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The comparative lifting power of magma from fresh and aged, pasteurized, and dehydrated eggs when used in sponge cake

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THE COMPARATIVE LIFTING POWER OF MAGMA FROM FRESH AND AGED, PASTEURIZED, AND DEHYDRATED EGGS WHEN USED IN SPONGE CAKE

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INTRODUCTION

Eggs are an important food item. Not only are they highly nutritious, but they also serve many useful culinary purposes acting as thickening, binding, emulsifying, and leavening agents. Egg proteins have been found to have a higher biological value than any other single source of protein; they contain all the essential amino acids and in addition are good sources of minerals and vitamins.

Like other high-moisture food materials, eggs are subject to bacteriological and chemical deterioration, the extent depending in the main on temperature and length of the period between production and use. Since egg production is seasonal, methods of preservation must be used if a constant supply is to be maintained.

Low temperatures, drying, and heat treatment sufficient to destroy spoilage microörganisms are the common methods of food preservation. Heat treatment methods have a distinct advantage over other processes in that pathogenic organisms are easily destroyed in heating to destroy spoilage types. However, the product needs additional treatment in order to maintain the degree of sterility obtained. Eggs are generally believed to contain few bacteria and no harmful ones, but cases have been reported of the isolation of enteric and of avian tuberculosis organisms from hens' eggs. When the eggs are broken out of the shell, the possibilities of contamination of the egg meats with pathogenic as well as other types of organisms are considerably increased.

Methods of cold storage, freezing, and drying eggs are rapidly being developed so that deteriorative changes of all kinds are kept to a minimum. In addition, recent developments indicate the possibility of heating liquid eggs to a sufficiently high temperature for a long enough period of time to destroy all pathogenic organisms and over 99 per cent of the total flora without causing an appreciable amount of denaturation of proteins. Heat treatment prior to drying has been found practical to facilitate the drying to a low moisture (2 per cent or less) so that two effects may be obtained in a pasteurization process. If broken out eggs for both freezing and drying were pasteurized, these sources of egg supply would be entirely eliminated as possible health hazards.

The prevention of spoilage is not the only factor to be considered in food preservation, however. The consumer wants the preserved food to be as much like the fresh product as possible. It is desirable, therefore, that the processes used for preservation of eggs cause the least damage of egg properties possible while accomplishing the aim of the process. This is amply illustrated by the drying procedure, one aim of which is to minimize shipping weight.

The formation of a stable foam has been accepted as one criterion of the culinary value of eggs since it is one of the most useful contributions of eggs to cookery. The entrapped air gives desirable lightness to many food products. The palatability of products in which eggs are a major ingredient is another frequently used test and is the more preferred since the ultimate aim is retention of good eating quality. These two tests may be combined by making a sponge cake and judging its palatability. The volume and texture of the cake reflect the foaming power of the eggs as the air entrapped in the foam is the leavening gas. The volume will be small and the texture compact if insufficient air was present in the batter. A tasting panel is necessary, however, to determine the palatability of the product; the formation of a foam and satisfactory texture and volume in a cake are useless if the flavor is unpleasant. On the other hand, retention of only one factor such as flavor is inadequate; all characteristics pleasing to eye, tactile senses, and taste enter into palatability.

It was the object of this investigation to determine the retention of culinary properties during various storage, pasteurization, and drying treatments of eggs, as indicated by the quality of sponge cakes made therefrom. It was the purpose to study specifically the effect on quality of sponge cakes of

1) holding shell eggs at room temperature for various periods of time,
2) heating liquid whole egg magma to definite temperatures for certain lengths of time,
3) heating liquid egg magma to definite temperatures for certain periods of time and then freezing,
4) different spray-drying procedures,
5) a secondary leavening agent when using spray-dried eggs,
6) storing commercial spray-dried egg powder for various lengths of time at one temperature,
7) initial quality of spray-dried eggs.

REVIEW OF LITERATURE

The papers that touch on the various aspects presented in this study are voluminous. Those selected for review seemed the most pertinent to the problems involved. They include studies on the effect of storage on the quality of shell eggs, the freezing of eggs and its effect on egg quality, pasteurization procedures, factors affecting the keeping quality of dried whole eggs, factors influencing the formation of egg foams, and sponge cake studies.

The Effect of Storage on the Quality of Shell Eggs

Quality in an egg refers to the physical characteristics of the white and yolk which consumers feel are desirable and which are apparently independent of the chemical makeup of the egg. An egg having an upstanding yolk with a large proportion of thick white closely adhering to the yolk is considered to be of high quality. Any apparent decrease in these characteristics is termed a decrease in quality. Thus, quality is a relative matter.

Cruickshank (1940) gave the percentage composition of the edible portion of the egg as follows:

Constituent	Whole egg %	White %	Yolk %
Water	73.7	87.77	49.0
Protein	13.4	10.00	16.7
Fat	10.5	0.05	31.6
Ash	1.0	0.82	1.5

The white contains a high proportion of water with protein as its main organic constituent. The proportion of thick white in eggs has been studied by many investigators. Cruickshank (1940) stated that it is now established that the percentage of thick white is characteristic of the individual hen and is determined largely by the histological structure of the albumen-secreting cells of the oviduct.

That the proportion of thick to thin white varies widely in freshly-laid eggs has been noted by many investigators. Nevertheless, quality is based largely on this factor, and objective methods of measuring it have been devised.

Observations on the aging of eggs reveal that there is a progressive thinning of the thick white, a gradual increase in yolk size, and a weakening of the vitelline membrane. The air cell may increase in size also if moisture loss is not prevented. In addition to physical changes, chemical changes are known to occur. Sharp (1937) mentioned the following changes: (1) loss of carbon dioxide, (2) change in pH resulting in increased alkalinity, (3) alkaline hydrolysis of protein, (4) increase in the amount of loosely bound ammonia in the yolk, (5) increase in water-soluble or inorganic phosphorus, and (6) an increase in acid number of fat of the yolk.

Cruickshank (1940) and others have reported a difference in chemical composition in thick and thin white; the thick white has been found to contain a higher percentage of ovomucin. Balls and Hoover (1940) stated that liquefaction of thick white was due to the breaking up of the mucin fibers. They reported that fresh eggs had 61 per cent apparent thick white, eggs stored eight months had 47 per cent whereas the total mucin content had shown no change during this period. Removal of mucin from thick egg white gave a product of low viscosity although 95 per cent of the initial protein remained.

McNally (1943) explained the presence of thick white to be due to the fact that mucin is in a gel form--the only protein that is a gel under normal conditions that prevail in egg--and that as the white became more alkaline, the gel began to break down. He attributed the increased alkalinity to loss of carbon dioxide. He stated that aging or other factors which cause changes in imbibitional capacity of gel may be at work in egg white and that these changes in thick white can be studied only after it is recognized that it is thick because of the mucin gel.

Sharp (1929) stated that the egg begins to decline in quality as soon as it leaves the hen and that an egg a week old may have deteriorated more in quality before it leaves the farm than an egg properly cared for that is a year old.

