



Physical, chemical and cooking qualities of eggs as affected by five methods of home preservation
by Sister Agnes Marie Nash

A THESIS Submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree
of Master of Science in Home Economics

Montana State University

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Abstract:

Eight hundred thirty-eight, one day old, grade AA eggs from New Hampshire hens were used in this study. Five methods of preservation that could be easily duplicated in the home were studied: waterglass, freezing, S-100, mineral oil, and vinylite. Untreated eggs were stored also and served as controls. These eggs were numbered, weighed, and stored in a home basement where the temperature range was from 50-60 degrees Fahrenheit. At the end of three and again at the end of six months the eggs were tested for the following physical, chemical, and cooking qualities: change in weight during storage; height, width and index of albumen; yolk color and height; pH of albumen; palatability of cooked yolk; acceptability for poaching; coagulating ability when used in custards; and baling value as determined in the making of sponge cakes. The same measurements were made on similar fresh eggs.

After six months' storage, all preserved eggs showed a loss in weight, though not as great as those receiving no treatment. The mean albumen index of storage eggs had changed as much as 0.051 at the end of six months. Yolk height had decreased and the color became progressively darker during storage. At the end of six months the pH of all treated eggs had increased noticeably and they were of poor poaching quality. After the eggs had been stored by any method the internal temperature at time of coagulation was from two to four degrees higher than that required for fresh eggs. At the end of six months' storage all the cakes, with the exception of those made from eggs treated with mineral oil, had larger volume indexes than after three months' storage. Volume index, by itself, was not considered an accurate measurement of the entire baking quality of the stored eggs. Photographs of the center cuts of sponge cakes indicated that the cakes made from the treated eggs stored for three months were of a finer texture than those from eggs stored six months. A composite rating of the various eggs based on all physical, chemical, and cooking measurements, placed these eggs in the order of their desirability as follows: fresh, S-100, waterglass, mineral oil, vinylite and no treatment. Measurements made on frozen eggs indicated they were of high quality.

PHYSICAL, CHEMICAL AND COOKING QUALITIES OF EGGS AS AFFECTED
BY FIVE METHODS OF HOME PRESERVATION

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ABSTRACT

Eight hundred thirty-eight, one day old, grade AA eggs from New Hampshire hens were used in this study. Five methods of preservation that could be easily duplicated in the home were studied: waterglass, freezing, S-100, mineral oil, and vinylite. Untreated eggs were stored also and served as controls. These eggs were numbered, weighed, and stored in a home basement where the temperature range was from 50-60 degrees Fahrenheit. At the end of three and again at the end of six months the eggs were tested for the following physical, chemical, and cooking qualities: change in weight during storage; height, width and index of albumen; yolk color and height; pH of albumen; palatability of cooked yolk; acceptability for poaching; coagulating ability when used in custards; and baking value as determined in the making of sponge cakes. The same measurements were made on similar fresh eggs.

After six months' storage, all preserved eggs showed a loss in weight, though not as great as those receiving no treatment. The mean albumen index of storage eggs had changed as much as 0.051 at the end of six months. Yolk height had decreased and the color became progressively darker during storage. At the end of six months the pH of all treated eggs had increased noticeably and they were of poor poaching quality. After the eggs had been stored by any method the internal temperature at time of coagulation was from two to four degrees higher than that required for fresh eggs. At the end of six months' storage all the cakes, with the exception of those made from eggs treated with mineral oil, had larger volume indexes than after three months' storage. Volume index, by itself, was not considered an accurate measurement of the entire baking quality of the stored eggs. Photographs of the center cuts of sponge cakes indicated that the cakes made from the treated eggs stored for three months were of a finer texture than those from eggs stored six months. A composite rating of the various eggs based on all physical, chemical, and cooking measurements, placed these eggs in the order of their desirability as follows: fresh, S-100, waterglass, mineral oil, vinylite and no treatment. Measurements made on frozen eggs indicated they were of high quality.

PHYSICAL, CHEMICAL AND COOKING QUALITY OF EGGS AS AFFECTED BY
FIVE METHODS OF HOME PRESERVATION

INTRODUCTION

While the scientific literature regarding commercial methods of egg preservation is fairly extensive, very little research has been published that compares the more recent methods of home preservation with those used for the past centuries. The array of preservativies on the market is confusing. Each season the consumer reads of new and more scientific ways of preserving eggs, and is left in doubt as to which method will produce the most desirable cake, custard or poached egg.

Preservation of eggs makes possible a better distribution throughout the year. Although selective breeding and artificial lighting of henneries have contributed much toward equalizing the fresh egg supply, most farmers still produce eggs largely on a seasonal basis. Spring is the most advantageous season for withdrawing eggs from the usual commercial channels and setting them aside for later use. Prices are lowest in March, April, May and June when egg production is highest in the northern hemisphere, and about half the year's total is produced during these months (48). If it were not for storage, eggs would be so cheap in the spring as to be unprofitable to the producer, and at other seasons so expensive as to be prohibitive to many people.

Though the egg is generally sterile when laid, it is an unstable system and is in a continual state of readjustment (56). The shell is a poor package material, for it allows the escape of moisture and the passage

of micro-organisms. It has been shown that the porosity of the shell is an important factor in the preservation of the egg contents and that the shrinkage of the egg is closely related to the porosity of the shell (3).

Eggs are classified as one of our most important foods, and next to milk are probably the most important human foodstuff. They are valuable food, for the iron in the yolk is an ideal supplement to the mineral content of milk. Eggs contain a generous amount of vitamin A and some vitamin D. The proteins of eggs are complete and efficiently transformed into body tissue. Besides being invaluable health foods, eggs are indispensable to good cooking. They perform at least seven different cookery functions: thickening, leavening, emulsifying, binding, coating, clarifying and flavoring. They are also frequently served as the main dish in the meal.

Egg consumption in the United States is by far the highest in the world on a per capita basis, amounting to 386 eggs per person in 1948 (2). During 1950, fifty billion eggs were used for human consumption in this country, and 91 per cent of these eggs were utilized directly from the shell (25, 10). In February of 1951, it was predicted that even more eggs would be available to consumers this year, since dried eggs would not be purchased under a government price support program as was the case last spring (36).

Since these conditions exist it was deemed especially interesting and worth while to obtain further information on the physical, chemical and cooking qualities of eggs as affected by certain methods of home preservation.

HISTORY

The study of egg preservation would not be complete without some knowledge of the ancestry of our present egg producing breeds of chickens. James and Dakan (24) state that no one knows what hen hatched that first clutch of golden eggs, and mothered the flock which became the ancestors of countless billions of domesticated chickens. However, we do know that she lived somewhere in the mysterious wilds of northern India, thousands of centuries ago. According to Cruickshank (8) the original jungle fowl laid only 20 to 25 eggs a year, while hens laying 250 eggs a year are now quite common. Poultry farming is not a modern occupation but was a flourishing industry some 2000 years ago, if we can judge by the works of Latin agricultural writers, notably Cato, Varro and Calumella (16). The first chickens to reach the New World were brought by Columbus on his second voyage in 1493 (37).

Newton (35) points out that undoubtedly back in the prehistoric and uncivilized era, man was concerned only with the problem of getting enough food. A little later he began to improve his hunting tools and to learn methods of storing a supply of food in seasons of plenty for later use. No doubt the first storage of eggs was before the dawn of recorded history, as eggs have been an ancient food for mankind, and they were of a limited and seasonable production.

The main objectives in the preservation of eggs for human consumption are to slow down the rate of physical and chemical deterioration, to preserve the nutritive value and the cooking characteristics, and to retain the natural appearance of the egg contents, Romanoff (43). These

objectives may be partially accomplished by modifying the storage environment, by treatment of the egg itself, or by a combination of both methods (42). Holding the egg in a humidified atmosphere, sometimes enriched with carbon dioxide, will lower the loss of moisture by evaporation and the escape of carbon dioxide from the egg, and hence aid in the preservation of the egg. Sharp (49) reports that the presence of carbon dioxide in the air markedly retards the development of off flavors and odors by retarding chemical changes in the egg contents. Other methods which have been used with varying success are packing the egg in a number of dry substances, immersing it in certain liquids, treating the shell with sealing agents, and coagulating a thin layer of albumen adjacent to the shell. A number of these methods have been found impractical and are no longer extensively employed, and a few are still in the experimental stage (43).

Romanoff (42) states that for many years the Chinese have preserved eggs by methods somewhat similar to "dry packing". However, these eggs were not retained in their original state but rather converted into an entirely different article of food, probably by bacterial action. "Dry packing" received considerable attention in this country about 40 years ago, and substances suggested for this purpose were bran chaff, oats, peat dust, salt, sand, sawdust, soda lime, straw, and wood ashes. However, none of these proved especially effective.

Probably almost as many liquids as solids have been tried as egg preservatives. Submersion has been made in molasses, brine, borax and salt solution, lime water, chlorine water, waterglass, and other fluids. However, only lime water and waterglass have met with any success (42).

Spaner (53) relates that as early as 1807 the Dutch farmers were preserving eggs for the winter season by the use of linseed oil. This was a forerunner of the method of pickling in lime water which came into vogue in 1875.

According to Wright (62) a recipe for preserving eggs in quick lime appeared in the August, 1842 issue of the Prairie Farmer. Morford (34) reports that Benjamin Franklin supplied ships on their journeys to the old country (sailing time 2 to 3 months) with eggs which had been treated with linseed oil. James and Dakan (24) state that lime packing of eggs was followed by water-glass, technically a colloidal sodium silicate, a preservative still in use.

The most satisfactory treatment for egg preservation according to Rosser and White (45) would appear to be the one that effectively disinfects a newly laid egg and at the same time seals it against future contamination, loss of moisture and carbon dioxide. The most feasible method (44) of preventing the escape of carbon dioxide and water is that of sealing the pores of the shell by means of a coating or an impregnating agent. Romanoff (42) states that without a doubt, the most extensively investigated possibility of preserving eggs has been that of sealing the eggshell itself by applying a substance directly upon it. Rather incredible materials have been given a trial for this purpose: alum, cactus juice, gelatin, Irish moss, lard, rubber, mineral oil, soap, sulfuric acid, varnish, vaseline and many more, but of these only mineral oil has lent itself successfully for use as a coating on the egg. Sharp (48) states that by 1937 over one hundred patents had been granted for materials to be used in the shell-treating of eggs. Since that time various plastic coatings have been used as egg

preservatives (42, 62, and 44), but many of these are still in the experimental state. One of the recent creamy emulsions now placed on the market and highly recommended is S-100 (7 and 5).

The shell coating method has been modified by means of sealing under vacuum so that actually the shell is impregnated with the sealing agent. The egg is first immersed in a sealing solution and then subjected to reduced atmospheric pressure. When normal pressure is restored, the tendency of the air to enter the pores of the shell causes the solution to be drawn in. These eggs lose weight more slowly than ordinary oil-dipped eggs and an increase in pH value is retarded.

A rather new process for egg preservation developed recently at the University of Missouri is that of thermostabilization. Funk (14) explains that according to this method the egg is immersed in water 15 minutes at 130 degrees Fahrenheit. After it is dried it is dipped into oil. He reports that this process does not interfere with the whipping quality of the albumen, or any of the final functions of eggs. However, Romanoff (43) does not agree with this statement and says that the foaming properties of the albumen are greatly reduced, and the egg is therefore rendered unsuitable for various culinary purposes, especially cake baking. Otherwise the preservative effects of this treatment are better than those of many others. In 1943 Funk (13) stated that embryonic development was arrested and such eggs were rendered infertile.

Another method for prolonging the keeping qualities of eggs referred to as "flash heat treatment" has been employed by housewives for many years (43). It consists of the immersion of the egg for a short time

in boiling water, or other liquid. This gives a result different from that of longer treatment at a lower temperature. Examination of eggs so treated indicates that the foaming properties of the albumen are not decreased, and fertilized eggs subjected to the same treatment, remain capable of supporting embryonic development. This fact indicates that the major portion of the egg's contents does not undergo chemical change when the egg is treated in this manner (43).

Freezing as a means of preserving eggs has had a rapid growth in recent years, but up to the present time, large institutions have been the chief users of frozen eggs, which have been packed in standard cans of 10-30 lb. capacity (43). As home refrigeration facilities improve it is certain that home freezing will become popular, for Urban and Miller (57) explain that the white portion of the egg suffers no breakdown as the result of freezing. However, the physical character of the yolk portion is altered on freezing, owing to separation and coagulation of the lecithin, but this may be prevented by the addition of 10 per cent by weight of dextrose or levulose. Lowe (29) states that the addition of salt, sugar, dextrose, honey, or a combination of salt and sugar to the egg yolk or whole egg before freezing tends to prevent gelation.

Since the escape of carbon dioxide and moisture takes place as soon as the egg is laid and causes the egg meats to deteriorate, it would seem that the most perfect preservative would be the one that would seal the egg completely. However, physiochemical changes occur within the egg even when the shell is sealed, so as yet, no perfect method of preserving eggs has thus far been found.

In 1923 Swingle and Pool (56) stated that the housewife had little to guide her in the choice and details of a method, for none of the papers on the subject reported on the actual changes that took place in the egg during storage. Since the publishing of that article considerable research has been carried on, studying the physical and chemical measurements of the preserved egg as compared to those of the fresh. Stewart, et al (54) explained that there was a small but definite relationship between the air cell width and the interior quality of the egg. Later, Funk (13) showed that loss in weight in shell eggs, by evaporation, manifests itself by an increase in the size of the air cell. The loss in weight during storage is related to the porosity of the egg shell. Sharp (47) reported that the shell had from five to twenty-five true openings or pores. Herrington and Sharp (22), in studying the effect of storage temperature on egg quality, concluded that the longer the egg is held, and the higher the temperature, the more the yolk flattens when the egg is opened, and the greater the water content of the yolk. Sharp and Powell (49) recommended the yolk index (height of the yolk divided by the width of the yolk) as a measurement of the interior quality of the egg. Other workers have found that merely the height of the yolk was correlated with egg quality, Stewart and Boise (53).

