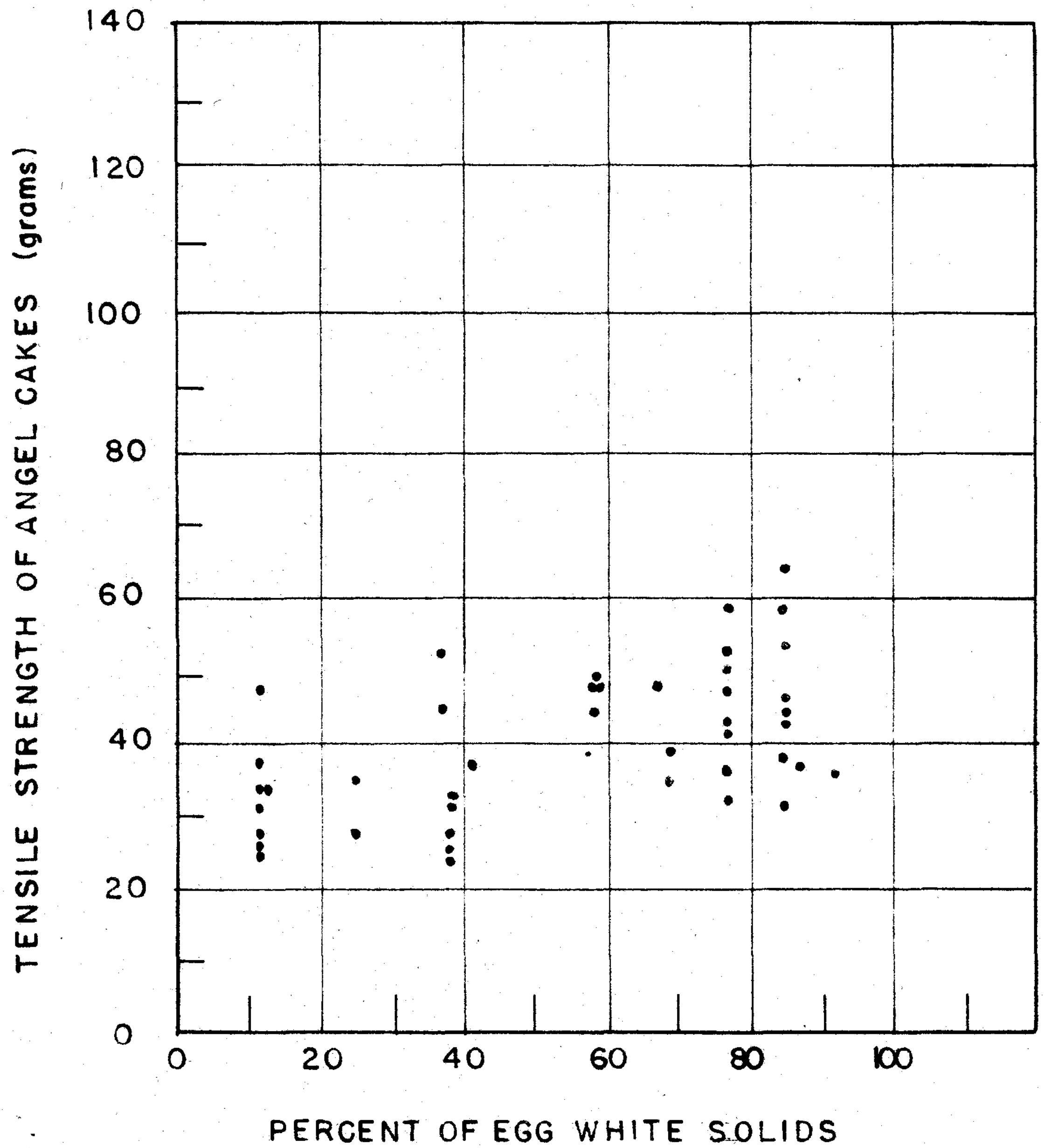

Figure 13. Effect of Degree of Concentration of Egg White by Air Film Process at 35°C.-45°C. on Tensile Strength of Angel Cakes

Table 28

Effect of Time and Degree of Concentration of Egg White by Air Film Process at 35°C.-45°C. on Palatability of Angel Cakes

Time of concentration at 35°-45°C.	Percent of egg white solids	Texture of angel cakes (25%)	Tenderness of angel cakes (25%)	Moistness of angel cakes (15%)	Eating quality of angel cakes (35%)	Total palatability scores (100%)
0	11.6	21.7	21.3	13.7	31.3	88.0
0	11.6	19.3	21.3	14.0	30.0	84.7
0	11.6	21.0	21.3	13.7	31.0	87.0
0	11.6	22.7	21.3	13.7	31.0	88.7
0	11.6	20.0	21.0	10.7	25.0	76.7
0	11.6	21.3	20.7	13.3	30.7	86.0
0	11.6	21.0	22.0	12.3	31.7	87.0
0	11.6	21.3	21.7	13.0	32.7	88.7
40 min.	41.6	21.7	21.3	13.7	31.7	88.3
43 min.	67.7	20.3	20.7	13.7	29.3	84.0
55 min.	77.3	21.7	22.7	13.7	32.7	90.7
1 hr.	24.7	22.0	21.7	12.3	30.7	86.7
1 hr.	24.7	21.7	22.0	12.0	31.3	87.0
1 hr. 15 min.	90.2	22.0	23.0	13.7	32.3	91.0
1 hr. 20 min.	39.3	21.7	22.7	13.7	32.0	90.0
1 hr. 20 min.	39.3	21.7	22.0	13.3	31.7	88.7
1 hr. 20 min.	39.3	21.3	22.3	13.3	30.7	87.7
1 hr. 25 min.	85.5	21.0	22.3	14.0	31.0	88.3
1 hr. 25 min.	39.6	21.7	22.0	11.3	31.3	86.3
1 hr. 25 min.	39.6	20.3	20.7	12.0	32.3	85.3
1 hr. 35 min.	85.5	19.7	22.0	14.0	31.3	87.0
1 hr. 35 min.	77.3	-	-	-	-	-
1 hr. 40 min.	77.3	18.0	21.7	9.7	27.7	77.0
1 hr. 40 min.	77.3	17.3	18.7	12.7	24.7	73.3
1 hr. 40 min.	69.2	20.3	21.0	12.3	29.3	83.0

Continued on next page

Table 28

Continued from last page

Time of concentration at 35^{o}-45^{o}C.	Per cent of egg white solids	Texture of angel cakes (25%)	Tenderness of angel cakes (25%)	Moistness of angel cakes (15%)	Eating quality of angel cake (35%)	Total palatability scores (100%)
1 hr. 40 min.	69.2	19.7	21.7	12.7	32.3	86.3
1 hr. 45 min.	85.5	20.3	20.7	13.7	30.0	84.7
1 hr. 55 min.	85.5	19.0	19.0	12.7	27.7	78.3
2 hr. 15 min.	87.0	18.7	21.3	12.0	30.7	82.7
2 hr. 50 min.	39.1	17.7	18.3	12.7	25.7	74.3
2 hr. 50 min.	39.1	18.7	19.3	12.3	28.3	78.7
3 hr. 25 min	59.3	18.3	20.0	13.3	28.7	80.3
3 hr. 25 min.	59.3	19.3	20.3	11.7	28.7	80.0
3 hr. 25 min.	59.3	17.3	19.7	13.3	27.7	78.0
3 hr. 25 min.	59.3	17.3	18.7	12.3	28.3	76.7
4 hr. 45 min.	77.7	16.7	19.7	11.7	26.7	74.7
4 hr. 45 mih.	77.7	18.7	17.3	10.3	25.0	71.3
4 hr. 45 min.	77.7	16.7	19.0	13.0	27.3	76.0
4 hr. 45 min.	77.7	18.7	18.3	12.3	28.0	77.3
9 hr.	84.4	16.0	17.7	11.7	27.0	72.3
9 hr.	84.4	19.0	20.7	11.0	28.3	79.0
9 hr.	84.4	15.7	17.7	12.0	26.3	71.7
9 hr.	84.4	18.3	19.7	12.0	29.0	79.0