Time and temperature have been cited as the two most important factors affecting quality of eggs during storage, with humidity closely related (Rohde, 1945). Bennion and Price (1940) stated, however, that high humidity was even more important than low temperature in preserving egg quality. Sharp (1937) also emphasized the importance of high humidity. He suggested a relative humidity of at least 90 per cent. A low humidity will increase air cell size and evaporation losses since the egg is in osmotic equilibrium at 99.5 per cent relative humidity, but above 90 per cent luxuriant mold growth may develop with its undesirable effects. Sharp (1937) listed the factors important in egg preservation as: initial quality of the egg, sterility of the egg, prevention of mold growth, pH of egg contents, prevention of evaporation, prevention of absorption of flavors, and temperature. He stated that the interrelation of these factors had not been determined.

Wilhelm (1939) stated that physical means were better than chemical means to determine egg quality since there were no great chemical changes until the egg became inedible usually due to the action of microörganisms. In egg storage studies he found a 40 per cent decrease in quality under any of the following conditions:

20	hours	at	32.2°C	(90°F)
3	days	at	21.1°C	(70°F)
24	days	at	10°C	(50°F)
134	days	at	-1.1°C	(30°F)

Pyke and Johnson (1941) determined changes in egg quality due to storage, using height of firm albumen and yolk index as measurements. The storage periods used were 0, 10, 20, and 30 days at 22-23°C (71.6-73.4°F) with a relative humidity of 20-25 per cent. Egg quality decreased rapidly, showing linear regression with days in storage.

Funk (1943) studied the influence of environmental temperature on the rate of deterioration in stored eggs. Relative deterioration was measured by scores of albumen, Haugh units, and pressure required to break the vitelline membrane. Fertile eggs, of 76 Haugh units when fresh, declined to a value of 46 after 43 days at 21.1°C (70°F). At 32.1°C (90°F) the eggs became inedible in 10 days.

In later studies Funk (1944) found that liquefaction of white was more rapid in fertile than in infertile eggs at temperatures higher than 10°C (50°F). Infertile eggs kept 42 days at 21.1°C (70°F) were rated "usable in cooked foods only" although the percentage of apparent thick white had not decreased. The yolk index decreased from 0.45 to 0.23. Humidity of the atmosphere surrounding the eggs was found to have little or no influence on the deterioration of the albumen or yolk of the eggs although it did control the amount of evaporation. The decline in albumen quality as measured by score was slightly greater when the eggs were held in low humidity (27-45 per cent) and at a temperature of 21.1°C (70°F) than when the relative humidity was 85-98 per cent at the same temperature. Humidity of the atmosphere when the temperature was 26.1°C (80°F) was not related to the albumen score. These findings are in agreement with those of Jeffery (1940) who concluded that interior egg quality as expressed by height of thick albumen was not affected by relative humidity of the egg-holding room, but they are the opposite of Bennion and Price (1940) mentioned above.

Other studies in egg quality have been concerned with changes in pH and in flavors during storage. Erikson et al. (1932) determined the pH of whites and yolks of large numbers of eggs. The changes in yolks during storage was from pH 6.320 to 6.976; in white, from pH 7.920 to 8.895. No reports were given for egg magma. King et al. (1936) found the pH of fresh magma of eggs from mature hens was 7.09 and 7.14.

Sharp (1936) reported studies in flavors of stored eggs. Those he believed were due to chemical changes in the egg were described as "flat" and "stronger" as distinguished from the characteristic "fresh" flavor of a freshly-laid egg. He found considerable variation in the ability of five judges to detect flavor defects; one was unable to detect "mustiness." In 1931 Sharp and Stewart (1931) had reported that a carbon dioxide atmosphere retarded chemical change in flavor. McCammon (1934) found that odor tended to vary more than flavor in eggs. The raw yolk was scored by eight blindfolded judges. All eggs held for one month at 21.1°C (70°F) showed signs of deterioration and flavor scores were described as "increasingly off but not definitely so"; eggs kept one week, "not quite fresh but good."

Many attempts have been made to delay the deteriorative changes in egg quality. Commercially, one-fifth of the eggs entering the large markets are "processed" to keep a constant supply during low-production months. Sharp (1937) mentioned three main methods of processing shell eggs: waterglass immersion, shell treating, and cold storage. He stated that over 100 materials had been patented for shell treating, the most successful of which was oil coating. Oiling prevents evaporation and retards loss of carbon dioxide, thus maintaining low pH. Also, there is less chance of infection by microörganisms. Waterglass immersion was said to be the cheapest and most successful method for home storage to date.

Recently developed ultra violet lamps with proper wave length have been suggested as showing promise in commercial cold storage (Ewell, 1945, and Veloz, 1945). The ultra violet radiation maintains a sterile atmosphere while allowing a high relative humidity.

Romanoff (1944) advocated a flash heat treatment as an efficient method for the preservation of table eggs. He recommended five seconds in boiling water as optimum for time and temperature of exposure. This exposure to heat forms a thin protective film of coagulated albumen adhering to the shell membrane. Treated eggs retained good quality for long periods of time at storage temperature and for reasonable lengths of time at ordinary room temperature. He estimated that a heat-treated egg in storage for 12 months would show the same quality as an untreated egg stored for three months; at room temperature the treated egg kept 12 months would have the same quality as an untreated one kept six months.

Freezing Procedures and Effects on Egg Quality

It is highly probable that the freezing of eggs will replace other methods of home storage when the production of home freezing units and freezer lockers is increased. LeClerc (1940) said that frozen eggs had already begun to replace shell eggs commercially and even to replace dried eggs in those products in which either may be used. Frozen eggs are more convenient to handle and require less storage space than do shell eggs.

The practice of freezing eggs began about 1910 (LeClerc, (1940). The object at first was to utilize the dirties, cracks, leakers, *et cetera*, and consequently the quality of the frozen product was low. Improvements in selection and handling methods have produced a good quality product.

From a bacteriological standpoint, the process of freezing eggs is highly desirable although manipulation of the liquid egg serves to contaminate it with microörganisms. Holtman (1943) reported that eggs held in the frozen condition for seven to nine months at 0°C (32°F) showed a reduction of 99 per cent of flora and, in most instances, the complete absence of coliform types. He concluded that frozen eggs were of no greater hazard to public health than fresh eggs. Nielson and Garnatz (1940) also reported marked decrease in flora in frozen egg products.

Microbial growth is inhibited in frozen products but is resumed when the products are thawed. Workers have reported increased counts in thawed commercially frozen eggs due to the long time and high temperatures required for complete thawing. Commercial packs are put up in 30-pound tins. Brownlee and James (1939) compared slow and fast defrosting and reported that a method of constant agitation not only eliminated bacterial growth during thawing but served to keep the egg meats well mixed. Quinn and Garnatz (1943) recommended thawing in running cold water. This method was found to be more rapid and resulted in lower bacterial counts than thawing in air at room temperature or at 4.4°C (40°F) in a refrigerator.

Schneiter et al. (1943) studied thawings and refreezings of eggs frozen on a commercial scale. They concluded that eggs of good quality were able to withstand at least two complete thaws and refreezings without a significant change in bacterial content or without acquiring abnormal appearance and odor. Eggs of poor quality led to progressive decomposition unless rapidly frozen and maintained in the frozen condition.