Realizing that the color of the yolk affected its desirability from the consumer's standpoint, various methods and charts have been developed for the measurement of yolk color. A device called the Yolk Color Roter was developed by Heiman and Carver (21), and numerous egg color charts such as that put out by Vernon and Whitfield (59) have been prepared. More recent methods have included an objective method in which

the color pigment is extracted and measured in a photoelectric colorimeter, Mayfield and Halbrook (31).

Rather extensive research pertaining to the physical and chemical aspects of egg albumen was conducted between the years 1930-1940. In 1936 Heiman and Carver (20) showed that the albumen index (height of the apparent dense albumen divided by the average of its long and short diameters) could also be used as a physical measurement of egg quality. Other workers, Sharp (46), Haugh (19), Wilgus (60) and Lorenz and Almquist (28) have reported that the height and condition of the thick albumen, as well as the percentage present were measurements of the quality of eggs.

The escape of carbon dioxide begins the moment the egg is laid and causes the albumen to become more alkaline as the egg is held in storage (63, 40). Measurement of the alkalinity of egg albumen is used as an indication of the aging process in the egg (63). A common way of expressing alkalinity is as pH, the logarithm of the reciprocal of the hydrogen ion concentration. The pH of the albumen of a newly laid egg is about 7.6 (45, 40). According to Khoury (27) and Gwin (8) egg white has germicidal properties due to a lytic substance called lysozyme which prevents bacteria from growing in the albumen. These germicidal qualities persist even in the liquid egg (30). The proteins of native egg albumen are not in a form that can be utilized by many bacteria, and furthermore, the alkalinity of the albumen in the aging egg is unfavorable to most bacterial growth (18). Hence the change in alkalinity is due mainly to loss of carbon dioxide rather than to bacterial development (1).

Little scientific literature has been published on the cooking quality of preserved eggs after definite periods of storage. However, the following have contributed information: Swingle and Pool (56), McIntosh et al (33), Slosberg et al (51), and Winter and Cotterill (61). Scientific methods for measuring the reaction of preserved eggs in cakes were devised and compared by Platt and Kratz (39) and also King et al (26).

EXPERIMENTAL PROCEDURE

Because of the importance of eggs as a food in the human diet; their seasonal production and tendency to deteriorate rapidly; and the scarcity of information concerning the comparative physical and cooking qualities of eggs stored by various home processes; this study was planned to investigate five different methods of preservation that could be easily duplicated in the home. Plans included the measurement of certain physical, chemical, and cooking qualities at the end of three and six months' storage.

Eight hundred thirty-eight grade AA eggs from New Hampshire hens were used for this experiment. They were supplied by the Poultry Department of Montana State College and were collected over a period of three weeks. They were delivered from the college farm to the laboratory with a minimum amount of jarring. Each day after the eggs had been candled and graded by an experienced operator, they were allowed to stand in a temperature of about 60 degrees Fahrenheit until the next day. Only clean eggs were selected, and all were about twenty-four hours old when used or treated. Each egg, except those to be broken and frozen, was dated, numbered, weighed on a torsion balance (sensitivity 15 mg.) and marked with its individual

fresh weight. Five hundred eggs were divided into four groups of 125, and preserved in each of the following ways: waterglass, S-100, mineral oil, and vinylite. After treatment the last three mentioned groups were packed, small end down, in new one-dozen egg paper cartons. All eggs were stored in a dark basement room in a private home where the air circulated freely and the temperature range was between 50-60 degrees Fahrenheit. The relative humidity was from 55-60 per cent. Twenty-two untreated eggs were stored in the same manner as the shell-treated eggs and were used as controls. Only ninety-two eggs were used for freezing as it was necessary to break these, hence fewer tests could be made.

WATERGLASS---Eggs to be preserved by this method were placed in gallon jars and covered with a mixture of one part of sodium silicate to nine parts of distilled water following recommended procedures (9). Covers were placed on the jars to prevent evaporation.

FREEZING---Fifty-seven eggs were broken out of the shell and mixed (about 8 seconds) in a Waring blender¹. Following established procedures (40) one tablespoon of sucrose was added for each cup of mixture. This substance was then poured into pint cartons, sealed, and frozen. The whites and yolks of twenty-two eggs were frozen separately. One teaspoon of sugar was added for each six yolks; however, the whites were frozen without sugar. A few eggs were well mixed and frozen without the addition of sugar. This is not a recommended procedure but it seemed worth while to include a little work on this treatment since it has received some discussion.

¹Manufactured by the Waring Corporation, New York, New York.

S-100---The S-100² emulsion was applied as directed by the Hearst Laboratories. A small amount was placed in the palm of the hand, then rubbed on the egg so that the entire surface was covered with a thin coat of the preparation. These eggs were then placed in cartons for storage.

OILING---Eureka White Mineral Oil³, that possessed a Saybolt Universal Viscosity specification of 50-60 seconds at 100 degrees Fahrenheit was used in the oil treatment of the eggs. They were submerged in the oil, that was at room temperature, and allowed to drain for about an hour before they were placed in the cartons.

VINYLLITE---The vinyl acetate resin dispersion W-125⁴ was applied by hand application in the same manner as was the S-100. The treated eggs were placed on greased wire racks until dry, then they were stored.

In order to determine the quality of the fresh and preserved eggs, it was decided to weigh the fresh eggs and also those preserved, both before and after storage; to take physical measurements of the albumen and yolk; determine the color index of the yolk; take the pH of the albumen; rate the flavor; test for poaching quality; ascertain coagulating quality; and determine the whipping and baking properties.

Eighty fresh eggs were used for physical measurements in order to develop techniques and establish methods. One hundred four were used for

²Furnished by Hearst Laboratories, 746 Natoma St., San Francisco 3, Calif.

³Furnished by Pierce Packing Company, Billings, Montana.

⁴Donated by Mr. J. C. Frymen of the Bakelite Corporation, 30 East 42nd St., New York 17, New York.

sponge cakes, twenty for poaching, ten for flavor, and ten for coagulating tests. However, ten preserved eggs were used for each measurement at the end of three and six months' storage.

Each egg used for physical measurements was cracked carefully with a blunt knife, and the contents were let slide gently into a pyrex pie plate. This was then placed over a centimeter scaled paper and the spread in length and width of the thick albumen was determined for each egg. The height of the thick albumen was measured with a spherometer, about one-half inch from the yolk, as explained by Funk (13). This instrument consists of a micrometer screw with a graduated head that moves against a vertical scale. This spherometer was also used to measure the height of the yolk as it rested on the white, a method recommended by Gibbons (15). This method is illustrated in Figure 1.

The yolk color was determined by comparison with a scale given on an Egg Color Chart, devised by Vernon and Whitfield (59).

Measurement of the pH of the albumen was made with a Macbeth pH Meter, about ten minutes after each egg had been broken.

Since it is known that off flavor in eggs is more pronounced in the yolk than in the white, (43), a tasting panel was conducted to determine the flavor of the egg yolks. Five members of the Home Economics staff served as judges. One quart of tap water was brought to a boil, then ten eggs were added and allowed to cook for three minutes in the hot, but not boiling, water. As soon as the eggs were removed a portion of the small end was cut off in such a manner as to expose the yolk. Each egg was then numbered and held in an upright position by resting in

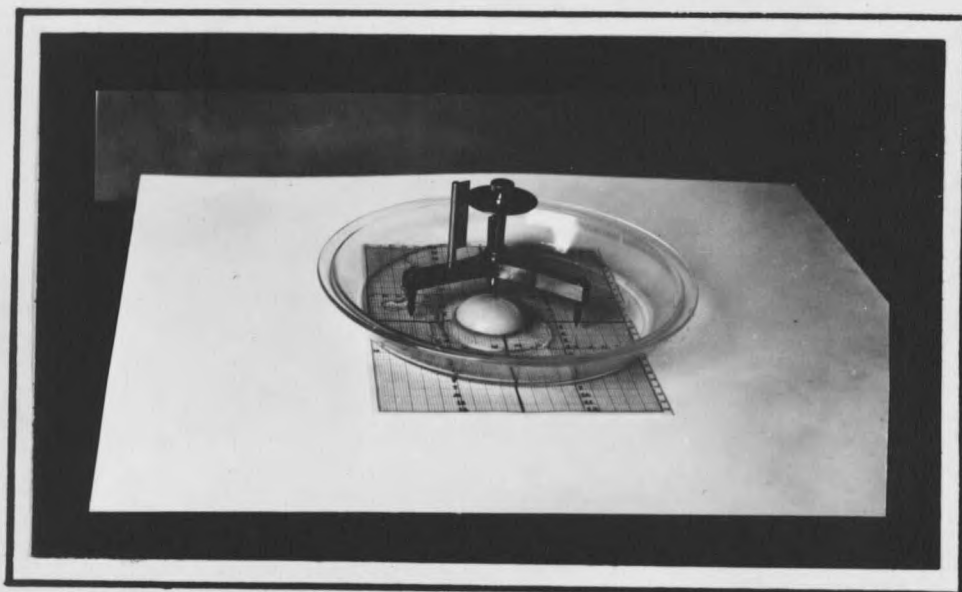


Fig. 1. Spherometer used to measure, in hundredths millimeters, the height of the yolk and of the thick albumen. The spread of the albumen was determined by means of the scaled chart under the egg.

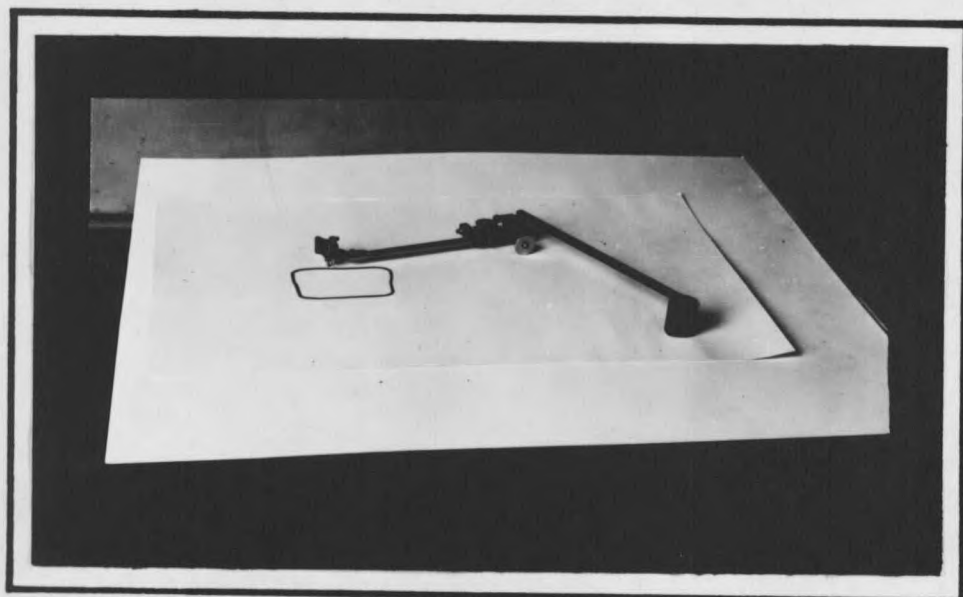


Fig. 2. Compensating Polar Planimeter, K&E No. 4235M, used to measure the area of the center cut of the sponge cakes in sq. cm. to tenths.

the top part of a 50 ml. beaker. Sufficient plastic spoons were supplied so that the judges could use a different spoon each time they tasted an egg yolk. Each of the judges scored all ten egg yolks. The judges did not know which type of preserved egg they were rating, and they were asked not to make any comments on samples until all judging was completed. Each judge was given a score sheet and asked to rate the flavor only by allotting from 1 to 10 points for each egg; 10 was high and 1 was low on the scale. The judges were told that any descriptive terms or additional comments concerning the samples would be appreciated. The tasting was done while the yolks were hot and neither salt nor pepper was added. Some judges removed the flavor of the individual egg from their mouths by taking a drink of water and others preferred crackers. This method of procedure was much the same as that followed by Pennington (37).

In poaching the eggs, practically the same procedure as that recommended by Lowe (29) was followed. Three-fourths teaspoon of salt and one pint of tap water were mixed in a two-quart pyrex utensil and brought to a boil. Each egg was broken into a sauce dish and then slid into fresh, boiling salt water. After the egg was placed in the water the utensil was removed from the heat, and the egg was allowed to cook undisturbed for five minutes (32, 4). Measurements were then made by placing the pyrex dish over a scaled centimeter paper and the length and width in spread of the thick and thin albumen were determined. An estimate of the yolk covering was made by rating each one as good, fair, poor or broken.

The coagulating quality of the eggs was tested by means of baked

custards. Ten preserved eggs were mixed for eight seconds in a Waring blender, and 288 grams of the magma were added to 150 grams of granulated sugar and six cups (1,464 grams) of milk that had been allowed to reach room temperature. One hundred twenty-five cubic centimeters of this mixture were poured into each of eleven well-greased pyrex dishes. These dishes were placed in a pan that contained several inches of hot water and allowed to bake in a gas oven at a temperature of 340 degrees Fahrenheit until the tip of a small knife carefully inserted came out clean, McCammon and Ufford (32). A thermometer, suspended from an oven rack, was extended into the center of one of the custards and the final internal temperature was recorded. Baking times were also recorded but preliminary work indicated that neither the time nor the internal temperature could be used as the final guide for doneness of the custard. On the following day ten grams of the top membrane, formed during baking, were removed from the top of each dish and the custard was carefully emptied onto a plate glass that covered a centimeter ruled paper. After standing for three minutes the measurements in spread of each custard were taken. A modification of the "Line-spread" method of measurement employed by Grawemeyer and Pfund (17) was used to obtain objective data in spread of the inverted custard.