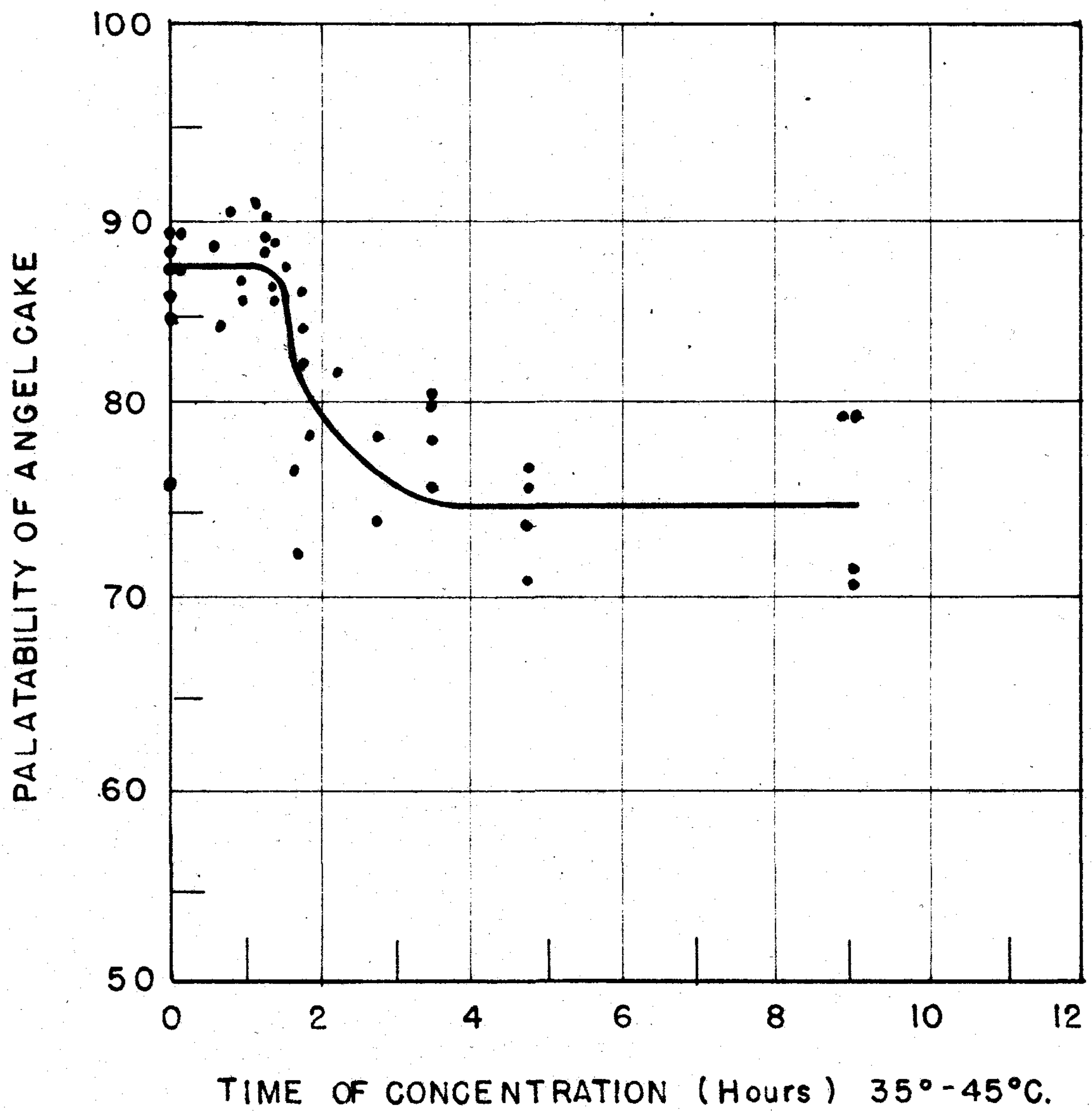

Figure 14. Effect of Time of Concentration of Egg White by Air Film Process at 35°C.-45°C. on Palatability of Angel Cakes

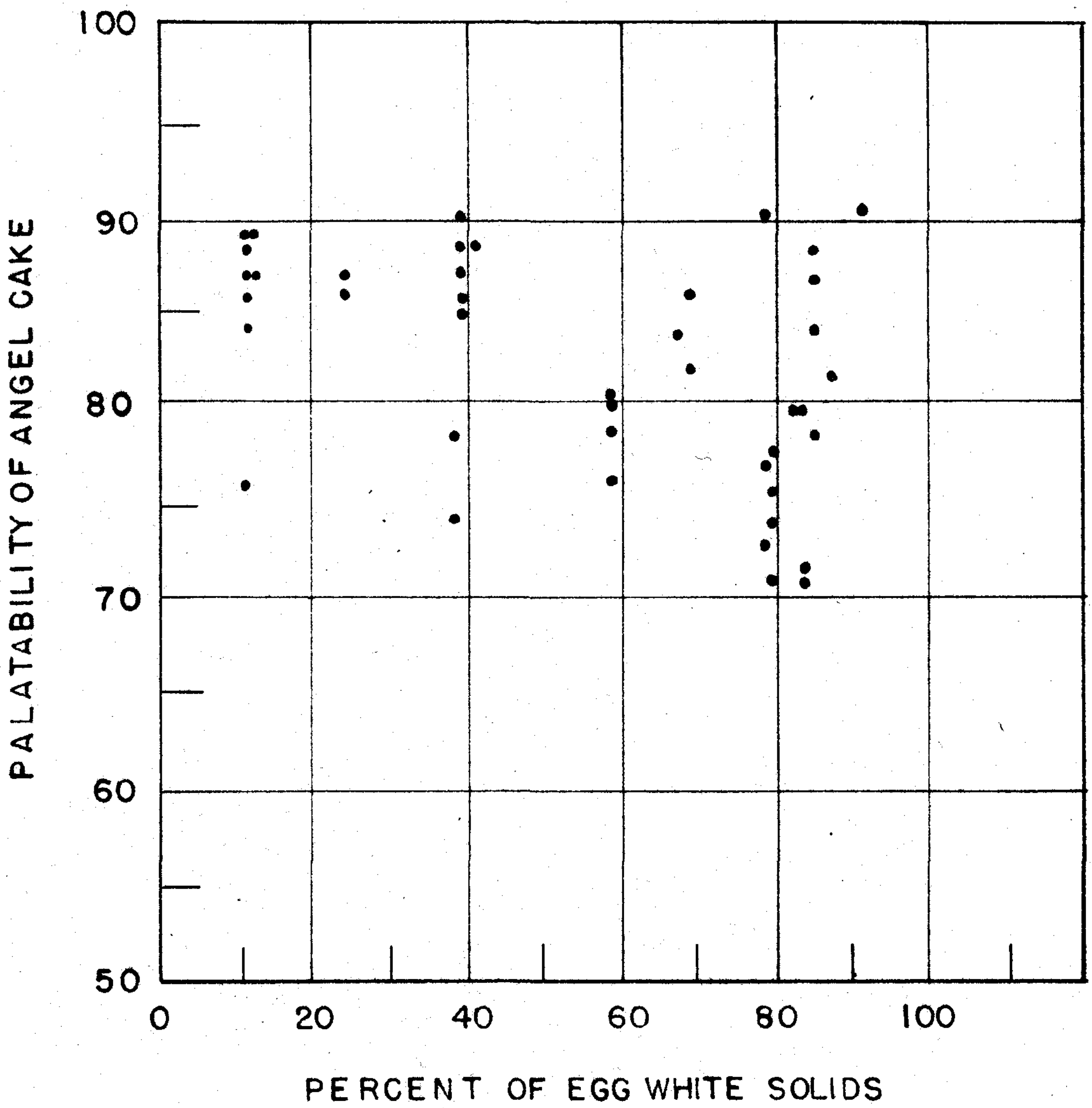

Figure 15. Effect of Degree of Concentration of Egg White by Air Film Process at 35°C.-45°C. on Palatability of Angel Cakes

d. Effect of air film concentration of egg white at 25°C. to 35°C. (77°F. to 95°F.) on angel cakes.

(1). Specific gravity of meringue and batter. The specific gravity of the meringues ranged from 0.167 to 0.187 and averaged 0.176. The specific gravity of the batters ranged from 0.243 to 0.273 and averaged 0.262. The meringues of all of the cakes in this series were beaten until they fell within a definite range in order that there would be no difference in the cakes caused by differences in specific gravity.

(2). Total beating time of meringue. The total beating time of the meringues ranged from 1 minute to 1 minute and 40 seconds. The effect of concentration of the egg white by the air film process at 25°C. to 35°C. on time of beating the meringue is shown in Table 29 and Figure 16. The total beating time was not affected by concentration at that temperature range for as long as 12 hours, except for the fact that the unconcentrated whites required the longest beating time.

(3). Temperature of batter. The temperature of the batter ranged from 21.5°C. to 23°C.