Studies have also been reported concerning the physical changes of frozen eggs. Pastiness of the yolk had been early observed, and workers used protective agents such as salt, glycerine, or sugar to overcome pastiness. Urbain and Miller (1930) studied the relative merits of sucrose, dextrose, and levulose as protective agents. They reported that the white was not altered by freezing and concluded that the substance causing the pastiness was in the yolk in the form of lecithoprotein. Coagulation was prevented by the addition of 10 per cent by weight of either dextrose or levulose; sucrose was less effective. As a result of the added substance, thawed magmas were no longer watery and ropy as they were without treatment.

Thomas and Bailey (1933) undertook to discover the controlling factors in the gelation phenomenon. They found that the consistency of the thawed product was greatly altered by the rate of thawing and by handling. They standardized handling procedures and reported that sucrose and dextrose showed quantitatively the same effect in preventing gelation when present in equimolecular quantities. In the absence of a protective agent, the degree of gelation of thawed whole egg was found to be a function of the mechanical treatment before freezing. Colloid-milled specimens showed practically no gelation on freezing. LeClerc (1940) also reported a quick-freezing method which gave a uniform homogeneous consistency without addition of extraneous material. In this method an egg stream was frozen in seven seconds; other methods required several hours.

LeClerc (1940) stated that properly stored frozen eggs undergo little physical, chemical, or bacteriological change. He mentioned that occasionally frozen eggs produced cakes of larger volume than fresh eggs and attributed this to greater uniformity of quality inherent in frozen eggs.

Schneiter *et al*. (1943) examined eggs kept frozen six years and found no physical change except the formation of ice crystals and small leather-like lumps of separated egg solids in whole eggs and yolks. Woodruff (1942) said that eggs kept longer than a year tended to thicken but there was no loss of cooking value. He reported results of baking experiments in which frozen eggs were compared with fresh in angel food, gold, and butter cakes: the angel cakes from fresh eggs had slightly better volume and texture but the angel cakes from frozen eggs were more moist; gold cake from frozen eggs had coarser grain, larger air holes, but were lighter, more tender, and more moist than gold cakes made with fresh eggs. All cakes were highly acceptable.

Pasteurization Procedures and Effects on Egg Quality

One of the most common methods of food preservation today is by heat treatment. The advantage of this method is that pathogenic bacteria are destroyed when the heating is sufficient to destroy spoilage types. Consequently, properly stored heated foods will be free from possible public health hazards. The pasteurization of milk has become a common practice, and some city ordinances require that all milk be pasteurized. Pasteurization of eggs, however, had not been believed possible without coagulation of egg proteins.

A few studies have been reported on heat treatment of eggs. Tittsler (1930) observed that shell eggs heavily inoculated with Salmonella pullorum were sterile after boiling five minutes. Hülphers (1941) inoculated yolks of eggs with Mycobacterium tuberculosis (avian) and found that eight minutes of boiling did not render them sterile. It is believed possible that eggs may be contaminated with tuberculosis organisms from hens.

Funk (1943) used various spoilage organisms for inoculation into shell eggs. After inoculation, he immediately immersed a portion of the eggs into oil at 60°C (140°F) and rotated them for 10 minutes. All inoculated eggs were then held at room temperature for 48 hours, after which examination was made for microbial growth. The treated eggs were found to be sterile whereas untreated inoculated eggs contained growth. Temperature measurements by thermocouple of the interior of the egg during heating showed that the center of the egg reached only 48.9°-50°C (120-122°F) and remained there no longer than eight minutes. Funk stated, "This method of heating shell eggs is not effective in raising the temperature of the center of the egg sufficiently high to be effective in destroying bacteria in the yolk of the egg." Furthermore, if the eggs were not treated until 30 hours after inoculation, the heat treatment gave incomplete sterilization.

Greco (1943) studied thermal death rates of organisms in liquid whole eggs using two strains of _Escherichia coli_ as indicator organisms. This species was selected on the basis of their reported resistance to heat, a resistance that is greater than that of _Mycobacterium tuberculosis_, the most heat-resistant of pathogens found in milk. He found that over 99 per cent of the flora were destroyed when the melange was heated for 80 minutes at 56°C (132.8°F) or for 1.5 minutes at 66°C (150.8°F). He reported an increased efficiency of bacterial destruction in the melange as compared to that in milk and attributed it to the difference in pH of the two products.

Payawal (1944) investigated the effect of heating liquid egg on the denaturation of the egg proteins. She reported a progressive denaturation at unequal rates, starting at lower temperatures for whole eggs and for egg white than for yolk. The temperature ranges in which denaturation occurs were reported as:

Whole egg, 56-66°C (132.8-150.8°F)
Egg white, 58-62.5°C (136.4-144.5°F)
Egg yolk, 62.5-70°C (144.5-158°F)

Winter (1945) studied the bacterial reduction in the pasteurization of liquid whole eggs. Samples were obtained from commercial plants and the effects of time and temperature of heating were observed on the reduction of standard plate count, destruction of coliform bacteria, and length of time that the product remained edible. The bacteria in 37 samples were found to vary greatly in number and in heat resistance. In trials with 11 different samples, the plate count was reduced to less than 3,000 per ml., or more than 99 per cent destruction of total flora was obtained as well as elimination of all coliforms by any one of the following treatments:

60.0°C (140°F) for 10 minutes
61.1°C (142°F) for 6 minutes
62.8°C (145°F) for 1 minute

Short-time heating of 14 different samples at 63.3°C (146°F) for 0.5 minute or at 68.2°C (155°F) for 0.1 minute gave the same results. Pasteurization was found to have little effect on the keeping time of the samples held at room temperature.

There were no studies found in the literature on the effect of pasteurization on the culinary properties of eggs.

The Effect of Drying and Subsequent Storage on Egg Quality

The egg-drying industry has been given a tremendous impetus since 1940. Stewart et al. (1943) estimated that a twentyfold increase had occurred in a three-year period. Along with increased production came increased activity in the study of problems involved. Egg powder was at best of poor quality. Most of the problems centered around the bacteriological, chemical, and physical changes that occurred during drying and subsequent storage of the powder and the effect of these changes on culinary properties.

That shell eggs may be infected with certain pathogenic bacteria has been observed (Tanner, 1944; and others). It is also recognized that contamination of liquid egg for drying is dependent on the sanitation of the plants. Due to the outbreak of a few cases of food poisoning purportedly from ingestion of dried eggs, Gibbons and Moore (1944) undertook to study the occurrence of Salmonella organisms, the suspected offenders, in dried egg powders. Salmonella species were isolated from 28 of 380 samples of powder tested. However, they occurred in small numbers and were rare in first-grade powders. These workers believed that properly treated powder would not be a health hazard. Although the number of organisms required for an infective dose is not known, they estimated that one egg of the worst powder would probably not be sufficient to poison most individuals; taste panels partook of "scrambles" of all positive powders with no ill effects. In further studies, Gibbons and Moore (1944) observed that over 99 per cent of the Salmonella organisms present in liquid eggs were destroyed on drying in a spray drier. During storage, the organisms survived longer the lower the temperature, but there was a 97 per cent reduction in eight weeks when powder was held at 7.2°C (44.9°F). Massive doses of Salmonella inoculated into reconstituted eggs were destroyed on cooking eggs as scramble, omelet, sponge cake, custard, and muffins.