The whipping and baking properties of the preserved eggs were determined by the quality of sponge cake each group produced. The formula used was that recommended by Pike and Johnson (38) for an altitude of 5,000 feet, with minor modifications. Preliminary work showed that more satisfactory results were obtained when the same quantity of flour was added as was suggested for 7,500 feet. Thirty-six cakes were made before

the formula, procedure, and results were standardized. The modified formula was as follows: 42.5 grams of cake flour, 15 cubic centimeters of water, 96 grams of egg magma, 67 grams of sugar, 0.5 grams of salt, 0.5 grams of cream of tartar, and 1 cubic centimeter of vanilla. The single meringue method of mixing was chosen. Ten eggs that were at room temperature, were broken out of the shell and mixed for fifteen seconds in a Waring blender. The eggs used for the five cakes were weighed from this magma. The salt, sugar, cream of tartar and vanilla were dissolved in the egg mixture and this was beaten for six minutes on a speed of "twelve" or "high" (980 r.p.m.) with a General Electric Mixer. Then the speed was changed to "one" or "low" (350 r.p.m.) and the cake flour was added slowly over a period of four minutes. The bowl was then thoroughly scraped down and the mixing continued one-half minute at low speed. A stop watch was used to insure accurate timing and the revolutions per minute of the beater were checked with a Strobotac machine⁵ for the rate of speed seemed to vary. This finding was corroborated in a report on this instrument (11). After beating, the batter was weighed in a standard tared cup and the weights were recorded. One hundred grams of this batter were baked in an unlined, ungreased, embossed tin loaf pan that measured $5\frac{1}{2}$ by $2\frac{1}{2}$ by $2\frac{1}{4}$ inches, for 35 minutes at a temperature of 350 degrees Fahrenheit. Each time the pan was placed in the same relative position of the gas oven. After the cake was removed from the oven, it was inverted on a wire rack to cool. In about half an hour, or when perfectly cool, the cake was removed from the

⁵Manufactured by General Radio Co., Cambridge, Mass., and loaned for use in this study by the Electrical Engineering Dept., Montana State College.

pan. On the following day each cake was cut crosswise at the center and one of the cut surfaces was placed against a piece of paper. The outline was then drawn with a soft pencil. Care was taken to avoid exerting any pressure against the cake with the pencil. The area of this cross section was measured with a Keuffel & Esser compensating polar planimeter as shown in figure 2. The area of the cross section is expressed as the "Index of Volume". The index of volume for each of the five cakes was measured in this way and the average was used for comparison. These procedures have been suggested by Platt and Kratz (39) who state that this area is proportional to the volume.

Barometric readings were obtained for the days on which the cakes were baked but, since there was no apparent correlation, this data is not recorded.

One half of the cut cake was taken to a commercial photographer and a picture was made of the crosswise center cut. The shape and grain of the cakes made from the various eggs was thus recorded. Pictures were taken of two representative cakes made from each of the various fresh and preserved groups of eggs.

RESULTS AND DISCUSSION

Changes in weight of eggs during three and six months of home preservation are presented in Table I. The mean weight of all eggs before storage was 61.94 grams. This is somewhat above the 58.10 grams given by Romanoff (43) as being the average weight of eggs from New Hampshire hens. It will be noted that the eggs preserved in waterglass gained an average of 1.52 per cent at the end of three months' storage and 0.16 per cent at the

TABLE I

CHANGES IN WEIGHT OF EGGS DURING STORAGE UNDER FOUR^a

METHODS OF HOME PRESERVATION

Method of Preservation	Months of Storage	Number of Eggs	Mean Weight		Mean Changes in Weight			
			Before Storage gm.	After Storage gm.	gm.	pct.	range	pct.
Waterglass	3	53	61.86	62.80	+0.94	+1.52	+0.15 to	+3.23
	6	65	62.44	62.53	+0.09	+0.16	0.00 to	+0.81
S-100	3	58	62.00	61.68	-0.32	-0.51	0.00 to	-2.81
	6	55	61.33	60.58	-0.75	-1.23	+0.17 to	-2.52
Mineral Oil	3	60	62.38	61.34	-1.04	-1.66	-0.15 to	-9.15
	6	60	61.41	58.66	-2.75	-4.47	+0.46 to	-21.08
Vinylite	3	60	61.35	56.48	-4.87	-7.94	-5.64 to	-14.85
	6	69	63.21	52.68	-10.53	-16.65	-9.17 to	-38.04
No Treatment	3	11	60.16	52.96	-7.20	-11.97	-7.72 to	-17.88
	6	11	63.32	48.20	-15.12	-23.85	-18.18 to	-33.22

^aNo measurements were made on frozen eggs.

end of six months. This gain in weight may be due to the deposit of sodium silicate on the shell. Romanoff and Yushok (44) have reported a rather complete covering of the egg with such a deposit and found that eggs preserved in waterglass and then stored for twenty days under incubating conditions lost no weight. Eggs preserved by treatment with the S-100 emulsion showed very little loss in weight at the end of either three or six months storage, 0.51 and 1.23 respectively. Work carried on by the United States Department of Agriculture (6) using the S-100 emulsion indicated a somewhat greater loss in weight at the end of three months, 3.00 per cent. However, the eggs used in their work were stored at room temperature, 75-80 degrees Fahrenheit, and those in this study at from 50 to 60 degrees Fahrenheit.

It would appear that treatment with the mineral oil did not seal the pores of the egg as adequately as did the S-100 emulsion, for losses in weight at the end of three and six months' storage were 1.66 and 4.47 per cent respectively. Other workers (6) have reported a loss in weight of 6.00 per cent when eggs were oil treated and held for three months at from 75 to 80 degrees Fahrenheit.

Eggs treated with the vinylite, vinyl acetate resin dispersion W-125, lost considerable weight during storage, 7.94 and 16.65 per cent at the end of three and six months' storage respectively. These losses in weight are much greater than those which occurred in the other three methods and more nearly resemble the losses in weight of eggs that received no treatment, 11.97 and 23.85 per cent.

A graphic comparison of the respective changes in weight following

the various methods of preservation and periods of storage are shown in figure 3.

The results of the physical measurements made on the albumen and yolk of the various treated eggs are shown in Table II. These include mean height and width of the thick albumen, the mean albumen index (height of thick albumen divided by its average width), and height and color of the yolk. The mean height of the albumen from the fresh eggs was 0.541 cm. After the eggs had been stored for three months by any of the four methods of preservation the mean height dropped considerably, being lowest in the vinylite treated eggs, 0.250 cm., and highest in those treated with the mineral oil, 0.388 cm. At the end of the six months' storage this height had become less in all cases other than the eggs stored in waterglass. The mean width of the thick albumen of the fresh eggs was 8.74 cm. This spread became larger in all instances after the eggs had been stored, being greatest in the eggs preserved with the vinylite. Since the condition and quality of the egg is related to both the height and spread of the thick albumen, the albumen index, based on both of these measurements gives a reliable indication of the condition of the egg white (20, 60). The mean albumen index of the fresh eggs is 0.062 and is within the range given by other workers for fresh eggs, 0.050-0.174 cm. (43). After three and six months' storage the various indexes show a decided drop regardless of the method of preservation. This fact is clearly indicated in figure 4. In comparing the albumen indexes of the treated eggs with those of the fresh eggs and the eggs receiving no treatment, figure 4, it is evident that all methods have slowed up deterioration but that none of them have in any degree

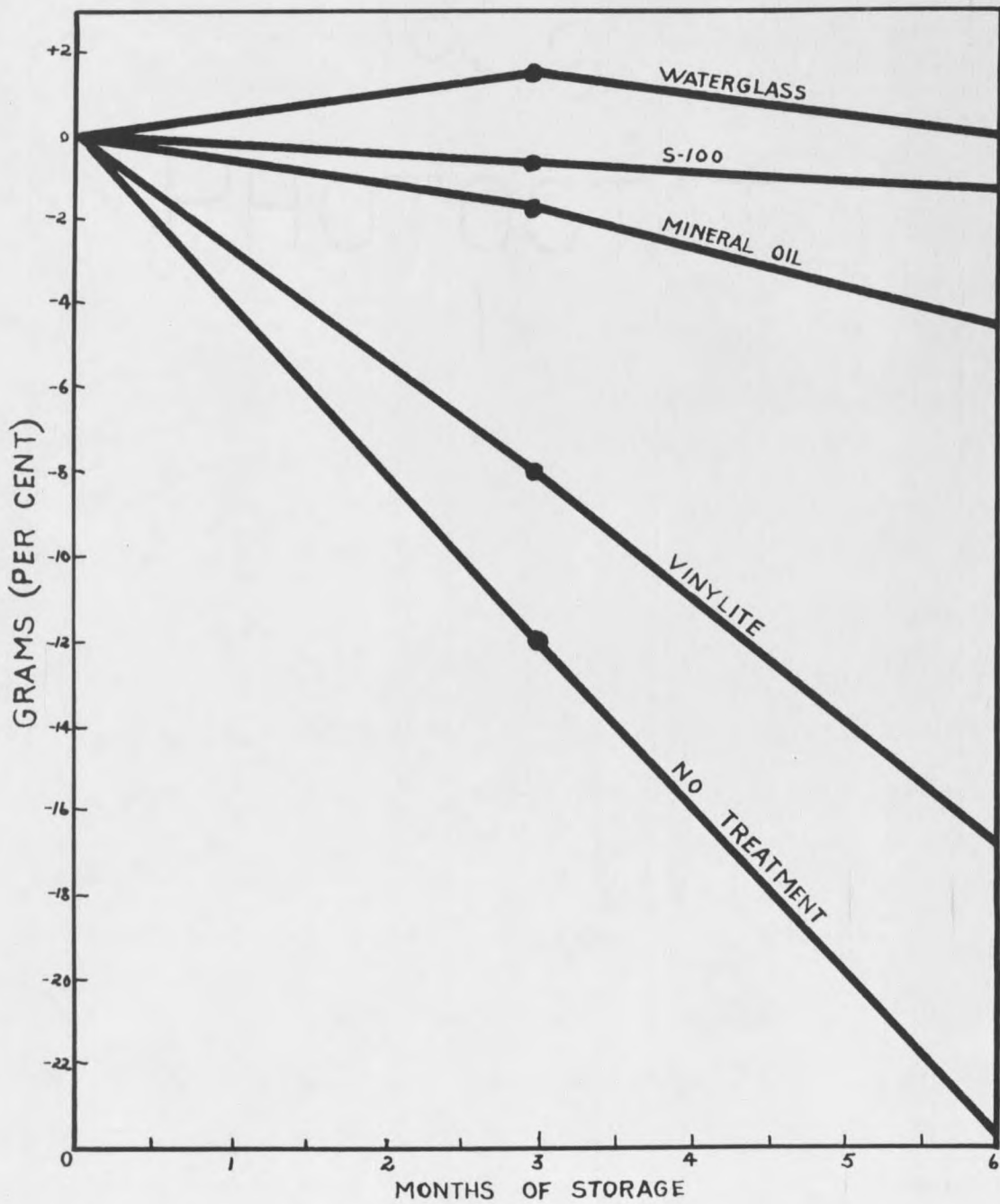


Fig. 3. Changes in weight of eggs during storage under four methods of home preservation.

TABLE II

ALBUMEN AND YOLK MEASUREMENTS OF FRESH EGGS, EGGS STORED
BY FOUR^a METHODS OF HOME PRESERVATION AND EGGS STORED WITH NO TREATMENT

Method of Preservation	Months of Storage	Albumen			Yolk	
		Mean Height cm.	Mean Width cm.	Index ^b	Color ^c	Height cm.
Fresh	0	0.541	8.74	0.062	90	1.94
Waterglass	3	0.277	11.78	0.024	84	1.68
	6	0.331	10.35	0.032	80	1.40
S-100	3	0.345	10.23	0.034	84	1.88
	6	0.319	9.24	0.035	79	1.86
Mineral Oil	3	0.388	9.03	0.043	84	1.87
	6	0.296	9.93	0.030	80	1.66
Vinylite	3	0.250	13.22	0.019	84	1.22
	6	0.198	13.36	0.015	74	1.43
No Treatment	3	0.176	14.44	0.012	76	1.24
	6	0.154	14.68	0.011	73	1.02

^aNo measurements could be made on frozen eggs.

^bHeight of albumen divided by its average width.

^cVernon and Whitfield egg color chart was used. A to F color values converted to numerical grades. B (light) 100; F (dark) 60.