(4). Loss of weight of cakes during baking. The loss of weight of the cakes during baking ranged from 11.8% to 15.5% and averaged 13.6%.

(5). Volume of cakes. The volume of the cakes ranged from 640 to 732 c.c. The volume of the cakes made from the unconcentrated whites was distinctly lower than that of the cakes made from the concen-

Table 29

Effect of Time and Degree of Concentration of Egg White by Air Film Process at 25°C.-35°C. on Time of Beating Meringue, Angel Cake Volume and Tensile Strength

Time of concentration at 25°C.-35°C.	Per cent of of egg white solids	Time of beating meringue	Angel cake volume (c.c.)	Tensile strength of angel cakes (gms.)
0	11.2	1 min.20 sec.	673	31.0
0	11.2	1 min.20 sec.	690	27.0
0	11.2	1 min.30 sec.	645	35.5
0	11.2	1 min.40 sec.	640	36.5
1 hr. 30 min.	70.0	1 min.	714	25.5
1 hr. 30 min.	70.0	1 min.	722	19.5
2 hr.	74.7	1 min.	732	32.0
2 hr.	74.7	1 min.	722	20.0
2 hr. 30 min.	70.0	1 min.	728	31.5
2 hr. 30 min	70.0	1 min.	720	22.5
3 hr.	78.1	1 min.10 sec.	694	40.5
4 hr.	77.2	1 min.10 sec.	694	40.0
4 hr.	77.2	1 min. 5 sec.	725	21.5
4 hr. 30 min.	77.2	1 min.10 sec.	676	44.0
4 hr. 30 min.	77.2	1 min.20 sec.	666	37.5
5 hr.	78.6	1 min.10 sec.	703	37.5
5 hr.	78.6	1 min.15 sec.	676	30.5
9 hr.	81.5	1 min.10 sec.	700	36.5
9 hr.	81.5	1 min. 5 sec.	725	23.0
9 hr.	81.5	1 min. 5 sec.	700	36.5
12 hr.	92.2	1 min.15 sec.	679	27.5

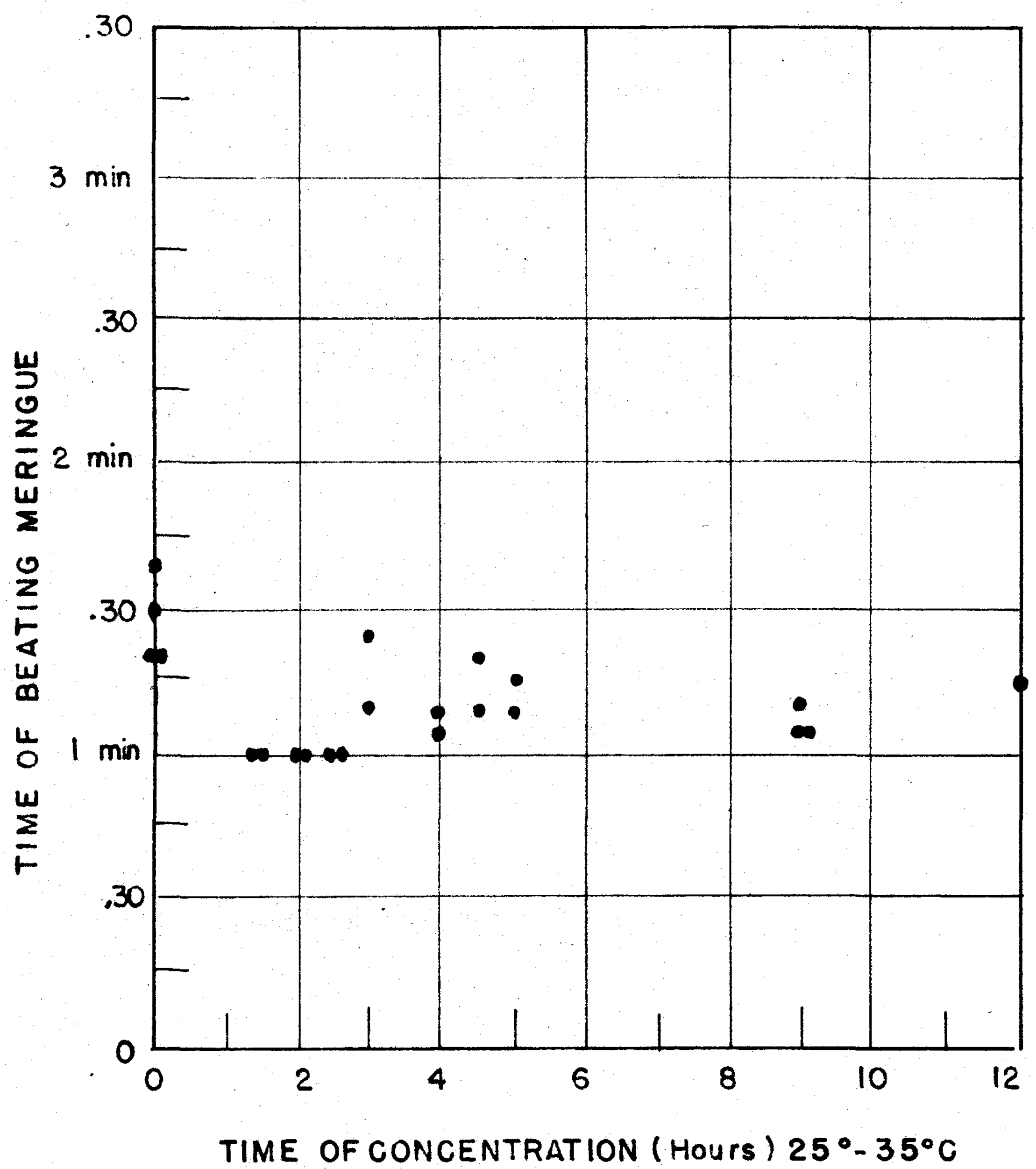

Figure 16. Effect of Time of Concentration of Egg White by Air Film Process at 25°C.-35°C. on Time of Beating Meringue

trated whites. Because of time limitations the fresh eggs used in this series were not stored at 70°F. for seven days as was the case with the previous series; and in preliminary experiments with the electric mixer used, it was found that thick egg whites required a longer beating time and produced a cake with a lower volume than thin egg whites. In spite of the fact that all of the egg whites were processed briefly on the Waring Blendor to break up the thick white, the control eggs still had a thick enough structure that the mixer used was inadequate for breaking it up sufficiently. There was no decrease in cake volume caused by concentration of the whites at this temperature range for as long as 12 hours. (Table 29 and Figure 17)

(6). Tensile strength of cakes. The tensile strength of the cakes ranged from 19.5 to 44.0 grams. Tensile strength was not affected by concentration at this temperature range for as long as 12 hours. (Table 29, Figure 18)

(7). Palatability of cakes. The total palatability scores of the cakes ranged from 80.7 to 89.3 out of a possible score of 100. Texture scores ranged from 18.3 to 22.0 out of a possible score of 25. Tenderness scores ranged from 18.3 to 22.7 out of a possible score of 25. Scores for moistness ranged from 11.7 to 13.7 out of a possible score of 15. Scores for eating quality ranged from 26.3 to

32.3 out of a possible score of 35. The palatability of the cakes was not affected by concentration at this temperature range for as long as 12 hours. (Table 30 and Figure 19)