Gibbons and Moore (1944) investigated the growth of organisms in reconstituted eggs. They observed that Streptococcus pyogenes did not grow in reconstituted egg and died off rapidly at temperatures above 15.5°C (60°F). Organisms that did grow well at that temperature, however, included species of Salmonella, the coliform species, Staphylococcus aureus and Streptococcus fecalis. These workers emphasized that the dangers in the use of dried egg lie in improperly treated reconstituted eggs which they recommended should be held at temperatures below 15.5°C (60°F) if holding were necessary.

Stateler (1945) stated that eggs of low bacterial count gave powders of superior quality to those of initially high bacterial count. He believes that pasteurization of eggs prior to drying may have additional benefits to that of a preheating treatment to facilitate drying. Standards regarding sanitation effective in March, 1944, and set by the Dairy and Poultry Branch of the Food Distribution Administration will no doubt do much toward improving the initial quality of dried whole eggs.

Consistently observed by various workers in chemical and physical studies on dried eggs have been:

1) an increase in pH of the eggs during drying with gradual decrease during storage of the powder (Brooks and Hawthorne, 1943; Stuart et al., 1942; Stewart et al., 1943);
2) progressive decrease in solubility during storage (Hawthorne, 1943; Hawthorne, 1944; Stuart et al., 1942; White and Grant, 1943; McNally, 1944; Stuart et al., 1945);
3) progressive increase in fluorescing substances during storage (Pearce, 1943; Stewart et al., 1943);
4) progressive increase in denaturation and refractive index during storage (Bumzahnov, 1942; McNally and Dizikes, 1944);
5) increase in acidity of ether extract during storage (Brooks, 1943);
6) progressive reduction of beating properties during storage (Hawthorne, 1943).

The factors affecting rate of change of egg powders are numerous. Outstanding among them are: the initial quality of eggs, heat treatment during drying and cooling, moisture content of the egg powder, the presence of added substances, the method of packing, and the time and temperature of storage.

White and Thistle (1943) studied the effect of outlet temperature on egg quality. They found that the rate of deterioration of quality was greatest on maintaining the temperature at 43.3°C (110°F) for one day and some change was observed even at 26.7°C (80°F). They recommended cooling to at least 26.7°C (80°F) within three hours after drying. Quality of eggs was assessed by water and salt (KCl) solubility, fluorescence, pH, and refractive indices of the extracts.

The lowering of the moisture tolerance to at least 2 per cent for governmental requirements in the United States in 1943 increased problems of heat treatment. It was impossible to dry to such a low figure with procedures then used without developing scorched flavor in the product. This was solved by instituting preheating procedures and multistage driers (Stateler, 1945).

The 2 per cent requirement for moisture was adopted after investigators reported that the rate of deterioration of egg powders decreased with decreasing moisture content. White and Thistle (1943) had observed a difference in the rate of deterioration in powders from two different plants and believed it to be due to difference in moisture contents.

They later found (Thistle and White, 1943) that a storage temperature of 7.1°C (44.8°F) was too high to prevent deterioration if the moisture content of the powder was as high as 8.5 per cent. Keeping qualities of the powders varied directly with moisture content regardless of the method of preparation and the initial quality differences. Later, Thistle _et al_. (1944) reported a slow deterioration at temperatures as low as -40°C (-40°F) although low moisture had a marked preserving action. They found that powders of 1.4 per cent moisture suffered some deterioration when held at 37°C (98.6°F). Similar results were reported by Hawthorne (1943) in England, but he reported that unaged powders of lower moisture content showed reduced beating properties. He attributed this to heat damage during the drying process.

Bumzahnov (1942) recommended an equilibrium in moisture between the relative humidity of the atmosphere and the powder and said this was attained when the powder had a moisture content of 6 to 8 per cent. He said,

> Under such moisture conditions the product will change least as far as its fundamental properties are concerned, while its restorability will be preserved and the hydrophilic properties will be least affected. The final moisture content of the product determines to a certain extent also all its other characteristics.

Stewart, Best, and Lowe (1943) reported that low moisture levels of 0.5 to 1 per cent improved the keeping quality in dried albumen and whole egg but not in dried yolk.

Pearce *et al*. (1944) studied the effect of added substances on the keeping quality of dried whole egg. Of the materials studied, sodium bicarbonate was effective at a concentration that did not affect the palatability of the egg powder. They felt that this was possibly due to the carbonate ion and not to the sodium ion or increased pH.

The effect of removing the glucose in egg by fermentation was studied by Stewart, Best, and Lowe (1943) since some quality changes had been found to be due to a sugar-protein reaction. There was a decrease in the rate of fluorescence changes and excellent retention of solubility when glucose was absent. They attributed the improvement to the lowered pH obtained and subsequent experiments using 10 per cent lactic acid before drying bore out this conclusion. Lowering the pH below 6.5, however, caused marked alteration in flavor and texture. Lowering the moisture content increased the benefits of the pH adjustment.

Elimination of the oxygen in packing of the powder has also been found to be beneficial for storing eggs (Thistle *et al*., 1944; and Stateler, 1945) and the use of carbon dioxide atmosphere in a hermetically sealed container has been recommended.

It is evident that much progress has been made on improving the quality and prolonging the shelf life of whole egg powders although no means of entirely eliminating the effects of time and temperature have as yet been found.

Under the right conditions, powder can be produced that will retain good quality for relatively long periods of time at ordinary temperatures. Stateler (1945) summarized the ways and means of improving flavor and stability as follows:

1) use of high quality eggs,
2) more effective use of refrigeration,
3) heat-treatment or pasteurizing liquid eggs,
4) multistage drying (to less than 2 per cent moisture content,)
5) quick cooling of the powder in closed systems,
6) packing in carbon dioxide atmosphere and sealing hermetically.

The culinary qualities and palatability of whole egg powders have been assessed by:

1) odor and flavor scores of "scrambles" by trained judges (Stewart, Best, and Lowe, 1943; Fryd and Hanson, 1944; Thistle, Reid, and Gibbons, 1943);
2) baking tests of pound cakes (Stuart _et al_., 1942),
3) beating properties (Bennion and Hawthorne, 1942; Bennion, Hawthorne, and Bate-Smith, 1942; Thistle, Pearce, and Gibbons, 1943);
4) baking tests of sponge cakes (Bennion, Hawthorne, Bate-Smith, 1942; Hawthorne and Bennion, 1942);
5) cooking tests of various products (Dawson _et al_, 1945).

Briefly, it has been found that odor and flavor changes were correlated with increased fluorescence and decreased solubility except for certain off flavors described as "fishy" or "cheesy". These flavors were observed in powders from fermented eggs which retained objective quality. Stewart, Best, and Lowe (1943) also reported off flavors in egg powder from fermented eggs. Brownish discoloration and undesirable granular texture were also observed in stored egg powders (Stuart et al., 1942; Dawson et al., 1945).

Stuart et al. (1942) reported a direct correlation between solubility of egg powder and the quality of pound cake. The most noticeable effect was on volume. In general, cakes made from the most soluble powders were the most satisfactory also in grain and texture.

Beating properties have been measured by whipping a reconstituted egg-sugar mix in an electric mixer under controlled conditions and measuring the volume of foam obtained in a given time. Thistle et al. (1943) reported no difference in beating properties of prime quality eggs from five different plants but a significant difference in dust-collector (poor quality) powder from various plants. Poor quality powder gave lower volume generally than prime quality powder.