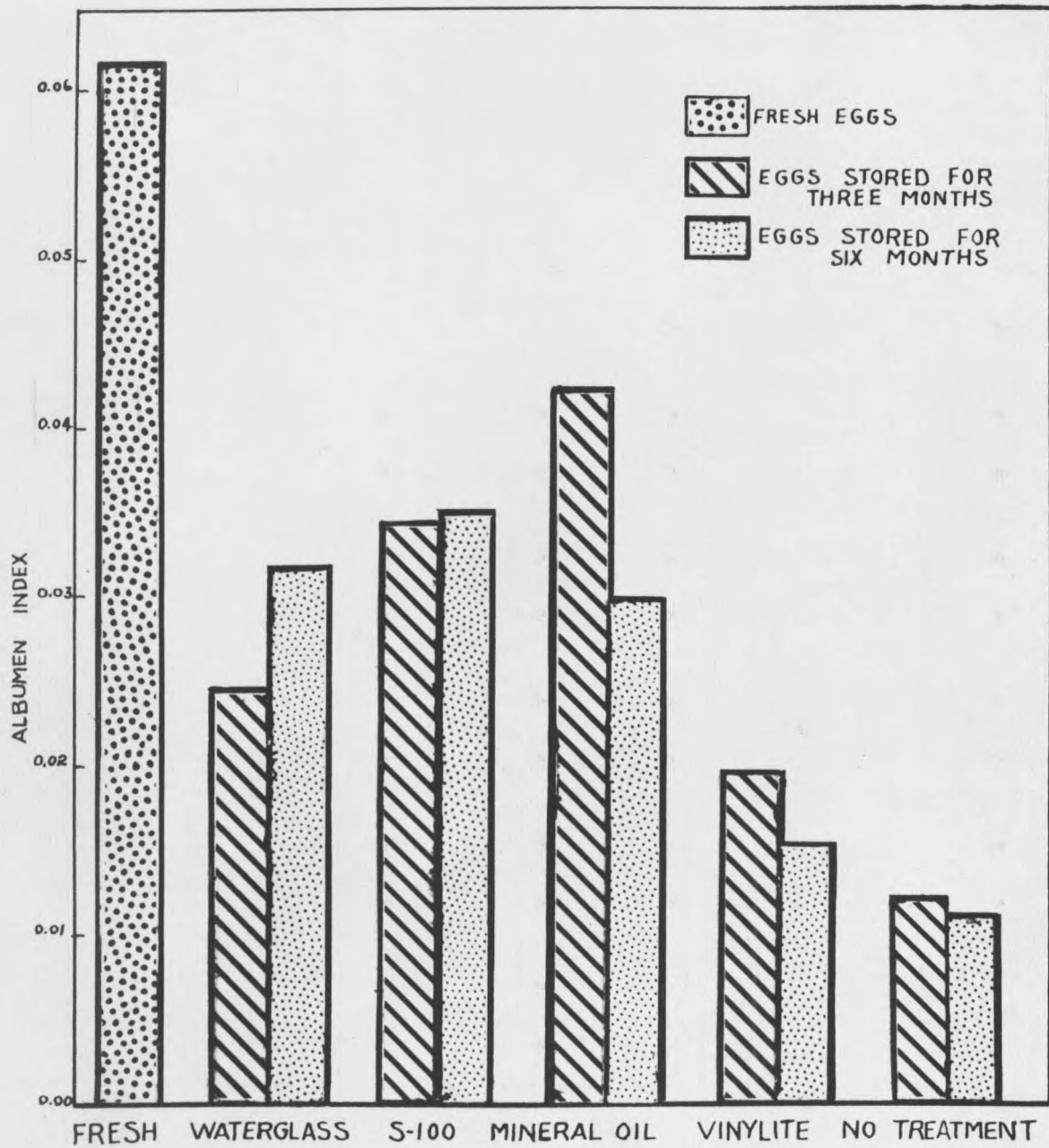


Fig. 4. Albumen index of fresh eggs, eggs stored by four methods of home preservation and eggs stored with no treatment.

retained the high index of the fresh eggs. When both storage periods are considered, the albumen indexes for the eggs treated with S-100 and mineral oil are superior and quite similar. The eggs preserved with waterglass rank next while those treated with vinylite have the lowest index of any of the treated eggs. There is no explanation for the apparent increase in the albumen index of the eggs stored in waterglass for six months as compared with the index at the end of three months.

The mean height of the yolks from the fresh eggs was 1.94 cm. as shown in Table II. While some changes in yolk height took place when the eggs were stored for three and six months, they were not as great as those that took place in the egg albumen, see figures 4 and 5. Measurement of the height of the yolk gives an indication of the "interior quality" of the egg for the flattening of the yolk and its decreased resistance to breaking are attributed largely to the passage of water from the white into the yolk during storage (20). As with the albumen index, when both storage periods are considered, the yolk height of the eggs treated with S-100 and mineral oil are superior and quite similar. The eggs preserved with waterglass rank next while those treated with vinylite have the lowest yolk heights of any of the treated eggs. When the vinylite eggs were opened at the end of six months the yolks were very stiff. Many of these eggs had yolks that were stuck to the inner membrane and thus would be rated inedible according to the U. S. Standards for Quality of Individual Shell Eggs (58). This probably accounts for the increase in yolk height at the end of six months' storage. In all but one case (vinylite--3 months) the mean yolk height of the treated eggs was superior to that of the untreated eggs.

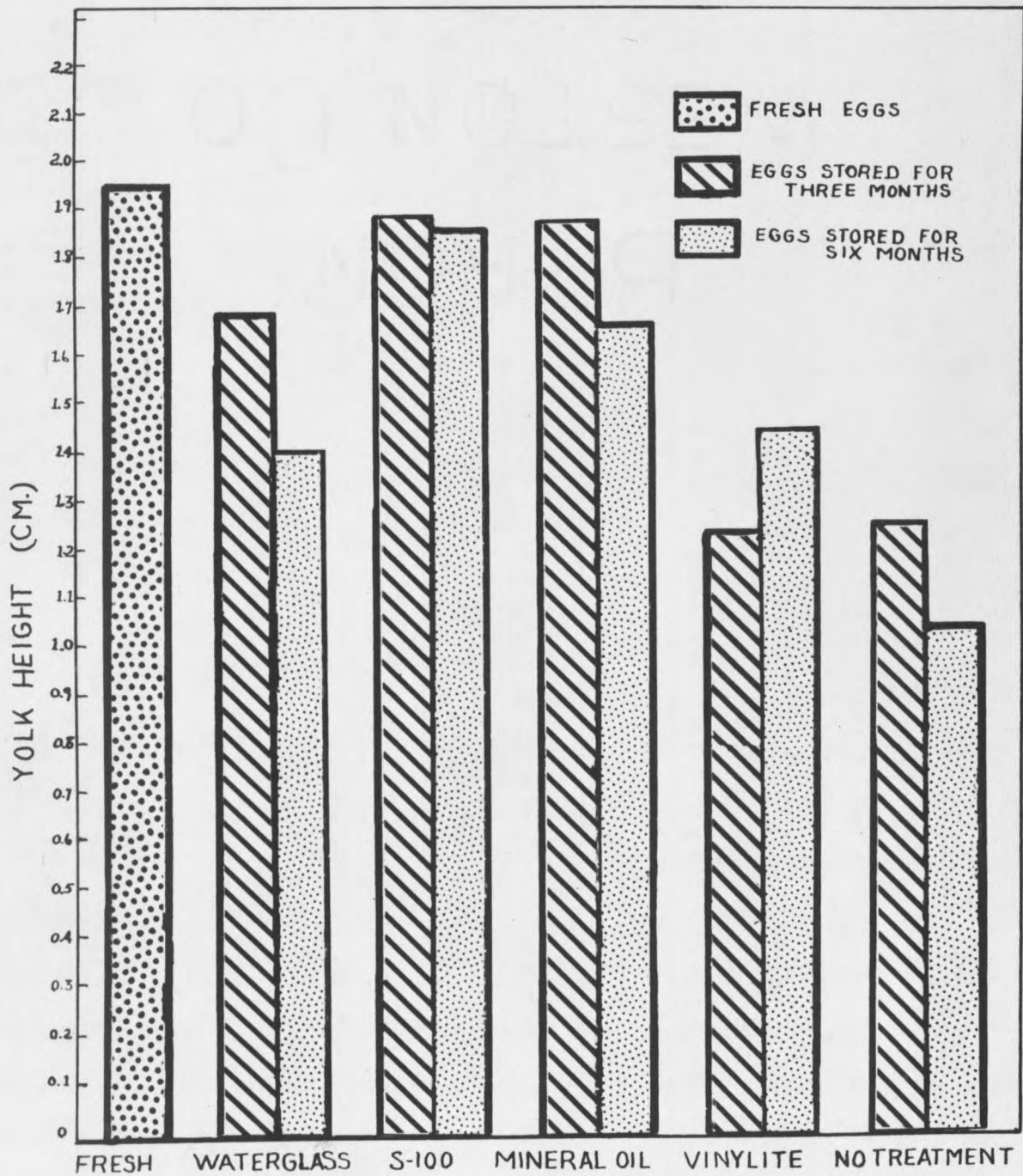


Fig. 5. Yolk height of fresh eggs, eggs stored by four methods of home preservation and eggs stored with no treatment.

The numerical yolk color values given in Table II were converted from visual color ratings made using the Vernon and Whitfield color chart (59). The light yolk color designated "B" was assigned a value of 100, C--90, D--80, E--70 and the dark color "F" was rated 60. The average color value of the fresh egg yolks was 90. After the eggs had been stored for three months by any of the methods, a darkening of the yolk was evident with a color value of 84. This darkening progressed and at the end of the six months' period the values were about 80 for eggs preserved with water-glass, S-100 and mineral oil. This finding is in harmony with that of Romanoff (43) for he states that there is a tendency for the aging egg to grow darker, especially if holding conditions are unfavorable. However, the eggs treated with vinylite had a yolk color value of 74 and were very similar in color to those receiving no treatment.

Information concerning the alkalinity of the albumen of the fresh and various treated eggs, as expressed in pH values, is given in Table III and figure 6. The individual values of the ten eggs tested as well as their mean are shown. The mean pH of the fresh eggs, 7.55, compares favorably with the value reported in the literature for fresh eggs, pH 7.6 (45). No explanation can be offered for the slight lowering in pH value of the eggs preserved with waterglass, S-100, and mineral oil at the end of three months' storage. Those treated with vinylite showed a very slight increase in pH at the end of three months' storage while those frozen remained the same as the fresh eggs. However, at the end of six months' storage the pH of the albumen of the eggs treated with waterglass, S-100, mineral oil, and vinylite had increased noticeably, pH 8.10, 7.96, 8.80, and 9.04,

TABLE III

pH OF ALBUMEN OF FRESH EGGS, EGGS STORED BY FIVE METHODS
OF HOME PRESERVATION AND EGGS STORED WITH NO TREATMENT

Method of Preservation	Months of Storage	pH of Individual Albumen										Mean pH
		Egg										
		1	2	3	4	5	6	7	8	9	10	
Fresh	0	7.60	7.61	7.48	7.60	7.50	7.48	7.60	7.58	7.53	7.51	7.55
Waterglass	3	7.30	7.35	7.50	7.45	7.45	7.50	7.30	7.30	7.30	7.30	7.38
	6	8.00	8.15	8.10	8.15	8.00	8.28	8.10	8.10	8.10	8.10	8.10
Freezing	3	7.54 ^a										7.54
S-100	3	7.20	7.25	7.30	7.35	7.30	7.40	7.40	7.35	7.45	7.45	7.35
	6	8.10	7.90	7.90	7.72	8.40	7.75	8.18	7.90	7.80	7.98	7.96
Mineral Oil	3	7.35	7.38	7.40	7.45	7.45	7.40	7.55	7.50	7.50	7.55	7.45
	6	9.05	8.85	9.00	8.85	8.70	9.00	8.53	9.00	8.78	8.20	8.80
Vinylite	3	7.80	7.68	7.62	7.75	7.68	7.60	7.60	7.68	7.63	7.65	7.67
	6	9.10	8.90	9.08	9.20	9.02	9.10	9.10	8.98	8.90	9.00	9.04
No Treatment	3	9.10	9.25	9.20	9.20	9.35	9.25	9.20	9.15	9.10	9.20	9.20
	6	8.68	9.20	9.10	8.95	9.10	9.00	9.00	9.10	9.05	8.95	9.01

^aNo measurement was made on albumen after 6 months of frozen storage.