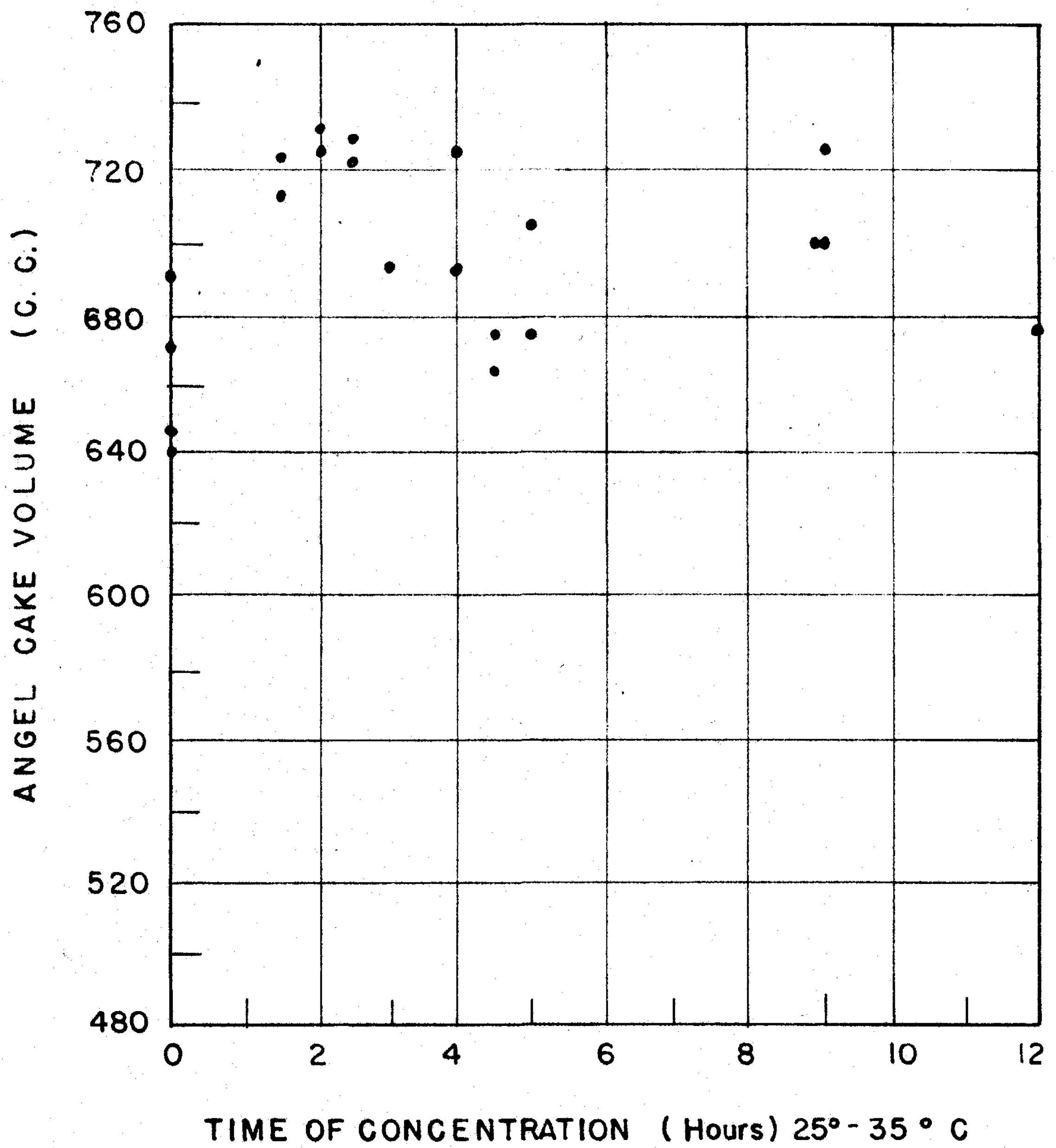

Figure 17. Effect of Time of Concentration of Egg White by Air Film Process at 25°C.-35°C. on Angel Cake Volume

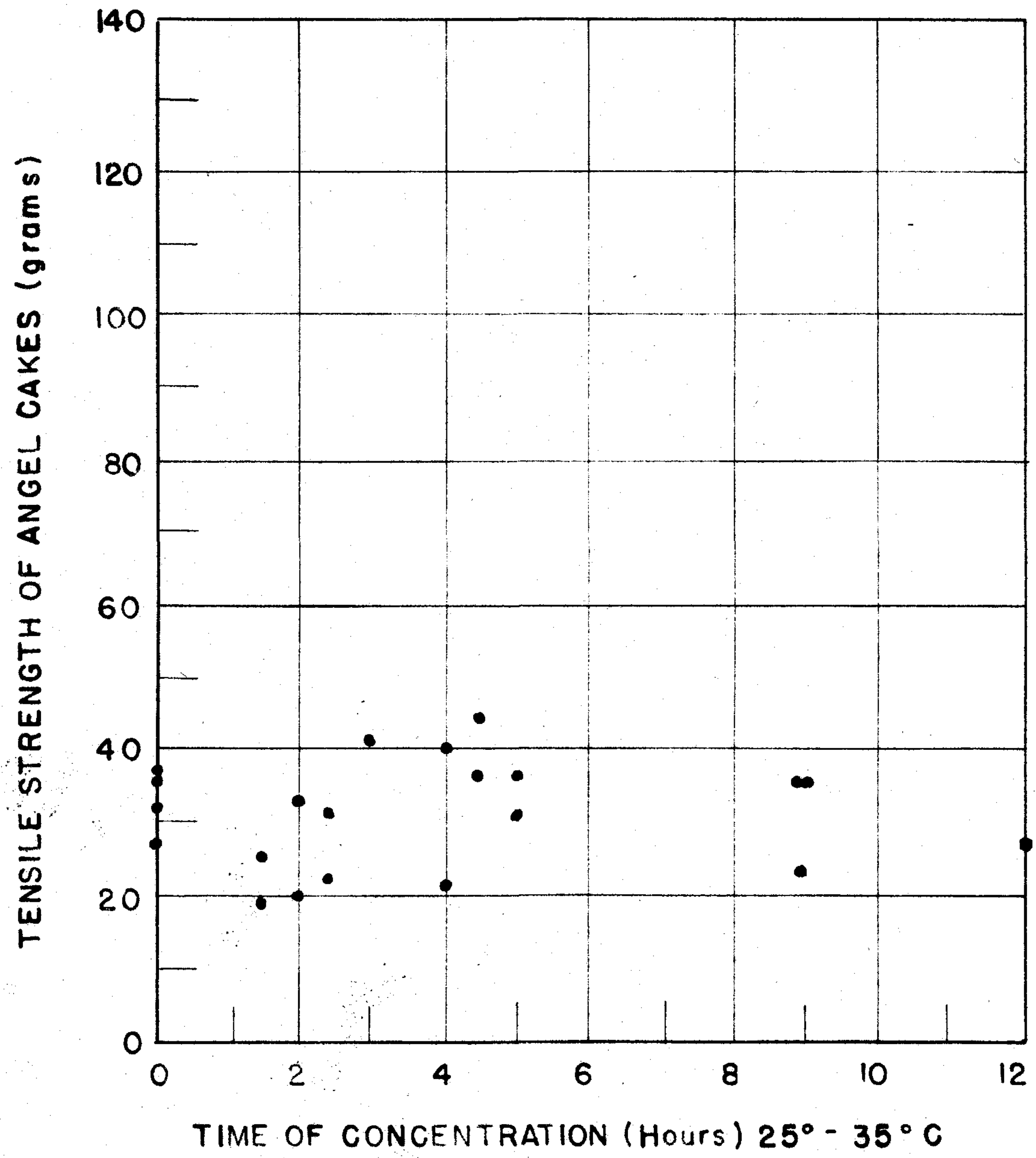

Figure 18. Effect of Time of Concentration of Egg White by Air Film Process at 25°C.-35°C. on Tensile Strength of Angel Cakes

Table 30

Effect of Time and Degree of Concentration of Egg White by Air Film Process at 25°C.-35°C. on Palatability of Angel Cake

Time of concentration at 25°-35°C.	Per cent of egg white solids	Texture of angel cakes (25%)	Tenderness of angel cakes (25%)	Moistness of angel cakes (15%)	Eating quality angel cakes (35%)	Total palatability scores of cakes (100%)
0	11.2	20.3	21.3	13.0	31.7	86.3
0	11.2	21.3	22.3	13.7	32.3	89.7
0	11.2	18.3	20.7	13.3	29.7	82.0
0	11.2	19.7	22.7	12.3	30.7	85.3
1 hr. 30 min.	70.0	20.3	22.0	13.7	32.0	88.0
1 hr. 30 min.	70.0	21.3	22.3	13.0	31.0	87.7
2 hr.	74.7	20.3	21.7	13.3	31.0	86.3
2 hr	74.7	19.7	22.7	13.0	29.7	85.0
2 hr. 30 min.	70.0	18.3	20.0	13.0	29.3	80.7
2 hr. 30 min.	70.0	19.7	22.3	11.7	29.3	83.0
3 hr.	78.1	20.3	21.0	13.3	26.3	81.0
4 hr.	77.2	20.0	22.3	12.7	27.7	84.7
4 hr.	77.2	22.0	22.3	13.3	31.7	89.3
4 hr. 30 min.	77.2	19.3	22.3	12.3	28.7	82.7
4 hr. 30 min.	77.2	20.3	21.0	12.0	31.0	84.3
5 hr.	78.6	19.0	18.3	11.7	28.7	81.0
5 hr.	78.6	21.0	22.0	12.7	30.7	86.3
9 hr.	81.5	20.3	22.7	12.0	29.0	84.0
9 hr.	81.5	21.0	22.3	13.0	30.7	87.0
9 hr.	81.5	20.0	22.3	12.0	30.3	84.7
12 hr.	92.2	21.0	22.0	11.7	27.7	82.3