The English workers, Bennion, Hawthorne, and Bate-Smith (1942), studied the beating properties of various powders by the volume of foam obtained and by the quality of sponge cakes baked therefrom. The quality of cakes was determined by taste panels. They found close correlation between foam volume and cake quality when a large-sized mixer was used;

no correlation with a small mixer. All samples of dried eggs tested were inferior in baking quality to fresh or frozen eggs. With many samples of spray-dried powder, the authors found improved beating with corresponding improvement in finished sponges by raising the temperature of the egg-sugar mix during beating. A temperature of 50°C (122°F) obtained by immersing the beating bowl in water at 60°C (140°F) was found to be beneficial when additional water was added to the mix to compensate for loss in evaporation. Without the additional water, the foams were too viscous and collapsed more easily during the incorporation of flour. These workers recommended beating of egg-sugar foam to a specific gravity of approximately 0.33. They stated that if the specific gravity is greater, the sponge cake will be of poor volume and heavy texture; if lighter, the foam will be too weak to hold the flour.

Dawson et al. (1945) studied the use of dried eggs of varying quality in five different food products. Scrambles were found to be the most sensitive method of showing deterioration in flavor of the dried eggs. Temperature of storage was extremely important in the retention of flavor and cooking quality. The length of time that egg powders stored at various temperatures remained usable in the different products is given in Table 1.

Table 1

Approximate Length of Time That Dried Whole Egg with 3-5 Per Cent Moisture Can Be Stored at Various Temperatures for Use in Five Food Products

Product	Storage life at temperatures of --					
	0°C (32°F)	7.2°C (45°F)	19.4°C (68°F)	24.4°C (75°F)	30.0°C (86°F)	43.3°C (110°F)
	wk.	wk.	wk.	wk.	wk.	wk.
Scrambled eggs	52	52	12	9	2	1
Baked custard	52	52	40	20	5	1
Popovers	52	52	40	21	7	2
Mayonnaise	52	52	52	31	7	2
Foundation cake	52	52	52	40	12	2

It was concluded that good quality dried egg can be used successfully instead of shell eggs in many types of food products.

Egg Foam Formation and Stability

The ability to form a stable foam is one of the most useful contributions of eggs to cookery. The entrapped air gives desirable lightness to such products as omelets, soufflés, meringues, angel cakes, sponge cakes, et cetera.

Lowe (1943) summarized the required properties of substances forming foams as: low surface tension, small vapor pressure, surface films that do not coalesce readily, and, for protein solutions, the ability to form a surface skin on the boundary layer to prevent evaporation. Eggs, especially egg albumen, possess these properties.

The influence of chemical and physical factors on egg-white foams has been very ably presented by Barmore (1934) to whose bulletin the reader is referred for details. Some of his findings were that:

1) stability of foam is inversely proportional to the specific gravity of the foam (stability was measured by change in bubble size as shown by photomicrographs and the amount of drainage from the foam in a given time);
2) heat treatment has no effect on foams since changes of as much as 14 degrees Centigrade (25.2 degrees Fahrenheit) produced no apparent effect on foam stability;
3) acids and acid salts have a marked effect in stabilizing foam but not all acids studied had equivalent effects; potassium acid tartrate was more desirable than citric acid or acetic acid;
4) in the presence of potassium acid tartrate, small amounts of yolk reduced the stability of the foam.

Bailey (1935), Carney (1938), and Hanning (1944) used rate of drainage as a measure of foam stability in egg white. A quantity of whip was either transferred to a glass funnel (Hanning) or "bled" from the beating bowl (Carney) and the amount of drainage in 60 minutes was measured by volume and/or weight.

Pyke and Johnson (1940), using Barmore's drainage method, tested whole-egg meringue for stability and reported that it was surprisingly stable. Speculating on the physical reactions occurring when flour is added to egg foams in making sponge cakes, they felt that a moderately stable foam which drained rather rapidly would give more desirable cakes. They reasoned that if the liquid is fairly readily available to the flour, there would be no competition between egg proteins and flour for the available water, thus producing a more stable batter.

Sponge Cakes

Sponge type cakes include angel food, yellow (yolk) sponge, sunshine, and true sponge cakes. They vary in proportion of white to yolk, but all depend upon the air entrapped in the beating of the eggs for their leavening. For this reason the retention of beating properties of eggs is essential for making sponge type cakes, and, conversely, the quality of sponge cakes is an indication of the culinary properties of the eggs used.

Hedstrom, reported by Lowe (1943) found that the volume of angel cake decreased with increase in the age of the egg used. This finding was similar to that of Stanley (Lowe, 1943) who stated that thin white gave a larger volume of foam than did thick but a smaller volume of cake. Miller and Vail (1943) found that thin frozen egg whites gave larger volumes in angel cakes than thick frozen or fresh whites.

King *et al*. (1936) investigated variations in the physical and chemical constants of eggs which might be correlated with the lifting power as used in sponge cakes. They beat whites and yolks separately in their method of mixing, using an electric mixer. The range and average values of specific gravities, pH, and tensile strength for some of their cakes are given in Table 2.

Table 2

Range and Average Values of the Specific Gravity of the Batter, pH, and Tensile Strength of Sponge Cakes

	Specific gravity of batter	pH of batter	Tensile strength of cake
Series I			
Range	0.342-0.378	4.80-5.80	21.92-28.26
Average	0.362	5.33	25.43
Series II			
Range	0.368-0.412	4.98-5.32	24.92-27.76
Average	0.394	5.19	25.68

They stated that a set of six cakes showed a range in variability even with the most careful manipulation. The chemical and physical properties of eggs measured were shown to have no definite relation to various cake measurements. Eggs used were representative of average fresh eggs. They later reported (King, Whiteman, Rose, 1936) that the diet of the hen also did not affect the properties of the eggs or the quality of the cakes. There was no relation between pH and carbon dioxide content of egg white, contrary to common belief.

Pyke and Johnson (1940) developed a method of mixing sponge cake in which the whole egg is made into a meringue with all of the sugar. They stated that this method gave a superior product to that made by conventional method (separating eggs). Flour was incorporated by mixing in the electric mixer at slow speed, and the desired specific gravity of the batter was obtained by varying the amount of mixing of the cake batter. These workers were concerned chiefly with high altitude baking problems, and they felt that the only accurate manner in which the amount of air incorporated might be controlled was by the specific gravity of the batter. They recommended the following changes in specific gravity for different altitudes:

87-91 grams per cup of batter for sea level
90-93 grams per cup of batter for 2,500 feet
92-96 grams per cup of batter for 5,000 feet

They further observed that high-quality frozen eggs produced sponge cakes of excellent quality by this method.

Pyke and Johnson (1940) used cream of tartar as the acid ingredient in their formula and stated that if lemon juice and rind were to be used for flavoring they were to be added at the end of the mixing and not to the meringue. They stated that lemon juice impedes the formation of whole-egg meringue and that in sufficient quantity it may prevent meringue formation entirely.