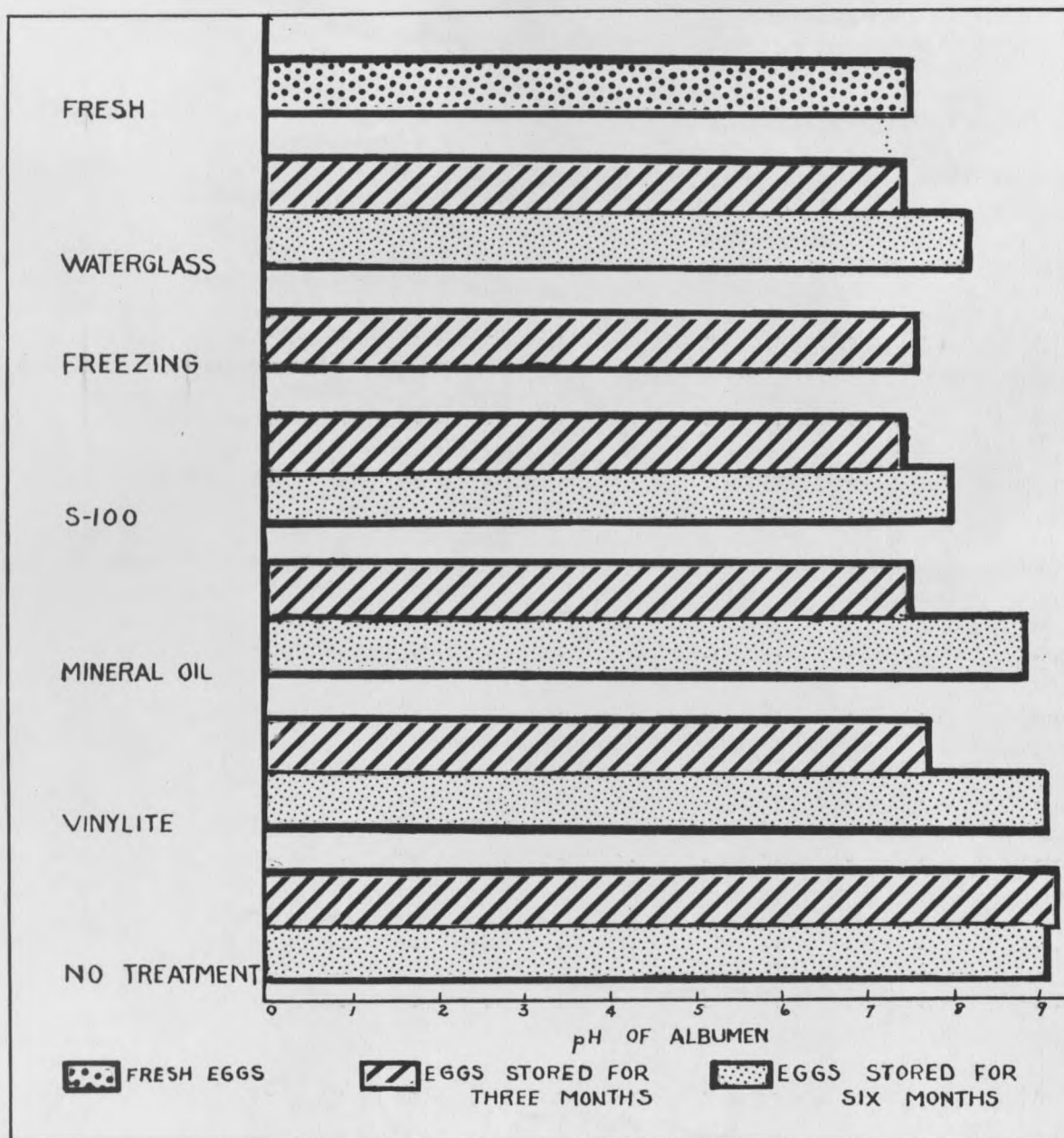


Fig. 6. pH of albumen of fresh eggs, eggs stored by five methods of home preservation and eggs stored with no treatment.

respectively. Since it has been shown that the pH increases as the egg deteriorates, Rosser and White (45) and Powell et al (40), these methods of preservation may be ranked in the order of their effectiveness (based on pH of the albumen at the end of six months' storage) as S-100, water-glass, mineral oil, and vinylite. It has been reported (45, 40) that change in the alkalinity of the albumen is due mainly to loss of carbon dioxide and may be associated with loss in weight during storage. In comparing the loss in weight of eggs stored for six months, by the various methods, with their respective pH values it is necessary to eliminate those preserved in waterglass since a mineral deposit has probably affected their weight. When this is done the per cent loss in weight increases in the same manner as does the pH, namely: S-100, mineral oil and vinylite. It will be noted that the eggs receiving no treatment had a pH value of 9.20 at the end of three months and 9.01 at six months. This lower pH after six months' storage may be explained by the fact that when spoilage occurs the pH of the egg albumen becomes less (45).

Mean palatability scores of the yolks of the soft cooked eggs before and after four methods of home preservation are presented in Table IV. Since each of the five judges scored all ten yolks the information is summarized and presented for the individual judges as well as for the mean of all five judges. The range in score of each judge for the ten eggs is also given as this information seemed pertinent. It was the plan of this study to have the five members of the tasting panel remain the same throughout the judging period. However, due to unavoidable circumstances, it was

TABLE IV

PALATABILITY SCORES^a OF YOLKS OF SOFT COOKED EGGS
BEFORE AND AFTER FOUR^b METHODS OF HOME PRESERVATION

Method of Preser- vation	Months of Storage	Mean Palatability Scores of Ten Yolks					Mean of Five Judges	
		Judge						
		1	2	3	4	5		
Fresh	0	Mean Range	7.9 (6-9) ^c	8.7 (6-10)	8.2 (6-9)	9.7 (9-10)	7.9 (6-10)	8.5
Waterglass	3	Mean Range	6.9 (5-8)	6.9 (3-9)	6.7 (4-9)	8.8 (5-10)	8.8 (7-10) ^d	7.6
	6	Mean Range	7.0 (5-8)	7.6 (6-9)	7.1 (4-9)	7.6 (5-9)	6.7 (5-8)	7.2
S-100	3	Mean Range	5.9 (2-8)	6.4 (2-9)	6.2 (2-9)	8.6 (6-10)	8.6 (7-10) ^d	7.1
	6	Mean Range	5.9 (3-9)	6.6 (4-8)	7.8 (6-9)	8.5 (7-10)	6.5 (4-8)	7.1
Mineral Oil	3	Mean Range	5.9 (3-7)	6.4 (2-9)	6.6 (1-9)	8.2 (5-10)	5.2 (2-8) ^e	6.5
	6	Mean Range	4.7 (1-6)	6.8 (5-8)	7.6 (6-9)	6.7 (5-8) ^f	6.9 (5-8)	6.5
Vinylite	3	Mean Range	6.4 (5-8)	7.8 (6-9)	6.8 (4-8)	9.2 (7-10)	7.4 (5-10) ^d	7.5
	6	Mean Range	5.8 (2-8)	6.0 (3-8)	6.5 (4-8)	5.4 (4-7) ^f	4.8 (0-8)	5.7

^aBased on a maximum score of 10 points.

^bNo measurements could be made on frozen eggs.

^cNumbers in parentheses represent range in scores.

^dJudge 5 - b

^eJudge 5 - c

^fJudge 4 - b

necessary to ask three substitute judges to serve at certain times. The scores of the substitute judges are indicated by means of footnotes in the table. It will be noted that the first three judges remained constant throughout the study and that a substitute was used twice for judge four, and four times for judge five. Scores of the three regular judges were averaged to determine if their rating would be decidedly different from that of the five judges and their substitutes. Since their rating was quite similar to that of the five, the results are not presented and it is believed that the mean palatability scores of the five judges are not unduly influenced by the use of substitute judges. Based on a maximum score of ten points, the fresh egg yolks were rated 8.5 with a range of from 6 to 10 points. At the end of three months' storage, the eggs treated with waterglass and vinylite were scored somewhat higher, 7.6 and 7.5, than were those preserved with S-100 and mineral oil, 7.1 and 6.5 respectively. However, at the end of six months the eggs preserved with waterglass and S-100 were scored about the same, 7.2 and 7.1, while those treated with mineral oil and vinylite were somewhat less palatable and were scored 6.5 and 5.7 respectively. It will be noted that in practically all instances the range of scores for the ten eggs for each judge was rather great. Since this is true in the fresh as well as the preserved and stored eggs, it appears that this variation in desirability of flavor existed in the fresh eggs and is not due to variations that developed during storage. Further comparison of the palatability of the yolks of fresh and preserved eggs, as shown in figure 7, indicates that eggs preserved in waterglass and S-100 were slightly more palatable at the end of six months' storage than were those preserved

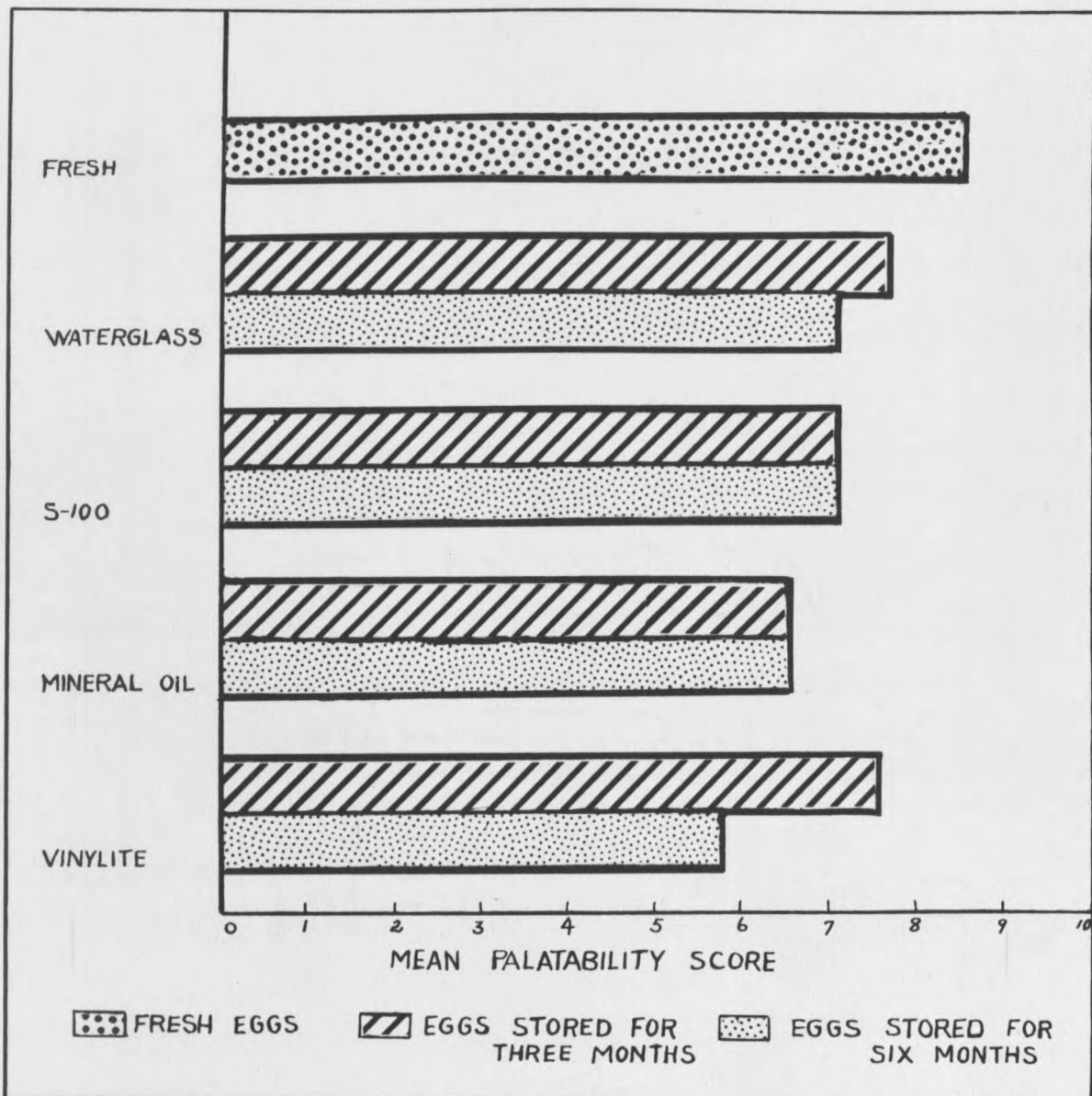


Fig. 7. Palatability scores of yolks of soft cooked eggs before and after four methods of home preservation.

in mineral oil or vinylite.

Results of the measurements used in judging the poaching quality of the fresh and preserved eggs are given in Table V. Such results are difficult to express in quantitative terms but the measurements taken are considered a definite indication of the poaching quality of an egg, according to St. John (55). It will be seen that the mean spread of the thick and thin albumen of the fresh eggs is 6.55 and 10.25 cm. respectively and that six of the ten eggs had good coverage of the yolk and three fair. After preservation and storage the mean spread of the thick and thin albumen was greater in all cases but was quite similar for those treated with waterglass, S-100, and mineral oil. The coverage of the yolk was rated somewhat higher for the eggs preserved with waterglass and S-100 than for those treated with mineral oil. However, the eggs treated with vinylite had a much greater spread of albumen, especially of the thick portion, than did any of the other eggs. At the end of six months' storage the thick albumen could not be distinguished from the thin and the coverage of all yolks was considered poor. From the data given in Table V, it is apparent that fresh eggs are the most desirable for poaching. Lowe (29) has stated that high quality eggs are better for poaching than deteriorated ones and that eggs with a low albumen index fail to "bind or veil the yolk" satisfactorily. In general, the results of the measurements of poaching quality are in agreement with the measurements of albumen index, figure 4.

Data concerning the coagulating quality of baked custards made from the various preserved and stored eggs are shown in Table VI. As already mentioned in the experimental procedure, the original plan of this

TABLE V

MEASUREMENT OF POACHING QUALITY OF FRESH EGGS
AND EGGS STORED BY FOUR^a METHODS OF HOME PRESERVATION

Method of Preser- vation	Months of Storage	Spread of Albumen		Water Cloudy due to dis- persion of albumen	Remarks			
		Thick	Thin		Coverage of Yolk			
		cm.	cm.		Good	Fair	Poor	Broken
Fresh	0	6.55	10.25	0 ^b	6 ^b	3	0	1
Waterglass	3	7.53	12.25	0	3	4	2	1
	6	7.41	13.83	0	3	2	4	1
S-100	3	8.75	12.09	0	5	3	2	0
	6	6.47	13.27	3	2	2	6	0
Mineral Oil	3	7.27	13.26	0	2	4	4	0
	6	7.49	12.40	4	1	4	4	1
Vinylite	3	11.70	13.78	0	0	1	8	1
	6	---- ^c	13.41	0	0	0	9	1

^aNo measurements could be made on frozen eggs.

^bIndicates number of eggs showing reaction in the group of ten.

^cCould not distinguish thick from thin albumen.