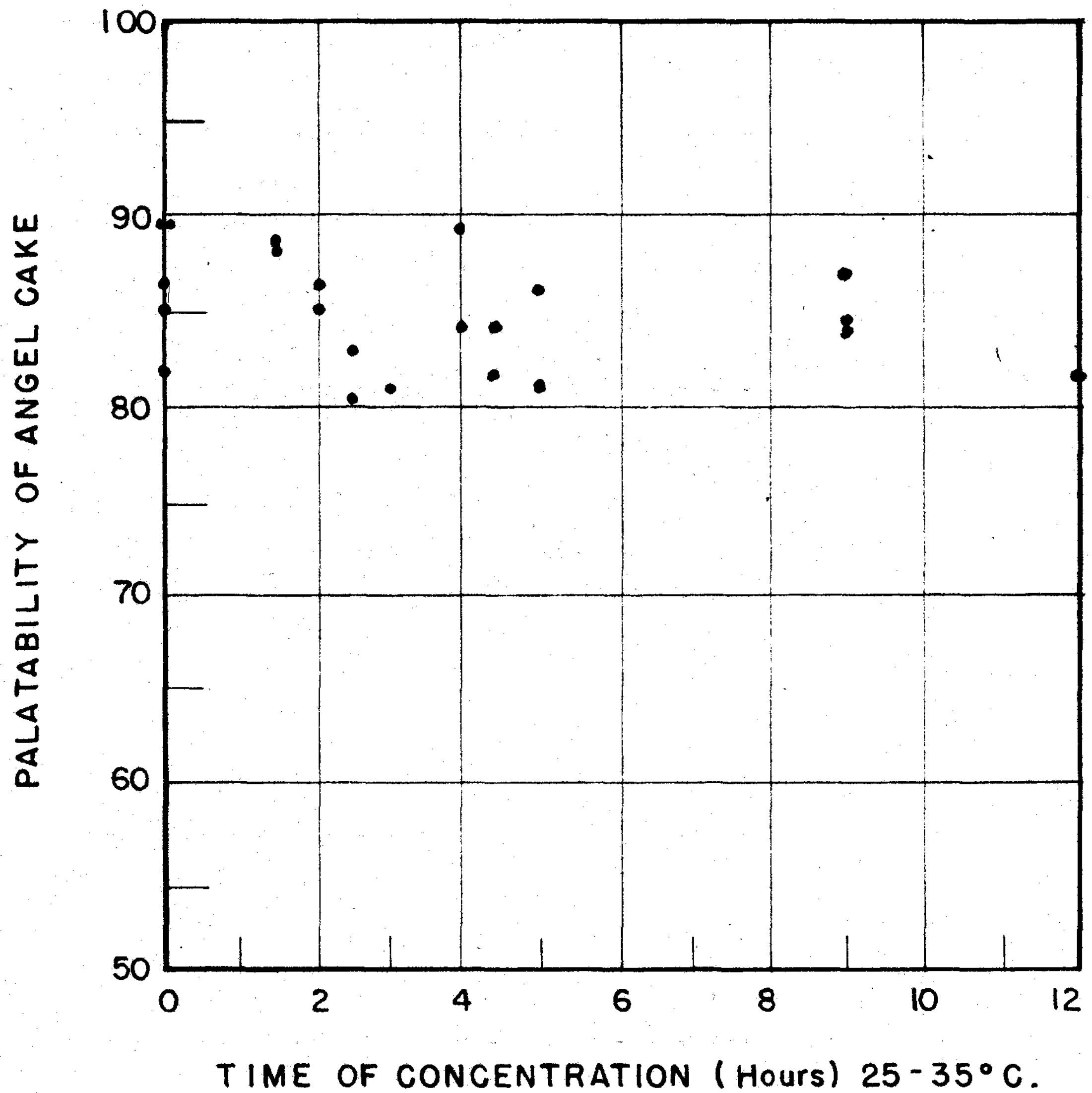

Figure 19. Effect of Time of Concentration of Egg White by Air Film Process at 25°C.-35°C. on Palatability of Angel Cakes

DISCUSSION

A. Objective and Subjective Methods of Testing

From the results of these experiments it appears that both objective and subjective methods of testing have a definite place in the judging of the quality of egg whites and of angel cake. The subjective method is necessary and can become extremely accurate in determining the stage of beating which represents a definite specific gravity of the meringue. Without accurate observation at this stage in the preparation of the cakes, all of the succeeding steps in the process would be worthless. The average specific gravities of the meringues in the various sections of the experiment were very close, indicating that the results of the different sections could be compared on an equal basis. The specific gravity of the meringues of the cakes in the section dealing with the treatment of mucin averaged 0.177. The small cakes baked from the egg whites which were concentrated by vacuum drying from the frozen state had an average specific gravity of meringue of 0.183, while that of the large cakes baked from whites given the same treatment averaged 0.177. The average figure obtained from the whites which were vacuum-dried from the frozen state and stored at 0°F. for 80 days was 0.179. The results from the two sections on air-film concentration were 0.178 for concentration at 35°C.-45°C. and 0.176 for concentration at 25°C.-

35°C. That comparable results could not have been obtained by controlling the beating time is demonstrated by the fact that in order to obtain such specific gravities, the beating time had to be varied from less than one minute to more than three minutes on the high speed of the electric mixer.

The accuracy of cake volume and tensile strength, the two objective measurements, is demonstrated by the statistical analysis. In no case where a statistical analysis was applied was there a significant difference in replications of volume or tensile strength scores. In other words, any particular treatment of the egg whites produced cakes which had volume and tensile strength scores which were typical of that particular treatment. Accurate objective tests, of course, required the development of an accurate and consistent technique in making the measurements.

On the other hand, the subjective test, the palatability score of the judges, was not demonstrated to be statistically consistent within anyone treatment applied to the egg whites. The analysis of variance of palatability scores of the angel cakes prepared from the whites which were concentrated by vacuum-drying from the frozen state showed a highly significant difference in replications. (Tables 12 and 44) The tenderness scores of the judges on the same cakes also showed a highly significant difference between replications (Tables 11 and 43), while the tensile strength scores (the objective measurement of tenderness) showed no difference in replications. (Tables 10 and 42) An analysis of variance of the palatability scores of each of the judges separately showed that for two of the three judges there was a highly significant difference in replications of the scores. (Tables 46, 47 and 48)

On the basis of observations made throughout the period of judging of all of the cakes, certain recommendations seem advisable for improving the accuracy of judges' scores. In the first place it seems probable that the number of judges should be greater than three, in order to minimize differences caused by day to day variation in the judges' moods, physical condition, or interest in the business at hand. Objective tests were performed at a definite time each day, which was a definite number of hours after the cakes were baked. The palatability of the cakes decreased as they were held, and the interest of the judges varied with the time of day at which the cakes were tested. Therefore, it is logical that if consistent results are to be obtained, the cakes should be judged at the same time each day. Lower palatability scores also resulted when the judges were fatigued, hurried, or when they were not feeling well. A drop of from 10 to 30 points in the total palatability scores could be attributed directly to these factors. Judging the cakes while sitting rather than standing would help to eliminate the feeling of haste and aid in better concentration. It was noted that the number of cakes judged at any one time affected the accuracy of the judging. It is recommended that for this type of product no more than six samples be graded at any one time. With more samples, the judges' accuracy and interest diminish, and they tend to hurry through the judging so that they can finish what becomes an irksome task. One of the most important aspects in attaining reproducible judges' scores is that of setting standards and maintaining them. During the preliminary practice period the judges should decide on the range of scores to be given a superior product and then grade the inferior products accordingly. If these standards were remembered from day to day, more comparable results would be obtained. In these experiments a control cake was baked each day from fresh egg whites so that the treated samples could be compared with the fresh sample. In the section on storage of concentrated whites, the control was a fresh sample which had been frozen and stored without concentrating.

In spite of day to day fluctuations, the judges' scores on the whole compared well with the objective tests. In one respect, the judges' scores were a more accurate indication of cake quality than were the measurements of cake volume. This particular case occurred in the section on concentration of the egg whites by the air-film process at 25°C.-35°C. Since this section was planned at a late date, there was not sufficient time to age the eggs for the usual seven-day period before concentrating them. The whites which were used were very fresh and had a large amount of thick white. On the mixer used, thick white could not be beaten to the required specific gravity as quickly as thin white, nor did it give as good a cake volume. In spite of the poorer cake volume of the fresh control eggs of this section, the judges ranked them as high as they had previously graded other control cakes.