In 1941, Pyke and Johnson (1941) reported studies on deterioration of eggs in storage and quality of cakes made therefrom. In this investigation the eggs were stored for definite periods of time at 22-23°C (71.6-73.4°F) with a relative humidity of 20-25 per cent. Eggs were weighed before and after storage and evaporation losses determined. They found that it was necessary to compensate for these losses to lessen the extent of collapse of structure of the cake. Collapse of structure was also observed when eggs of good quality were used if the water in the formula had been decreased to the same extent as found in the stored eggs. The collapse in cakes was attributed to faulty coagulation and gelation of the aged egg. This, however, does not explain the collapse of fresh egg cakes whose coagulation temperature was lowered when concentration of egg was increased (decreased water). The cakes were baked at high altitudes (5,000 and 10,000 feet), and the workers predicted that eggs of inferior quality could be more effectively used in cakes at or near sea level than they could at the higher altitudes. They observed that the temperature of coagulation was raised considerably as the eggs deteriorated and the altitude, with its decreased atmospheric pressure, permitted a greater expansion in the cakes before coagulation temperatures were reached.

Further, they said, the ability to resist expansion during baking was progressively lost as the egg deteriorated. Additional flour prevented collapse of cakes from poor quality eggs by increasing the amount of structural material. Length of storage period of eggs was negatively correlated with cake measurements of volume and tensile strength.

Platt and Kratz (1933) reported on methods for assessing objectively and subjectively the quality of test sponge cakes. Although especially designed for bakers, they have also been useful in the small-scale laboratory.

Bennion, Hawthorne, and Bate-Smith (1942) used sponge cake quality as an indication of the quality of dried whole eggs. The procedures for cake-making used for fresh eggs were not suitable for use with dried eggs, and it was necessary to raise the temperature of beating to obtain satisfactory foam volume. They found that beating the reconstituted egg-sugar mix at 50°C (122°F) gave foams of satisfactory volumes for sponge cakes. A point of interest noted in this investigation was that the marked and unpleasant flavor of dried eggs, which rendered scrambles and custards unpalatable, was not noticeable in the finished sponge cakes.

EXPERIMENTAL PROCEDURE

Preliminary Investigation

More than 120 sponge cakes were made in the preliminary investigations in developing a desirable formula and mixing procedure and stardardizing technique. The formula as given by Lowe (1943) was used as a basic recipe, and the method of mixing was by whole-egg meringue in which 60 per cent of the sugar was used in the meringue and the remainder was mixed with the flour. The whole-egg meringue method was indicated inasmuch as most of the egg materials in the study were to be the egg melange. Eggs used in the preliminary work were fresh market eggs obtained from the foods and nutrition storeroom. Cakes were tested in the same manner and scored by the same judges who scored the experimental cakes later. Work with the experimental eggs was begun when judges' scores and tensile strength measurements indicated that a desirable sponge cake was being produced and that conditions were controlled sufficiently so that variations from day to day were reasonably low.

Procedure

General plan

A statistical design was set up before experimental work was begun in order to facilitate statistical analyses. Mechanics and practical considerations limited the daily treatments to six. These were randomized by table and five to seven replications were made on successive days. This plan permitted analysis of variance measurements to be made to determine whether egg treatment affected cake quality as shown by judges' scores.

The work was conducted in a small laboratory in which the room temperature was held constant at $24^{o}C \pm 1^{o}C$ ($75.2^{o}F \pm 1.80^{o}F$). Unfortunately, no control of humidity was possible so that cake crusts were sticky when humidity was high.

Experimental-size cakes were made of the different egg products under investigation. pH determinations of egg magma and cake batters were made as soon as possible after all cakes had been mixed for the day. Weight losses during baking and volumes were determined on the same day the cakes were baked, after which the cakes were removed from their tins, wrapped in waxed paper containers, and stored in a giant desiccator until the following day when they were scored. Tensile strength measurements were made on the day the cakes were scored, the first three slices being used for that purpose.

After the desired number of replications had been completed, a "family-size" (six-egg) cake was made from each egg product to ascertain whether the results obtained were comparable to a household situation.

Data on the following were collected in the study:

- Index of quality of shell eggs
- Estimate of quality of dried eggs
- Stability of egg-sugar foam
- Specific gravity of foam
- Foam temperature
- Specific gravity of cake batter
- pH of egg magma
- pH of cake batter
- Time required to beat egg-sugar mix to definite specific gravity
- Baking losses of cakes
- Volume of cakes
- Palatability of cakes by judges' scores

Formula

The formula developed in the preliminary investigation was used throughout the entire study. The proportions were as follows:

Ingredients	Experimental cakes	Whole recipe ("family-size")
Whole egg magma	96 grams	288 grams
Granulated sugar	80 grams	240 grams
Lemon juice	8 ml.	24 ml.
Distilled water	7 ml.	21 ml.
Cake flour	35 grams	105 grams
Salt	0.5 grams	1.5 grams
Baking powder (when used)	1.0 grams	3.0 grams

Selection and treatment of ingredients

Eggs. The eggs for the study constituted the known variable. The sources and treatments for each experimental series follow.

Series I. Fresh and aged infertile shell eggs.

Infertile shell eggs were obtained from the College Poultry Farm. They were random selections from mature hens. The eggs were gathered shortly after they were laid and were kept refrigerated until delivered to the laboratory the following day. Eggs were received daily and were stored in the laboratory in a constant-temperature, constant-humidity cabinet for 0, 7, 14, 21, 35, and 42 days. The temperature of the cabinet was approximately 25°C (77°F). The relative humidity was approximately 60 per cent. No mold growth was observable.

When eggs were to be used they were brought to room temperature, and measurements for Haugh unit were made. Six to 12 eggs for each treatment were blended without foaming with 100 turns of a rotary beater, and the magma was strained to remove the chalazae. Samples for cakes and pH determinations were taken from the blended magma. A separate lot of eggs was used for each replication.

Series II. Fresh infertile shell eggs. Fresh infertile eggs from the same source as for Series I were obtained daily and used 24 hours after they were laid. A blend of 12 eggs was obtained as described for Series I and sufficient meringue was prepared at one time for three experimental cakes. When beaten to the desired lightness, the foam was divided into three equal parts, and the dry ingredients were folded in with 50, 60, and 75 strokes. The three cakes were baked at one time.

Series III. Pasteurized liquid whole egg. Two sources of egg supply were utilized in this series:

(1) shell eggs of known history and (2) commercially frozen eggs of unknown history.

1) A random selection of 36 eggs was obtained daily from the College Poultry Farm. They were refrigerated at the farm until delivered to the laboratory the day after they were laid. The eggs were stored in the laboratory for seven days at 27°C (80.6°F) in a constant-temperature, constant-humidity cabinet. When they were to be used, they were brought to room temperature and an index of quality by Haugh unit was obtained. The 36 eggs were then blended by use of a household homogenizer and were strained to remove the chalazae. A portion of the magma was set aside to serve as an unheated control; the remainder was divided into three portions, each of which was heated to a certain temperature for a definite time. The times and temperatures used were:

60.0°C (140°F) for eight minutes
61.1°C (142°F) for five minutes
62.2°C (144°F) for three minutes

2) A quantity of commercially frozen eggs sufficient for the series was obtained on the open market and was kept frozen until used. When used, a portion of the lot was thawed; one-half of the thawed magma was set aside to be used as unheated control, and the remainder was heated in the laboratory pasteurizer to 61.7°C (143°F) for approximately 30 minutes.

All samples were allowed to remain at room temperature until used, only a few hours after preparation. Samples were prepared daily to eliminate variation due to storage of the liquid egg.