TABLE VI

COAGULATION QUALITY OF BAKED CUSTARDS MADE FROM EGGS
BEFORE AND AFTER FIVE METHODS OF HOME PRESERVATION

Method of Preservation	Months of Storage	Internal Temperature at time of Coagulation °C	Mean Spread of Inverted Custard cm.	Texture of Custard		
				Smooth and Creamy	Average	Coarse
Fresh	0	86	8.00	...	x	...
Waterglass	3	90	7.70	...	x	...
	6	88	7.80	x	...	...
Freezing (with sugar)	3	88	7.85	x	...	...
	6	86	8.80	x	...	...
Freezing (No sugar)	6	88	8.73	x	...	...
S-100	3	88	7.24	...	x	...
	6	86	7.51	x	...	...
Mineral Oil	3	90	7.78	...	...	x
	6	90	8.03	...	x	...
Vinylite	3	90	7.94	x	...	...
	6	88	7.79	...	x	...

study was to bake all custards to a specific internal temperature of 86 degrees centigrade as recommended by Lowe (29) and verified by preliminary work in this laboratory with fresh eggs. However, after the eggs had been treated and stored, the custards were not congealed at this temperature and it was necessary to bake them until the "clean knife" test was obtained. For this reason the mean spreads of the inverted custards may not be as significant as they might have been if all were cooked to the same internal temperature. However, Lowe (29) reported a rather similar finding which suggests that the temperature at which coagulation takes place may vary with the quality of the eggs. The internal temperatures of the custards at the time of coagulation, as shown in Table VI, indicate that those made from fresh eggs coagulated at 86 degrees centigrade. After the eggs had been treated and stored, it was necessary to increase the internal temperature from 2 to 4 degrees centigrade in most cases. The texture of the custards made from all the preserved and stored eggs, other than those treated with mineral oil was equal in quality to that of those made from fresh eggs. It was necessary to bake the custards made from the eggs treated with mineral oil to an internal temperature of 90 degrees centigrade and the resulting texture was somewhat less desirable than that of the custards made from the fresh eggs. Custards were made using the eggs preserved by freezing with and without sugar. It will be noted that both methods produced similar results. The whole egg magma frozen without sugar was very satisfactory in the making of custards. It was well blended and there was no tendency for the egg yolk to separate out or become

congealed. It mixed easily with the milk in the preparation of the custard. Since it is not a general recommendation that whole eggs be frozen without the addition of some form of sugar or salt, this finding is of particular interest. Attention is called to the fact that these eggs were well mixed in a Waring blender for eight seconds before freezing.

The volume indexes (mean area of the center cuts) of the sponge cakes made from the fresh and various stored eggs together with the weights of one standard cup of the respective batters are presented in Table VII. The mean area of the center cuts of the cakes made with fresh eggs is 34.3 sq. cm. After three months' storage the cakes made from eggs treated with waterglass, S-100, and mineral oil showed slightly smaller volume indexes while those made from eggs preserved by freezing or by use of vinylite showed slightly larger volume indexes than did those made from the fresh eggs. At the end of six months' storage all the cakes with the exception of those made from eggs treated with mineral oil had larger volume indexes than after three months' storage. This increase in volume index with longer storage is clearly illustrated in figure 8 and may be partially explained by the fact that thin white beats up to a larger volume than thick white, and the volume of cakes made from thin albumen is above that made from the thick, Hunt and St. John (23). Though no actual quantitative measurements were made on the relative amounts of thick and thin albumen in the various treated eggs, it may be assumed from the data presented in Table V, measurements of poaching quality, that the amount of thin albumen increased during storage. This agrees with the findings of Stewart et al (54).

TABLE VII

VOLUME INDEX OF SPONGE CAKES MADE FROM FRESH EGGS, EGGS STORED
BY FIVE METHODS OF HOME PRESERVATION AND EGGS STORED WITH NO TREATMENT

Method of Preservation	Three Months				Six Months			
	Area	Mean	Weight	Mean	Area	Mean	Weight	Mean
	Center Cut	Area	1 cup Batter	Weight	Center Cut	Area	1 cup Batter	Weight
	sq.cm.	sq.cm.	gm.	gm.	sq.cm.	sq.cm.	gm.	gm.
Fresh (No storage)	35.0		117.0					
	33.7		117.0					
	34.5		115.5					
	34.4		119.0					
	31.9		123.8					
	32.4		100.7					
	32.0		98.5					
	34.5		100.0					
	37.6		104.3					
	36.6	34.3	97.9	109.4				
Waterglass	26.0		114.5		34.4		99.5	
	27.8		114.9		33.3		100.5	
	29.0		112.8		33.0		112.8	
	26.3		113.1		34.2		97.7	
	31.7	28.2	111.4	113.3	31.8	33.3	109.7	104.0
Freezing	35.7		104.3		39.0		95.3	
	37.7		104.2		41.3		92.7	
	38.7		105.4		36.4		85.0	
	37.0		104.5		38.9		84.3	
	37.0	37.2	104.4	104.6	40.4	39.2	86.2	88.7
S-100	31.4		107.4		32.9		109.5	
	33.0		110.6		34.0		99.2	
	33.2		113.9		34.6		90.0	
	33.8		107.1		31.4		99.1	
	36.1	33.5	103.9	108.6	35.8	33.7	92.1	98.0
Mineral Oil	30.0		124.2		29.6		119.5	
	31.0		118.3		31.9		116.9	
	34.0		120.8		32.0		111.1	
	31.8		121.3		34.8		107.7	
	33.7	32.1	113.1	119.5	32.3	32.1	107.9	112.6
Vinylite ^a	34.9		108.0		35.0		107.0	
	31.5		107.0		37.0		101.5	
	37.5		110.8		36.4		98.9	
	35.5		106.0		36.9		105.4	
	34.4	34.8	106.3	107.6	36.3	36.3	102.1	103.0
No Treatment	34.6	34.6	104.6	104.6	39.7		109.6	
					39.6	39.7	108.5	109.1

^aSee figure 13, page 53, for further information.

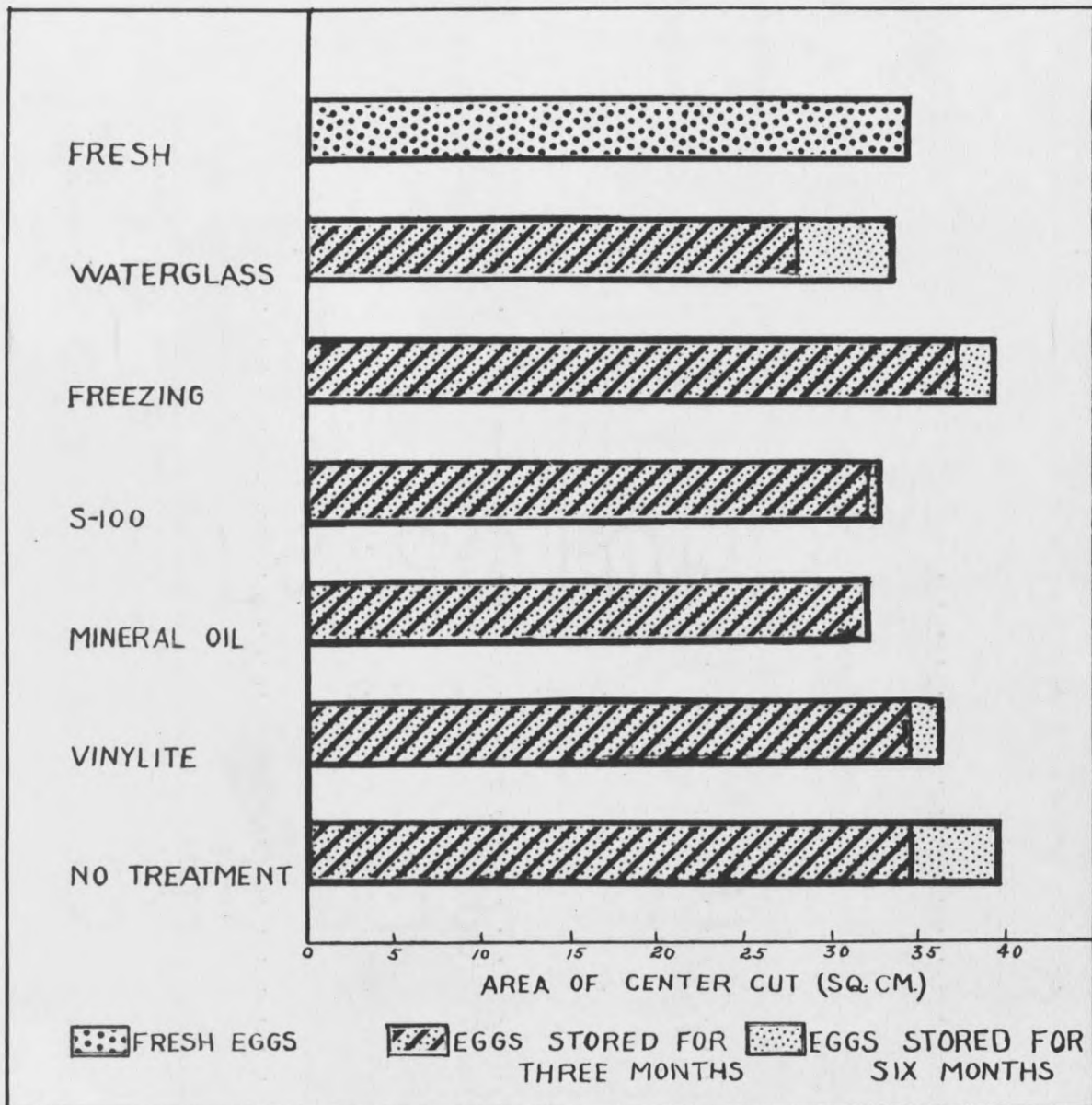


Fig. 8. Area of center cut of sponge cakes made from fresh eggs, eggs stored by five methods of home preservation and eggs stored with no treatment.

Table VII presents the net weight of one cup of batter from each cake. The mean weight of all batter is 106.4 grams. Pike and Johnson (38) state that the correct net weight of one cup of batter for proper leavening at 5,000 feet should be from 92 to 96 grams. The difference in weight may be partially due to the increase of flour that was found necessary. It will be noted that there is little correlation between cake volume and the weight of batter unless the difference in weight is pronounced.

Further information on the quality of the cakes made from the various treated eggs is shown by means of photographs in figures 9 and 10 and by means of silhouettes of the cut surfaces of the cakes in figures 11 and 12. It should be noted that cakes made from treated eggs stored three months, figure 9, are of a finer texture than those from eggs stored six months, figure 10. This supports a supposition that volume alone cannot be used as a true measurement of cake quality. The silhouettes shown in figures 11 and 12 serve as a further means of comparing the contour and volume of the cakes. Though the volume index of the cake made with eggs treated with vinylite and stored six months is rather large, 36.3 cm., Table VII, it should be noted from its silhouette, figure 12, that it fell somewhat.

All experimental cakes listed in Table VII, were made from the same standard cake formula, using 96.0 grams of whole egg magma. Since the eggs treated with vinylite and stored six months lost about 24 per cent in weight it is evident that the cakes made from the vinylite treated eggs, as given in Table VII, had actually more egg solids and less moisture than did the other cakes. Sufficient eggs were treated with vinylite so that further work was done to determine what would happen if the housewife

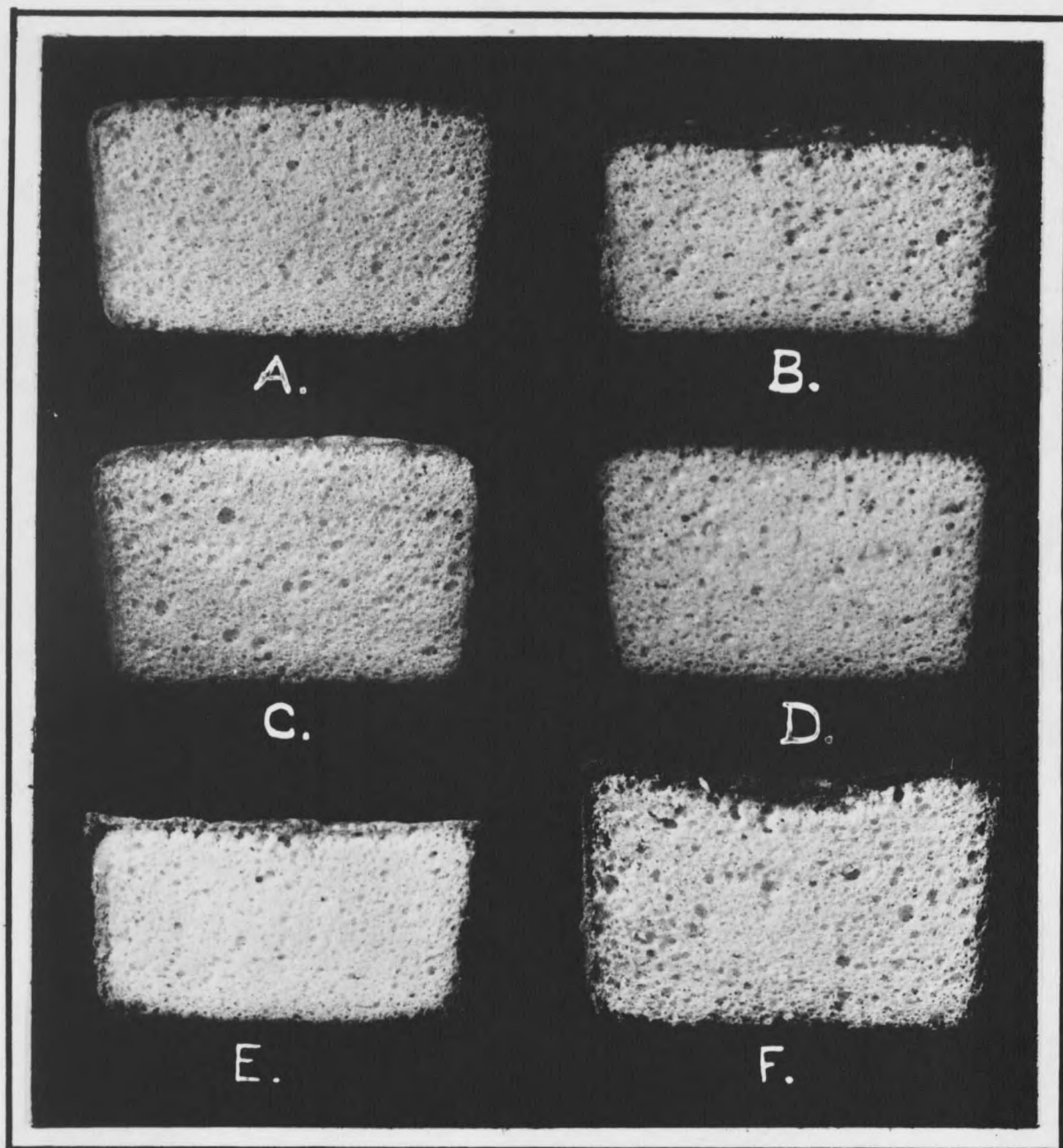


Fig. 9. Grain and general appearance of center cut of sponge cakes made from fresh eggs and eggs stored for three months by five methods of home preservation. A.-Fresh; B.-Waterglass; C.-Frozen; D.-S 100; E.-Mineral Oil and F.-Vinylite.