B. Beating Time of Meringue as an Index of Angel Cake Quality

After a study of the relationship between the beating time of the meringue, cake volume, tensile strength, and palatability scores, it is apparent that for some purposes there is no need of baking angel cakes to determine the performance ability of the egg whites. The time required to beat the meringue to within a certain specific gravity range bears a direct relation to cake volume, tensile strength, and palatability scores. When the experimental conditions are controlled, the time required for beating the meringue makes possible a prediction of cake volume within a range of 50 c.c., tensile strength within 19 grams, and palatability scores within 10 points. The longer the time required for beating the meringue, the lower the volume, the higher the tensile strength, and the lower were the palatability scores.

In considering the fresh control eggs and the eggs concentrated by either of the two methods, it was noted that the data seemed to fall into three groups. When the meringue could be beaten to a definite specific gravity within a time range of 50 seconds to 1 minute and 15 seconds, the resulting cakes could be classed as superior. When the beating time fell within a range of 1 minute and 16 seconds to 1 minute and 45 seconds the cakes were less desirable, and when the beating time was extended to 2 minutes and 20 seconds the cakes were definitely inferior. Obviously there was no absolute line of demarcation such that a difference of one or two seconds in beating time would result in a drastic change in the cakes. However, a difference of ten seconds in beating time would ordinarily produce a definite difference in the cakes. All of the meringues discussed were beaten until they were within a range of 0.167 to 0.187.

For example, the values obtained from the cakes baked from egg whites concentrated by vacuum-drying from the frozen state may be considered. When the beating time ranged from 50 seconds to 1 minute and 15 seconds, the volume of 96% of the 25 cakes ranged from 685 to 735 c.c. The tensile strength of 100% of these cakes ranged from 30 to 49 grams, and the palatability scores of 100% of them ranged from 82 to 92.

When the results of air film concentration were considered, it was found that with the same beating time (50 seconds to 1 minute and 15 seconds), 90% of the 30 cakes had a volume of 685 to 735 c.c. and 86.7% of them had palatability scores of 82 to 92. The tensile strength scores for these cakes were lower, but 90% of the values fell within a range of 19 to 38 grams. The figures which fell outside of the ranges mentioned were, in most cases, very close to the extreme limits. With the air film concentration, the results on the eggs processed at 35°C.-45°C. were much more consistent than those at 25°C.-35°C., probably because of the variability in storage conditions of the latter, which has been discussed previously.

When the meringues from the egg whites which were concentrated by the air film process required a beating time of 1 minute and 16 seconds to 1 minute and 45 seconds, the volumes of 82.6% of the 23 cakes fell within a range of 640 to 690 c.c. Under the same conditions the tensile strength of 91.3% of them fell within a range of 30 to 49 grams, and 65.2% of the palatability scores fell within 77 to 87 points. These results would indicate that the judges were more successful in recognizing the superior cakes, and they reproduced their scoring on those cakes with more accuracy than they did on the less desirable cakes. They probably remembered the top scores they had given the cakes more easily than the intermediate ones.

When the meringues from the egg whites which were concentrated by the air film process required a beating time of 1 minute and 46 seconds to 2 minutes and 20 seconds, the volume of 88.9% of the 18 cakes fell within a range of 590 to 640 c.c. Under these conditions the tensile strength of 83.3% of the cakes fell within a range of 41-60 grams, and the palatability scores of 83.3% of them were within a range of 70 to 80 points.

The advantage of noting the relationship between time of beating of the meringues and the quality of the angel cakes lies in the fact that in many instances a simple beating test could be substituted for the baking of cakes. The time saved would amount to approximately one-half hour for each sample tested. In addition there would be a number of variables eliminated, all of which play an important part in the results obtained on cakes. For instance, if the techniques involved in making the cakes were not practiced continually, they would be easily forgotten. The same judges would not ordinarily be available over a long period of time, and if they were available they might readily forget the standards they had set for scoring the products. Slight variations in the cake caused by fluctuations in oven temperature, changes in the laboratory temperature or unconscious variations in the technique of mixing the batter would not influence the results. The beating test should be of particular advantage in a storage study which extended over a considerable period of time. It would also be very valuable when a rough test was needed on a large number of samples to give an indication of their performance ability in angel cake. Along with beating tests it would probably be advisable to run occasional tests on angel cakes to be certain that the eggs were performing as was expected.

It should be noted that a beating test of this character is only valid under the particular set of conditions on which it has been tested. Different beaters, different speeds of beating, or different temperatures of the ingredients would all produce results which could not be compared with those obtained originally. Similarly, different treatments applied to the egg whites would first have to be tested on cakes before a beating test could be applied.

C. Storage of Concentrated Egg White

Although methods have been described for successfully concentrating egg white, the problem of the storage life of the concentrated product has only been started. The results of this study have indicated that there is a deterioration in quality of egg white concentrated by vacuum-drying from the frozen state and stored for 80 days at 0°F. It is evident that if concentrated egg whites are to be practical, some method must be devised for storing them under conditions such that their quality does not change over a reasonable length of storage time. It would be interesting to repeat the one storage study which was reported, removing samples at varying time intervals to determine the relation, if any, between storage time and degree of concentration. Then further studies should be begun in an attempt to find more desirable storage conditions, if those are necessary to retain the quality of the product. Similar research needs to be done on storage of egg white concentrated by the air film process, since no storage tests were attempted in these experiments. Since storage of the unconcentrated sample at 0°F. for 80 days resulted in no measurable change in its quality, unconcentrated whites could be stored in such a manner to serve as a control for the concentrated product.

D. Reconstitution of Concentrated Egg Whites

It has been observed in the course of this research that the method and completeness of reconstitution of the concentrated whites are of greatest importance. With certain samples of the whites concentrated by the air film method it was noted that when the reconstituted samples were not thoroughly blended, the resulting angel cakes were distinctly inferior. For example, in one series part of the water used for reconstituting the samples was quite well mixed with the sample, and the remaining portion was poured into the flask without mixing on the theory that the two layers would come to equilibrium. When, after standing for two days in the refrigerator, the samples were collected for baking the cakes, it was noted that there were still two distinct layers present. A small egg beater was used for blending the layers without causing foam formation. The samples then appeared to be homogeneous throughout, but cakes baked from them were definitely inferior. The cakes prepared from four of the samples had an average beating time of the meringue of 1 minute and 30 seconds, cake volume of 637 c.c., tensile strength of 40 grams, and palatability score of 64. After the samples had stood over night again in the refrigerator, excellent cakes were obtained. The beating time for the same four samples averaged 1 minute and 10 seconds, cake volume 693 c.c., tensile strength 39 grams, and palatability score 83. Evidently the egg protein was not thoroughly dispersed until after blending and standing for 24 hours, and the foaming properties were somewhat dependent on the degree of dispersion of the protein. On the other hand, when an attempt was made using the same technique to improve the quality of cakes made from egg white concentrated by vacuum-drying and stored at 0°F., no improvement was obtained. Flakes of incompletely dispersed egg white floated in the liquid. Treatment with the Waring Blendor at this stage made the liquid appear homogeneous but caused a decrease in angel cake quality.

E. Temperature and Time of Concentration of Egg White by Air Film Method

The relation of time and temperature of concentration of the egg whites to angel cake quality, which was indicated in the section on air film concentration, suggests a partial explanation for the failure of most commercially dried whites to perform satisfactorily in angel cake. At higher temperatures there seems to be a rather definite length of time within which processing must be completed. Since most commercial methods involve drying periods beyond the limits which have been found in this study to be acceptable, a change in processing methods appears to be advisable for dried egg whites intended for use in cake making. A lower drying temperature or a shorter period of drying should give improved results. According to the results of this study the egg white can be processed in safety for a considerably longer time at 25°C.-35°C. than at 35°C.-45°C. On the other hand, when the same amount of material is processed, a somewhat longer time is required at the lower temperature to reach the same concentration of solids. This difficulty could be overcome by concentrating the egg white in thinner layers, since it has been shown that the time of concentration is related to the depth of the layer of egg white being concentrated. Regulation of the humidity of the air current passing over the eggs and the speed of circulation of the air would be additional means of controlling the time of concentration. The time of concentration in this experimental work was shortened in the early stages by stirring the product whenever a film of dry material appeared on the surface. Some method might be devised whereby commercial processes could be accelerated by periodically removing the film formed and thus exposing fresh surfaces for drying.