Series IV. Frozen pasteurized liquid whole egg. Shell eggs were obtained from the College Poultry Farm the day after they were laid and were stored seven days at 27°C (80.6°F) as in Series III. They were assumed to be of the same quality as in Series III and no objective measurement of quality was made. When used, they were blended in the household homogenizer and strained. A portion of the blended magma was set aside to serve as the unheated control; the remainder was divided into four portions, each of which was heated to a certain temperature for a definite time. The times and temperatures used were:

61.7°C (143°F) for 15 minutes
61.7°C (143°F) for 30 minutes
64.5°C (148°F) for 0.5 minute
68.3°C (155°F) for 0.1 minute

All samples were put into glass pint jars and were quick-frozen by direct contact single-plate method at -35°C (-31°F). Eggs were prepared daily and were kept frozen only until the following day when they were used in baking. The samples were thawed without agitation by immersing the containers in cold water. The thawed magma was thoroughly stirred before it was weighed for whipping.

All samples were prepared daily so that all remained in the frozen state the same length of time.

Series V. Spray-dried whole egg (0.5 per cent moisture). A spray-dried whole egg powder, dried originally to 0.5 per cent moisture according to army requirements, was obtained from the Poultry Products Laboratory in sufficient quantity for the series. It was stored in tightly closed glass containers and kept in the refrigerator. The powder at the time of use had a moisture content of 4.41 per cent because the powder had been exposed to the atmosphere in the Poultry Products Laboratory. Moisture content was not taken into consideration in reconstituting the egg.

The powder was reconstituted with distilled water at room temperature after it had been thoroughly mixed with a portion of the sugar. The proportions used for reconstituting were three parts water to one part egg by weight. The reconstituted egg-sugar mix was warmed slowly to 68°C (154.4°F) and was beaten at 45°C (113°F).* Additional water was added to compensate for evaporation losses during beating. A sufficient quantity of meringue was prepared at one time for three experimental cakes, the division being made by weight after the desired lightness of foam was obtained.

Series VI. Unaged and aged commercial spray-dried whole egg (5.0 per cent moisture). A commercially spray-dried whole egg powder dried originally to 5.0 per cent

*Data from Western Regional Research Laboratory moisture, was obtained from the Poultry Products Laboratory. Portions of the powder were packed into tin cans and sealed. Four containers were incubated at 37°C (98.6°F) and one was stored immediately at -10°C (14°F). One container was removed at each of 7-, 14-, and 28-day intervals and kept at -10°C (14°F) until used. Since the sample incubated 28 days did not form a foam, further aging was abandoned. After the containers were opened, the powder was transferred to glass jars so that they might be kept tightly closed. Sufficient powder for all replications was treated at one time and the powders were kept refrigerated during the experimental period.

Egg powders were reconstituted and warmed in the same manner as in Series V. It was necessary, however, to surround the egg-sugar mix with hot water--approximately 80°C (176°F)--during beating in order to obtain a foam. History of the powder showed that it had been kept in the Iowa State College experimental freezer locker at -10°C (14°F) for approximately a year, but according to other investigators, beating properties should not have been impaired. Additional water, determined by trial, was added to compensate for evaporation losses during beating. Sufficient meringue was prepared at one time for two experimental cakes and was divided by weight. One served as control, and baking powder was added to the other.

<u>Series VII. Spray-dried whole egg from different plants</u>. Spray-dried whole egg powders were obtained through the Poultry Products Laboratory from three different drying plants operated by one firm. They were samples of egg powders prepared according to army specifications to contain no more than 2 per cent moisture. The powders arrived at the laboratory in hermetically sealed tin containers. When opened, moisture determinations were made and the powder was transferred to glass jars, which could be kept tightly closed, and refrigerated. The experiment was conducted a few days after the powders had been received. Moisture contents of the samples were:

Plant 1, 1.6 per cent
Plant 2, 1.7 per cent
Plant 3, 0.7 per cent

Samples were reconstituted after they had been thoroughly mixed with a portion of the sugar; the mix was slowly warmed to 68°C (154.4°F) and was whipped at 45°C (113°F). Additional water, determined by trial, was added to compensate for evaporation losses during heating and beating.

A vacuum-dried sample to serve as a control was prepared by a member of the Poultry Husbandry Department according to the method used in the Poultry Products Laboratory, as described by Best (1944). The moisture content of the powder was 3.39 per cent. A sufficient amount of powder for the series was prepared a few days before the experiment was begun and was stored in a tightly closed glass jar in the refrigerator. When used, the powder was thoroughly mixed with a portion of the sugar, reconstituted, and allowed to remain at room temperature for one hour before whipping. It then had the consistency and appearance of magma from shell eggs. The mix was not preheated, but it was beaten at 45°C (113°F) as the foam did not form readily.

The shell egg control was a blend of two market eggs obtained from the foods and nutrition storeroom and was representative of the quality used in the preliminary investigation. They were obtained daily and were blended and strained before use. They were beaten at 24°C (75.2°F).

Series VIII. Shell eggs, frozen pasteurized liquid whole eggs, and dried whole eggs. Two treatments of each preservation method under investigation were used in this series.

The treatment of shell eggs, fresh and stored, was similar to that used in Series I. Infertile eggs were obtained from the College Poultry Farm the day after they were laid. The sample to be aged was kept in a bacteriological incubator at 37°C (98.6°F) for seven days. An index of quality by Haugh unit indicated they were similar in quality to those stored 14 days in Series I. Samples were blends of six eggs, beaten and strained as in Series I.

The eggs for pasteurization were from the same source and were stored for the same period as those in Series III and IV. Sufficient eggs for two pasteurization treatments were broken out, homogenized, and strained. One-half of the melange was heated to 62.2°C (144°F) for 30 minutes; the remainder to 71.1°C (160°F) for 20 seconds --essentially the same times and temperatures for hold and flash pasteurization of milk. After pasteurization they were put into tightly closed glass jars and frozen in the same manner as in Series IV. When used, the magma was thawed in cold water and was thoroughly stirred before samples for whipping were weighed.

The spray-dried whole egg in this series was the same as in Series V (0.5 per cent moisture), and it was treated in the same manner. The vacuum-dried sample was prepared in the Poultry Products Laboratory in the same manner as for Series VII. In this experiment the vacuum-dried sample was treated in the same manner as the spray-dried samples; that is, the egg-sugar mix was reconstituted and warmed to 68°C (154.4°F) before beating. Both dried egg samples were beaten at 45°C (113°F); liquid egg samples were beaten at 24°C (75.2°F).

Sugar. Cane sugar of reasonably fine grind was purchased in sufficient quantity for the entire study. Portions used in each experiment were weighed, put in paper packets, and stored in a constant temperature cabinet at 25°C (77°F) before the experiment was begun.

Lemon juice. Citric acid as lemon juice was selected because it is commonly used in sponge cake. Sufficient lemons for one series were reamed, and the juice was strained, mixed thoroughly, and frozen in covered beakers. One beakerful provided enough for one day's baking. The juice was thawed and brought to room temperature and stirred when used. The pH of the lemon juice was approximately 2.3.

Water. All water used in reconstituting dried eggs and in the cake formula was distilled water of pH approximately 6.92.