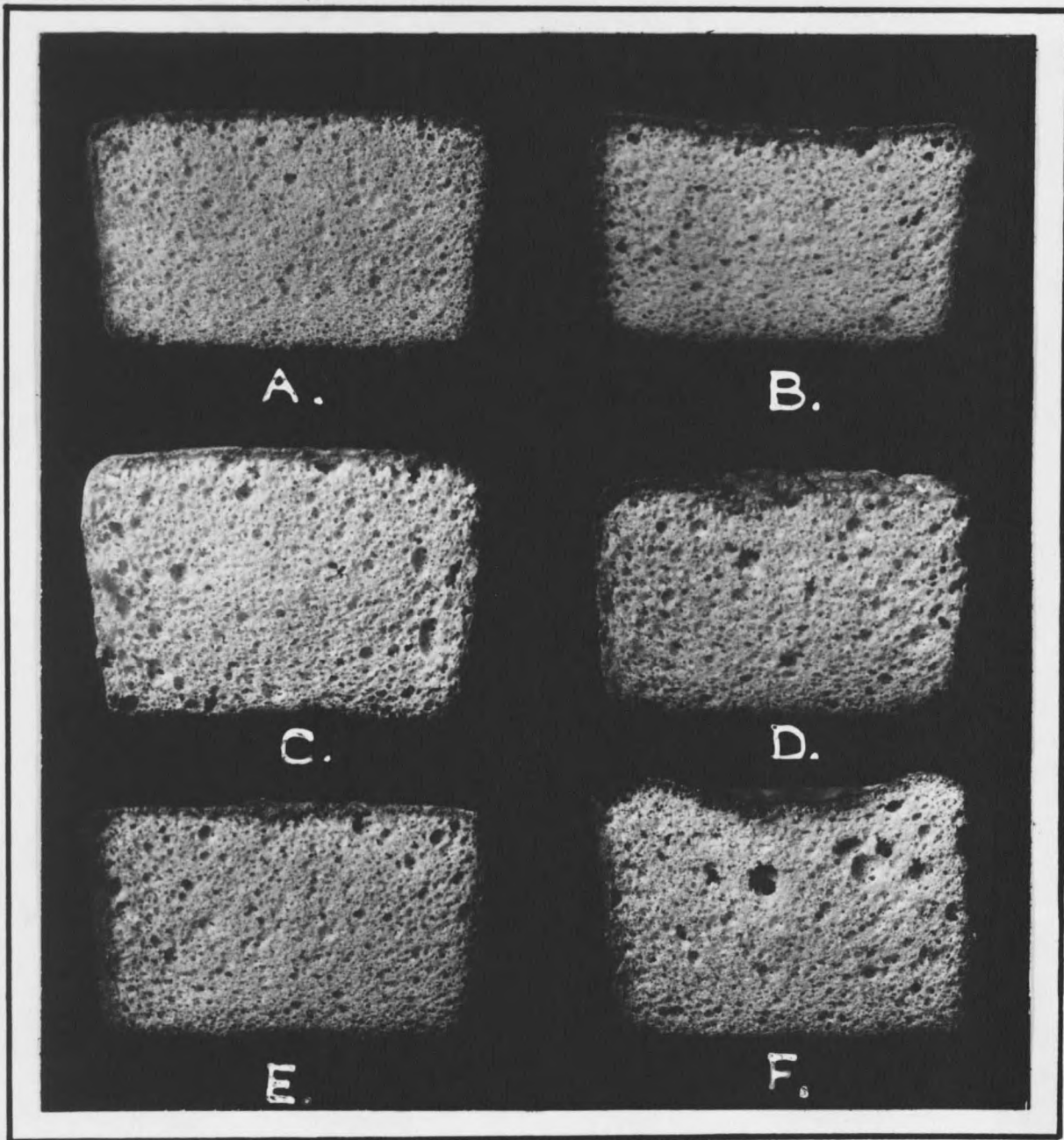


Fig. 10. Grain and general appearance of center cut of sponge cakes made from fresh eggs and eggs stored for six months by five methods of home preservation. A.-Fresh; B.-Waterglass; C.-Frozen; D.-S- 100; E.-Mineral Oil; and F.-Vinylite.

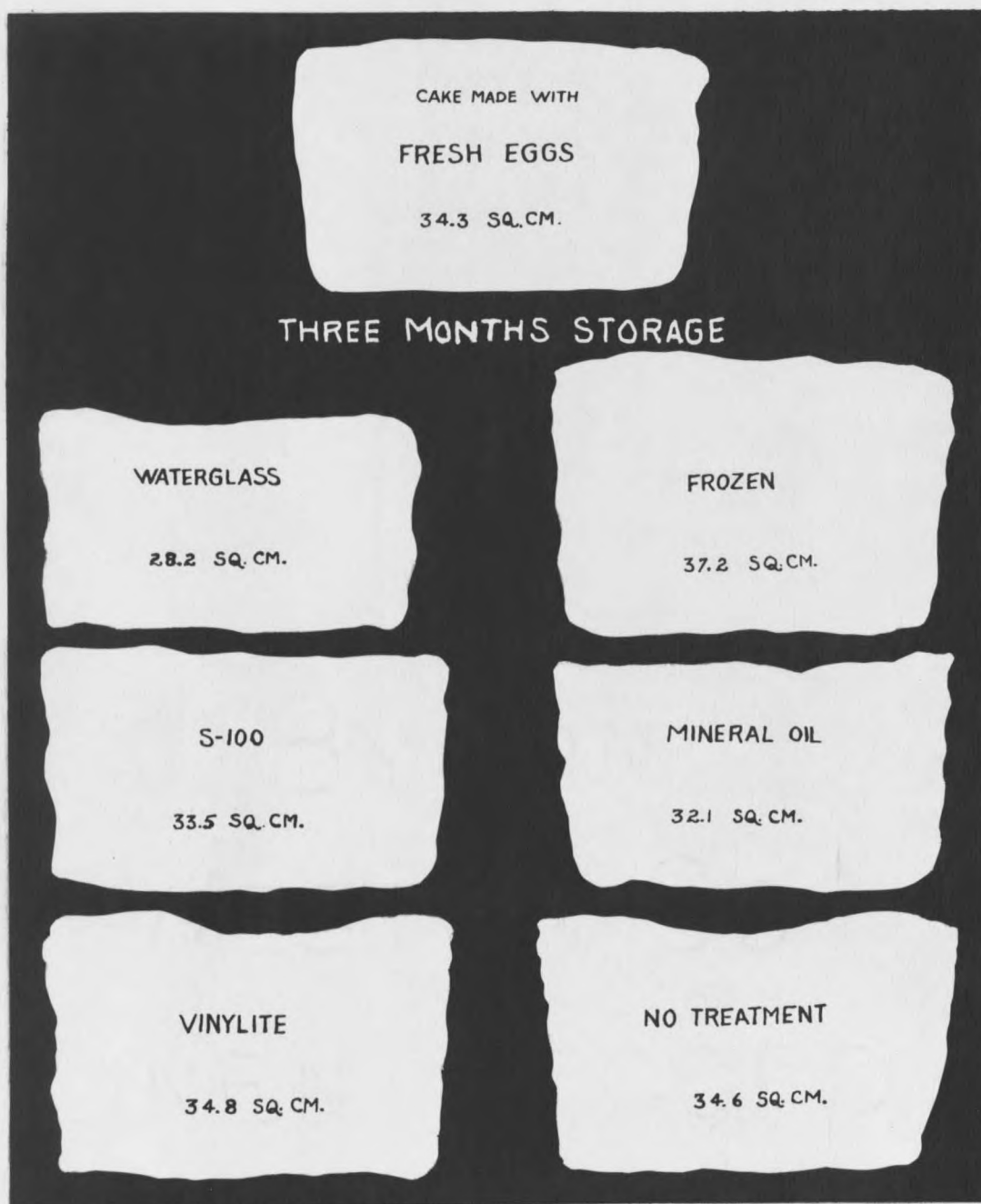


Fig. 11. Silhouettes of center cuts of sponge cakes chosen to represent the average cake produced with eggs stored three months. The mean area of the center cut of the five cakes made with the respective eggs is given in sq. cm. Silhouettes reduced to 7/9 normal size.

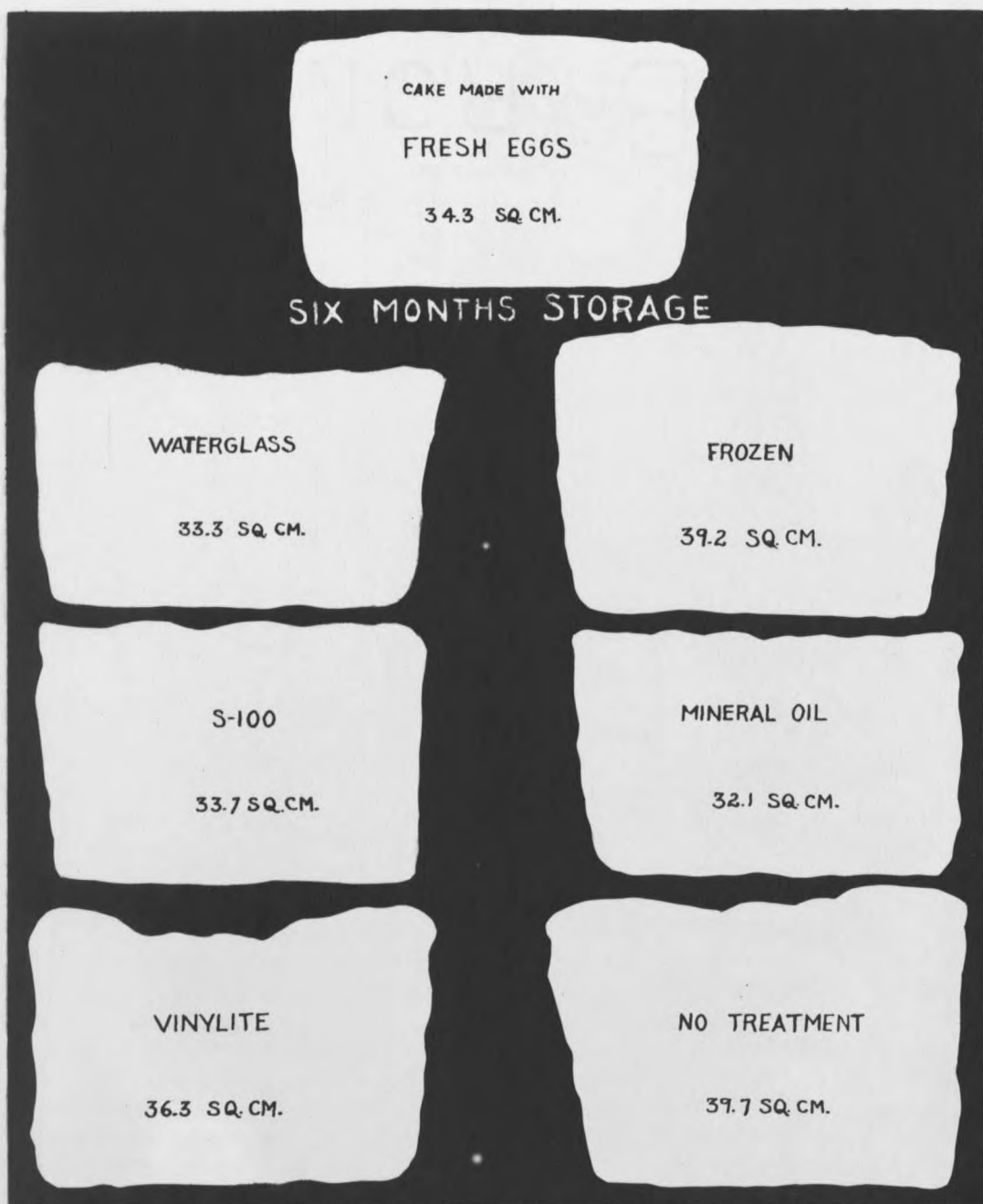


Fig. 12. Silhouettes of center cuts of sponge cakes chosen to represent the average cake produced with eggs stored six months. The mean area of the center cut of the five cakes made with the respective eggs is given in sq. cm. Silhouettes reduced to 7/9 normal size.

used these vinylite treated eggs, stored six months, in a recipe calling for two eggs and what the results would be if additional water were added to compensate for that lost by evaporation. The photographs of those respective cakes are shown in figure 13. Cake A was made with the standard formula, 96 grams of stored eggs; B - standard formula on the basis of the fresh weight of the egg, stored egg 79.2 grams; and C - standard formula on the basis of the fresh weight of the egg, stored egg 79.2 grams plus water, 16.8 grams to equal the fresh weight of egg in the standard formula, 96 grams. It is evident that the cakes were of very poor quality when made from the vinylite treated eggs as shown by either B or C. The B cake illustrates the results of the housewife who ordinarily uses eggs in her cooking on the "egg" basis.