F. Characteristics of Meringues after Various Treatments of Egg Whites.

Although the meringues for all of the angel cakes in these experiments were beaten to approximately the same specific gravity, the appearance of the meringue varied with the time required to beat it to that specific gravity. When a short beating time was required the meringues appeared to have much larger bubbles and a more mobile structure than that which was characteristic of longer beating. When a longer beating time was required, the meringues appeared to have smaller bubbles and a much stiffer structure. The peaks which formed when the beater was removed were stiffer and did not turn down at the tips as was the case with shorter beating times. It was possible to gain a fairly accurate idea of the performance ability of the egg whites in angel cakes after only ten seconds of beating of the egg whites. Those which foamed most rapidly made the best angel cakes under the conditions in these experiments.

In preliminary experiments with egg whites which required a long beating time to reach the predetermined specific gravity range, the appearance of the meringues suggested that they might be overbeaten. When the time of beating was shortened so that the meringues had an appearance similar to those of the controls, the cakes were not improved. Therefore, in the remaining experiments the meringues were all beaten until they fell within a certain specific gravity range.

G. Characteristics of Angel Cakes after Various Treatments of Egg Whites

The performance of the egg whites after various treatments was tested by their ability to make high quality angel cakes. The superior angel cake was one which had good volume, low tensile strength, and a high rating for palatability. Palatability ratings were based on the cellular structure, the tenderness, moistness and velvetiness of the cake. A high rating for texture was based on an even cell structure, medium sized cells and thin cell walls. The cakes in which the mucin was treated had a typically coarse, compact texture with thick cell walls and a characteristic gummy quality. They were also characterized by the tendency to shrink away from the edges of the pan during the latter part of the baking period and while they were cooling. On the whole the cakes made from the mucin-treated whites rated lowest of any of the series in volume and palatability scores.

Somewhat similar characteristics were noted in the series made from the whites concentrated by vacuum-drying from the frozen state followed by storage for eighty days. The volume of these cakes was somewhat better than in the mucin-treated series, but shrinkage from the side of the pan was a common characteristic. The shrinkage on the whole was not as great as that of the cakes in which the mucin was removed, but it was about the same as that of the cakes in which the mucin was precipitated. The unconcentrated sample in this series had good volume but showed the same amount of shrinkage as the concentrated samples. Palatability scores in this series were considerably higher than the scores from the mucin-treated series, but there was a tendency for the cakes to show a coarser texture than would be considered desirable.

Superior cakes were produced from egg whites which were reconstituted and used shortly after concentrating by vacuum-drying from the frozen state. The same was true of egg white concentrated by the air-film method at 25°C.-35°C. for 12 hours and at 35°C.-45°C. for one and one-half hours. There was a gradual deterioration in cake quality when the whites were concentrated at 35°C.-45°C. for as long as two and one-half hours, but no further decline was noted up to nine hours of concentrating.

The change was characterized by decreased cake volume, increased tensile strength, and decreased palatability scores. There was no outstanding characteristic of these cakes comparable to the shrinkage and coarse texture of the mucin-treated cakes. On the other hand, there seemed to be simply a gradual decline in all of the desirable qualities.

CONCLUSIONS

Under the conditions described in these experiments, the following conclusions may be drawn:

1. Egg white treated to remove or precipitate the mucin did not make an acceptable angel cake. The cakes from such egg whites were characterized by low volume, decreased palatability, and a coarse, compact, and gummy texture. The cakes tended to shrink from the sides of the pan during the final period of baking and during cooling.

2. Concentration of egg white by vacuum-drying from the frozen state to a solids' concentration of approximately 92% did not cause a significant change in the cake-making properties of the reconstituted product.

3. Concentration of egg white by vacuum-drying from the frozen state resulted in a decrease in the number of microorganisms as determined by the standard plate count. There was little appreciable change in the standard plate count of either concentrated or unconcentrated samples during a storage period of one month at 1.7°C. (35°F.). Concentration to approximately 75% solids reduced growth of microorganisms at 21.1°C. (70°F.) as determined by the standard plate count on egg white concentrated by vacuum-drying from the frozen state.

4. Concentration of egg white by the air-film process at 35°C. to 45°C. for periods up to approximately one and one-half hours did not affect the cake-making properties of the reconstituted product. Processing periods longer than approximately one and one-half hours at

this temperature caused a decrease in the cake-making properties of the reconstituted egg white. The degree of concentration to approximately 90% solids had no effect on the cake-making properties of the reconstituted egg white.

6. Concentration of egg white by the air-film process at 25°C. to 35°C. for periods as long as twelve hours did not affect the cake-making properties of the reconstituted product.

SUMMARY

The primary purpose of this problem was to find a method for concentrating the whites which would not affect the cake-making qualities of the reconstituted product. A study of the effect of different concentrations of the egg white was included in order to determine whether the degree of concentration was a factor limiting the range over which the process could be successfully extended. An investigation of the role of mucin in the cake-making properties of the egg white was also planned, since preliminary experiments had shown its importance in the preparation of superior angel cakes.

It was found that when mucin was removed or precipitated, certain structural properties of the egg white were lost. Meringues made in the preparation of angel cakes from such egg whites required prolonged beating to reach a definite specific gravity range. The angel cakes made from such egg whites were characterized by low volume, decreased palatability, and a coarse, compact, and gummy texture. They tended to shrink from the sides of the pan during the final stages of baking and during cooling.

Concentration of the egg white was successfully accomplished by two methods. One of these involved vacuum-drying from the frozen state, and the other was a modification of the present commercial method of pan-drying. Two different temperature ranges were maintained in the latter process, using infra-red lights as the source of heat.

It was shown that concentration of the egg white by vacuum-drying from the frozen state to a solids' concentration of approximately 92% did not cause a significant change in the cake-making properties of the reconstituted product. Successful concentration of egg white by the air-film method (pan-drying) was limited by the time and temperature used in the process. At a concentration temperature of 35°C. to 45°C., superior cakes were obtained from the reconstituted product if the time of concentration was not longer than approximately one and one-half hours. With longer times of concentration there was a deterioration in cake quality, but cake quality was not affected by the degree of concentration to approximately 90% solids. The time of concentration could be regulated by control of the depth of the egg white layer, mechanical manipulation to remove the dried layer of egg white, and regulation of the humidity and rate of flow of the air current. When egg whites were concentrated by the air-film process at a temperature of 25°C. to 35°C., superior cakes were obtained from the reconstituted products when the time of concentration was as long as twelve hours.

Concentration by vacuum-drying from the frozen state caused a decrease in the number of microorganisms present in the egg white product as determined by the standard plate count. Concentration to approximately 75% solids reduced the growth of microorganisms as determined by the standard plate count in samples held for one month at a temperature of approximately 21.1°C. (70°F.)

Concentration of egg-white by vacuum-drying from the frozen state followed by storage for eighty days at -17.8°C. (0°F.) resulted in decreased quality of the angel cakes made from the reconstituted product. However, the data were insufficient to show to what extent the factor of degree of concentration was responsible for the deterioration in quality. Further storage studies should be performed to clarify this point and to establish satisfactory storage conditions for concentrated egg white products.