Photographs are shown in figure 14 of the center cuts of cakes made with whole egg magma frozen for six months with and without the addition of sugar. The volume and general appearance of the cakes were very similar. The egg magma frozen without sugar was very satisfactory when used in sponge cakes and there was no difficulty in obtaining a perfect blend with this egg mixture. This agrees with the results obtained when these eggs were used in custards. Mention is made again of the fact that these eggs were well mixed, eight seconds in a Waring blender, before freezing.

In order to bring together for comparison the various quality measurements of the fresh and stored eggs, a composite table of ratings was prepared, Table VIII. Each method of preservation was evaluated and

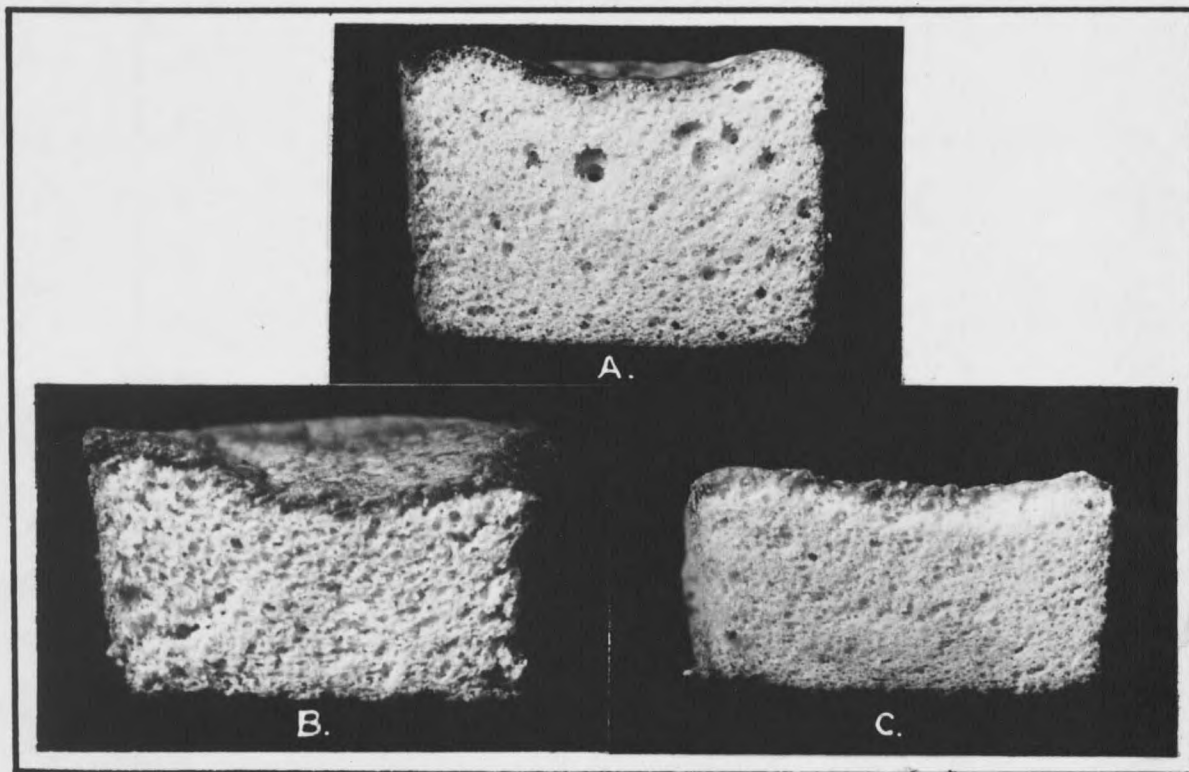


Fig. 13. Grain and general appearance of center cut of sponge cakes made from eggs treated with Vinylite and stored for six months. A.-Standard formula, 96 gm. of stored eggs. B.-Standard formula on basis of fresh wt., stored egg, 79.2 gm. C.-Standard formula on basis of fresh wt., stored egg, 79.2 gm. plus water, 16.8 gm. to equal fresh wt., 96 gm.

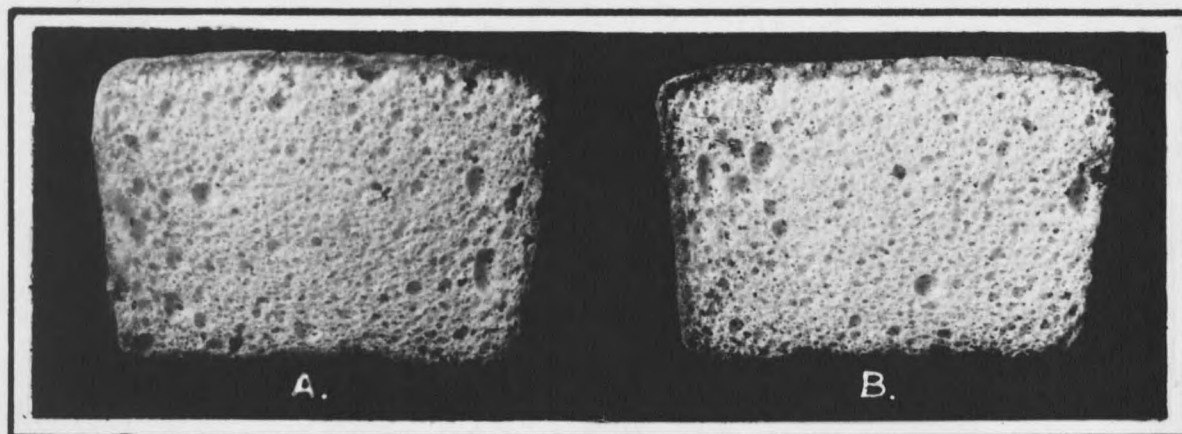


Fig. 14. Center cut of sponge cakes made from whole eggs frozen for six months. A.-Eggs frozen with sugar; B.-Eggs frozen without sugar.

TABLE VIII

RATING OF FRESH EGGS, EGGS STORED BY FOUR^a METHODS OF
HOME PRESERVATION AND EGGS STORED WITH NO TREATMENT

Quality Measurement	Method of Preservation					No Treatment
	Fresh	Waterglass	S-100	Mineral Oil	Vinylite	
Weight Change	1	2	3	4	5	6
Albumen Index	1	3.5	3.5	2	5	6
Yolk Height	1	4	2	3	5	6
Yolk Color	1	3	3	3	5	6
pH of Albumen	1	3	2	4.5	4.5	6
Palatability	1	2	3	4	5	 ^b
Custards	1	3	3	5	3	 ^b
Poaching	1	2.5	2.5	4	5	 ^b
Cakes ^c	1	4	3	2	5	 ^d
Mean	1	3.0	2.8	3.5	4.7	6

^aFrozen eggs were used only for making cakes and custards. Cakes made with whole eggs frozen six months rated third.

^bNo treatment eggs were deemed unfit for tasting, custards, and poaching.

^cTen judges rated the sponge cakes by observing photographs in figure 10.

^dNo picture was taken of cakes made with no treatment eggs.

rated on the results obtained at the end of both three and six months' storage. They were ranked as first, second, third, fourth, fifth or sixth for each of the nine quality measurements. In certain instances, such as in yolk color, where eggs preserved by three different methods, waterglass, S-100, and mineral oil, had about the same color and were in the two, three, four rating groups, they were all given the mean rating of three.

No doubt some of the quality measurements are better indexes of egg quality than are others. For instance, when change in weight is considered, the ranking of second for the eggs preserved in waterglass may not be very significant since the weight of the mineral deposit on the shell was not determined. However, no attempt was made to weight the values for any of the measurements.

Eggs preserved by freezing were used only for making cakes and custards since the egg contents had to be removed from the shell and mixed before freezing. Cakes made from whole eggs frozen for six months, with or without sugar, rated third. Custards made from similar eggs were comparable to those made with eggs preserved with waterglass, S-100 or vinylite.

When the mean of the nine quality ratings is considered for the fresh eggs, eggs stored by the four methods of preservation and eggs stored with no treatment, the eggs and methods of preservation may be ranked in order of desirability as follows: fresh, S-100, waterglass, mineral oil, vinylite and no treatment.

SUMMARY

Eight hundred thirty-eight, one day old, grade AA eggs from New Hampshire hens were used in this study. Five methods of preservation that could be easily duplicated in the home were selected: waterglass, freezing, S-100, mineral oil and vinylite. Untreated eggs were stored also and served as controls.

These eggs were numbered, weighed, and stored in a home basement where the temperature range was from 50-60 degrees Fahrenheit. At the end of three and again at the end of six months the eggs were tested for the following physical, chemical and cooking qualities: change in weight during storage; height, width and index of albumen; yolk color and height; pH of albumen; palatability of cooked yolk; acceptability for poaching; coagulating ability when used in baked custards; and whipping and baking value as determined in the making of sponge cakes. The same measurements were made on similar fresh eggs.

The mean weight of all eggs before storage was 61.94 grams. After six months' storage, the eggs stored in waterglass showed a slight gain in weight, 0.16 per cent; those preserved with S-100, a slight loss in weight, 1.23 per cent; those with mineral oil a loss of 4.47 per cent; while those with vinylite showed the greatest loss of any of the methods, 16.63 per cent. The eggs receiving no treatment showed a loss of 23.85 per cent at the end of six months.

The mean albumen index of the fresh eggs was 0.062. After three or six months' storage, this factor had become much less, being as low as 0.011 in the untreated eggs; 0.015 in the vinylite; 0.024 in the waterglass;

0.030 in the mineral oil, and 0.034 in the S-100 eggs.

The yolk color of eggs became progressively darker during storage. Eggs stored with no treatment and with vinylite were rated the darkest in yolk color, while those preserved by waterglass, S-100 and mineral oil were quite similar but darker than the fresh egg yolk.

Fresh eggs had a mean yolk height of 1.94 cm. This factor decreased during storage by any of the methods and was as low as 1.02 cm. in the untreated eggs; 1.22 cm. in the vinylite; 1.40 cm. in the waterglass; 1.66 cm. in the mineral oil, and 1.86 in the S-100 eggs.

Measurement of the pH of the albumen indicated a mean of 7.55 for the fresh eggs. At the end of six months' storage, the pH of the albumen of eggs treated with waterglass, S-100, mineral oil and vinylite had increased noticeably, pH 8.10, 7.96, 8.80 and 9.04 respectively. Eggs with no treatment had a pH of 9.01.

Based on a maximum score of 10 points, the yolks of the cooked fresh eggs received a palatability score of 8.5. After six months' storage, the eggs preserved with waterglass, S-100, mineral oil, and vinylite were scored 7.2, 7.1, 6.5, and 5.7 respectively.

The poaching quality of the fresh eggs as measured by spread of albumen and coverage of yolk was considered as good, or standard. Eggs treated with vinylite were of poor poaching quality, those preserved with waterglass and S-100 were of fair poaching quality while those treated with mineral oil were ranked in between these groups.

Custards made from the fresh eggs coagulated at an internal

temperature of 86 degrees centigrade and were of an average texture. After the eggs had been stored by any method, the internal temperature at the time of coagulation was from two to four degrees higher in most cases. Custards made from eggs treated with mineral oil did not coagulate until the internal temperature was 90 degrees centigrade and the resulting texture was somewhat less desirable than that of the custards made from the fresh eggs. Custards made from the other preserved eggs were equal in quality to those made from the fresh eggs.

The volume index of the sponge cakes, as measured by the area of the center cut, was 34.3 sq. cm. for cakes made from the fresh eggs. After three months' storage the cakes made from eggs treated with waterglass, S-100 and mineral oil showed slightly smaller volume indexes while those made from eggs preserved by freezing or by use of vinylite showed slightly larger volume indexes than did those made from the fresh eggs. At the end of six months' storage all the cakes, with the exception of those made from eggs treated with mineral oil, had larger volume indexes than after three months' storage. Volume index, by itself, was not considered an accurate measurement of the entire baking quality of the stored eggs. Cakes made from eggs treated with vinylite and stored six months had a large volume index but were judged as having fallen somewhat and were considered irregular and coarse in texture.

Photographs of the center cuts of the sponge cakes made from eggs stored three and six months indicated that the cakes made from the treated eggs stored three months were of a finer texture than those from

eggs stored six months.

Based on examination of the photographs of the center cuts of cakes, the fresh and stored eggs were rated in the order of their sponge cake making value as follows: fresh, mineral oil, S-100, waterglass, and vinylite.

Eggs frozen for six months either with or without the addition of sugar were very satisfactory in the making of cakes and custards.

A composite rating of the various eggs, based on all physical, chemical and cooking measurements, placed these eggs in the order of their desirability as follows: fresh, S-100, waterglass, mineral oil, vinylite and no treatment. Measurements made on the frozen eggs indicated they were of high quality.

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