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APPENDIX

SCORE CARD FOR ANGEL CAKE

Date: ____________

	Number								
	Perfect score								
Texture 1. Thin cell walls 2. Size cells: not too compact and fine, not great large, even.	25								
Tenderness Not tough	25								
Moistness: Not dry Not gummy	15								
Eating quality Best quality is where "melts in mouth" Velvety, smooth	35								
Total	100								

Scorer ____________

Table 31

Analysis of Variance of Effect of Mucin Treatment on Time of Beating of Meringue (Data of Table 1)

Source of variation	Degrees of freedom	Sum of squares	Mean square
Total	23	63340.5	
Replications	5	342.5	68.5
Treatments	3	61735.5	20578.5**
Error	15	1262.5	84.17

**Highly significant

Table 32

Analysis of Variance of Effect of Mucin Treatment on Angel Cake Volume (Data of Table 3)

Source of variation	Degrees of freedom	Sum of squares	Mean square
Total	23	95237.8	
Replications	5	1768.8	353.7
Treatments	3	79581.5	26527.2**
Error	15	13887.5	925.8

** Highly significant

Table 33

Analysis of Variance of Effect of Mucin Treatment on Tensile Strength of Angel Cakes (Data of Table 3)

Source of variation	Degrees of freedom	Sum of squares	Mean square
Total	23	6821.1	
Replications	5	694.4	136.9
Treatments	3	4184.5	1394.8**
Error	15	1942.2	129.5

** Highly significant

Table 34

Analysis of Variance of Effect of Mucin Treatment on Tenderness of Angel Cakes (Data of Table 4)

Source of Variation	Degrees of freedom	Sum of squares	Mean square
Total	23	78.78	
Replications	5	5.86	1.17
Treatments	3	62.28	20.76**
Error	15	10.64	0.71

** Highly significant

Table 35

Analysis of Variance of Effect of Mucin Treatment on Moistness of Angel Cakes (Data of Table 4)

Source of Variation	Degrees of freedom	Sum of squares	Mean square
Total	23	115.69	
Replications	5	2.13	0.43
Treatments	3	101.57	33.85**
Error	15	11.99	0.79

**Highly significant

Table 36

Analysis of Variance of Effect of Mucin Treatment on Eating Quality of Angel Cakes (Data of Table 4)

Source of Variation	Degrees of freedom	Sum of squares	Mean square
Total	23	639.04	
Replications	5	14.56	2.91
Treatments	3	536.70	178.90**
Error	15	87.78	5.85

**Highly significant

Table 37

Analysis of Variance of Effect of Mucin Treatment on Palatability of Angel Cakes (Data of Table 4)

Source of variation	Degree of freedom	Sum of squares	Mean square
Total	23	4439.87	
Replications	5	59.55	11.91
Treatments	3	3951.93	1317.31**
Error	15	428.39	28.56

**Highly significant

Table 38

Analysis of Variance of Effect of Concentration of Egg White by Vacuum-Drying from the Frozen State on Time of Beating of Meringue (Data of Table 8)

Source of variation	Degrees of freedom	Sum of squares	Mean square
Total	24	942.0	
Replications	4	76.4	19.1
Treatments	4	692.8	173.2**
Error	16	172.8	10.8

**Highly significant

Table 39

Analysis of Variance of Effect of Concentration of Egg White by Vacuum-Drying from the Frozen State on Specific Gravity of Meringue (Data of Table 8)

Source of variation	Degrees of freedom	Sum of squares	Mean square
Total	24	0.000854	
Replications	4	0.000071	0.000017
Treatments	4	0.000378	0.000094*
Error	16	0.000405	0.000025

*Significant

Table 40

Analysis of Variance of Effect of Concentration of Egg White by Vacuum-Drying from the Frozen State on Specific Gravity of Batter (Data of Table 8)

Source of variation	Degree of freedom	Sum of squares	Mean square
Total	24	0.000896	
Replications	4	0.000213	0.000053
Treatment	4	0.000081	0.000020
Error	16	0.000602	0.000038

Table 41

Analysis of Variance of Effect of Concentration of Egg White by Vacuum-Drying from the Frozen State on Angel Cake Volume (Data of Table 10)

Source of variation	Degrees of freedom	Sum of squares	Mean square
Total	24	6648.0	
Replications	4	971.4	242.8
Treatments	4	2846.9	711.7*
Error	16	2829.7	176.9

*Significant

Table 42

Analysis of Variance of Effect of Concentration of Egg White by Vacuum-Drying from the Frozen State on Tensile Strength of Angel Cakes (Data of Table 10)

Source of variation	Degrees of freedom	Sum of squares	Mean square
Total	24	2734.0	
Replications	4	415.9	103.9
Treatments	4	974.0	243.5
Error	16	1344.1	84.0

Table 43

Analysis of Variance of Effect of Concentration of Egg White by Vacuum-Drying from the Frozen State on Tenderness of Angel Cakes (Data of Table 11)

Source of variation	Degrees of freedom	Sum of squares	Mean square
Total	24	15.95	
Replications	4	7.70	1.92**
Treatments	4	3.10	0.77
Error	16	5.15	0.32

**Highly significant

Table 44

Analysis of Variance of Effect of Concentration of Egg White by Vacuum-Drying from the Frozen State on Palatability of Angel Cakes (Data of Table 11)

Source of variation	Degrees of freedom	Sum of squares	Mean square
Total	24	83.64	
Replications	4	46.50	11.6**
Treatments	4	11.90	2.9
Error	16	25.24	1.57

**Highly significant

Table 45

Analysis of Variance of Difference in Palatability Scores Given by Three Judges to Angel Cakes Prepared from Egg White Concentrated by Vacuum-Drying from the Frozen State

Source of variation	Degrees of freedom	Sum of squares	Mean square
Total	74	2090.0	
Replications	24	290.0	12.1
Treatments	2	249.3	124.6*
Error	48	1550.7	32.3

*Significant

Table 46

Analysis of Variance of Palatability Scores given by Mary Morr to Angel Cakes Prepared from Egg White Concentrated by Vacuum-Drying from the Frozen State

Source of variation	Degrees of freedom	Sum of squares	Mean square
Total	24	229.0	
Replications	4	48.7	12.2
Treatments	4	55.0	13.7
Error	16	125.3	7.8

Table 47

Analysis of Variance of Palatability Scores given by Dorothy Harrison to Angel Cakes prepared from Egg White Concentrated by Vacuum-Drying from the Frozen State

Source of variation	Degrees of freedom	Sum of squares	Mean squares
Total	24	392.0	
Replications	4	214.0	53.5**
Treatments	4	17.2	4.3
Error	16	160.8	10.0

**Highly significant

Table 48

Analysis of Variance of Palatability Scores given by Elma Crain to Angel Cakes Prepared from Egg White Concentrated by Vacuum-Drying from the Frozen State

Source of variation	Degrees of freedom	Sum of squares	Mean square
Total	24	178.6	
Replications	4	101.4	25.3**
Treatments	4	9.0	2.25
Error	16	68.2	4.26

**Highly significant

Table 49

Analysis of Variance of Effect of Concentration of Egg White by Vacuum-Drying from the Frozen State on Time of Beating of Meringue for Large Angel Cakes (Data of Table 12)

Source of variation	Degrees of freedom	Sum of squares	Mean square
Total	11	1070.90	
Replications	3	10.20	3.40
Treatments	2	1045.15	522.57**
Error	6	15.55	2.59

**Highly significant

Table 50

Analysis of Variance of Effect of Concentration of Egg White by Vacuum-Drying from the Frozen State on Volume of Large Angel Cakes (Data of Table 14)

Source of variation	Degrees of freedom	Sum of squares	Mean square
Total	11	124491.0	
Replications	3	59454.3	19818.1
Treatments	2	38220.5	19110.2
Error	6	26816.2	4469.3

Table 51

Analysis of Variance of Effect of Concentration of Egg White by Vacuum-Drying from the Frozen State on Volume of Small Angel Cakes (Data of Table 14)

Source of variation	Degrees of freedom	Sum of squares	Mean square
Total	11	5400.25	
Replications	3	1826.25	608.75
Treatments	2	2226.50	1113.25
Error	6	1347.50	224.58

Table 52

Analysis of Variance of Effect of Concentration of Egg White by Vacuum-Drying from the Frozen State on Tensile Strength of Large Angel Cakes (Data of Table 15)

Source of variation	Degrees of freedom	Sum of squares	Mean square
Total	11	2036.07	
Replications	3	953.74	317.91
Treatments	2	345.38	172.69
Error	6	736.95	122.83

Table 53

Analysis of Variance of Effect of Concentration of Egg White by Vacuum-Drying from the Frozen State on Tensile Strength of Small Angel Cakes (Data of Table 15)

Source of variation	Degrees of freedom	Sum of squares	Mean square
Total	11	2250.73	
Replications	3	338.56	112.85
Treatments	2	489.29	244.64
Error	6	1422.88	237.14

Table 54

Analysis of Variance of Effect of Concentration of Egg White by Vacuum-Drying from the Frozen State on Tensile Strength of Large versus Small Angel Cakes Baked from the Same Batter (Data of Table 15)

Source of variation	Degrees of freedom	Sum of squares	Mean squares
Total	23	5023.9	
Replications	11	2430.9	220.9
Treatments	1	737.1	737.1
Error	11	1855.9	168.7

Table 55

Analysis of Variance of Effect of Concentration of Egg White by Vacuum-Drying from the Frozen State on Palatability of Large versus Small Angel Cakes Baked from the Same Batter (Data of Tables 16 and 17)

Source of variation	Degrees of freedom	Sum of squares	Mean square
Total	23	791.73	
Replications	11	286.46	26.06
Treatments	1	256.76	256.76**
Error	11	248.51	22.59

**Highly significant