Flour. A case of fine-grade boxed cake flour* provided sufficient flour for the entire study. Flour from the same box was used in each series. It was weighed, sifted once with a portion of the sugar and the salt, and stored in packets in the constant temperature cabinet. The amounts for the single series were weighed out before the experiment was begun.

Salt. Salt used was fine-grade table salt all from the same box. It was added with the flour.

Baking powder. A sulfate-phosphate baking powder was selected because it is the type commonly used. Portions were taken from the same box. When used, it was sifted with the flour.

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*Swans Down Cake Flour

<u>Weighing and measuring</u>

All weighing was done on a Cenco trip balance sensitive to 0.1 gram. Measurements were made in graduated cylinders.

<u>Method of mixing cakes</u>

<u>Formation of whole-egg meringue</u>. A KitchenAid electric mixer Model G, three speeds, was used for beating eggs. This mixer has a concentric arm, and the r.p.m. for 110-115 volts was given as 1750. Eggs were weighed, transferred quantitatively to the standard 5-quart mixing bowl, and brought to the desired temperature by immersing the bowl in water, after which the sugar was added. When dried eggs were used, the powder was mixed with the required amount of sugar before the eggs were reconstituted. The egg-sugar mix was then warmed slowly by placing the bowl in water at 45^{o}C (113^{o}F) and heating with high heat on an electric plate. Heat was turned off when the mix reached 60^{o}C (140^{o}F) so that the water never reached the boiling point. Heating required from 10 to 15 minutes, depending upon the amount of mix.

When the eggs had reached the desired temperature, the formula water was added, and the egg-sugar mix whisked by the regulation wire whip with mixer set at high speed (speed #3). The lemon juice was added slowly after the first 15 seconds of beating. Beating was continued at high speed until the foam appeared to be of the proper lightness; mixing was then continued at speed #1 for from one to four minutes to equalize the air bubble size. Time of beating at each speed was recorded by stopwatch. If the foam was not sufficiently light (specific gravity approximately 0.27), beating was resumed at high then low speed and the extra time added to the first. Foams that were too light were discarded and another sample was taken.

The temperature of the foam was taken when beating was complete and the foam was transferred as quantitatively as possible to a two-quart enamel mixing bowl. A loss of three to five grams was unavoidable.

Mixing. The flour, sugar, and salt, thoroughly mixed and sifted three time, were added to the meringue in four portions. A flat seven-wire hand whip was used to fold the dry ingredients into the meringue using 10 to 15 strokes for each portion of flour, with an additional 10 to 15 strokes so that each cake was folded 50 to 75 times. The number of strokes was kept constant for each series according to the apparent dryness of the major foams. They were:

Series I.	50 strokes
Series II.	Varied: 50, 60, 75 strokes
Series III.	50 strokes
Series IV.	50 strokes
Series V.	60 strokes
Series VI.	60 strokes
Series VII.	60 strokes
Series VIII.	Fresh shell eggs, 75; all others, 60 strokes

When mixing was completed, a portion of the batter for specific gravity determinations was obtained by two strokes of a metal tablespoon, dipped to the bottom and across the entire diameter of the mixing bowl.

In all series 150 grams of batter were weighed into tared tin baking pans approximately 2-3/4 inches deep and measuring approximately 5-1/4 x 3-1/4 at the bottom and 6 x 3-1/2 inches at the top, and of 730 to 755 cc. capacity.

Baking

Cakes were baked in a preheated Clark Jewel gas oven with thermostatic control. The temperature of the oven was determined by an uncalibrated centigrade oven thermometer placed in the center of the oven. When cakes were baked singly, they were placed in the center of the oven. When baked in pairs or triplicates, they were distributed at random on the same shelf and as close to the center as possible with two inches of space between. All experimental-sized cakes were baked 30 minutes at approximately $173^{o}C \pm 2^{o}C$ ($343.4^{o} \pm 3.6^{o}F$); large cakes were baked 50 minutes.

Cooling

Cakes were inverted on wire cake racks and cooled at room temperature. Baking losses were determined by weight difference after the cakes had cooled one hour. Cakes were kept inverted until the volume determinations were made at the end of the day's baking, after which they were removed from their tins and stored.

Methods

Index of quality of shell eggs

The objective test used to determine quality in shell eggs was the Haugh unit. Haugh's procedure was followed in making the measurement (Haugh, 1937). The eggs were brought to room temperature, weighed to the nearest 0.1 gram on a trip balance, and broken out onto a level glass surface. The height of the thick white in millimeters was measured at the point equidistant from the yolk and the edge of the firm white on the axis where the firm white was widest. The Haugh units were read from a nomograph developed for this purpose (Haugh, 1937). There was no selection of eggs on the basis of this measurement, but a sufficient number of eggs for each treatment were used so that the average would be kept constant for the replicate bakings. Results are reported in average units for each sampling.

Pasteurization of eggs

The pasteurization process was carried out by Dr. Alden Winter in the bacteriology laboratory.

Liquid whole egg, homogenized and strained, was preheated as quickly as possible to the desired holding temperature by passage through 8 feet of bent thin glass tubing submerged in a constant temperature water bath. It was possible to heat the egg from room temperature to 62.8°C (145°F) in four seconds when the bath was maintained at 65°C (149°F). The temperatures to which the egg was heated, as well as the time required to raise it to a given temperature, were varied by changing the temperature of the water bath, the length of glass tubing in the heater, and the rate of passage through it. The temperature of the egg at the end of the glass tubing heater was measured by introducing a copper constantan thermocouple wire through a T glass tube and attaching it to a Leeds and Northrup potentiometer indicator.

The holder for pasteurizing consisted of a Dekhotinsky constant temperature water bath and wire cylinder, wrapped with varying lengths of thin pure gum rubber tubing (inside diameter 1/8 inch). The cylinders were joined by coupling adjacent ends of the rubber tubing with a short piece of glass tubing. They were immersed in the water bath. The time the egg was held at a given temperature was measured by the time required for the egg to pass through different lengths of tubing the length being varied according to the time desired.

The pasteurized egg was cooled by passage through glass tubing submerged in ice water and by surrounding the receiving flask with ice water.

<u>Estimate of extent of denaturation of dried egg proteins</u>

The ferricyanide method for determination of denaturation by exposed sulfhydryl was used as an estimate of quality of dried egg magma. The procedure as described by Mirsky (1941) was followed. The lower the proportion of exposed sulfhydryl groups, the higher the quality of the egg powder.

Two-gram samples of egg powder were weighed on a trip balance and were reconstituted by adding 20 ml. of redistilled water per gram of powder. The suspension was then centrifuged for 10-30 minutes and the sediment discarded. Determinations were made on aliquots of the centrifugate.

The reaction mixture consisted of:

1 ml. egg suspension
0.2 ml. phosphate buffer, pH 7.0
0.2 ml. molal ferricyanide solution

For exposed sulfhydryl, this mixture was allowed to react at room temperature for 30 minutes, after which time 0.2 ml. of 1N sulfuric acid and 2.0 ml. of Duponol (sodium lauryl sulfonate) were added and then 1.0 ml. of ferric sulfate solution. The color was allowed to develop for 1000 to 1200 seconds, after which the mixture was made up to 25 ml. in a volumetric flask and read. Determinations were made in triplicate.

The readings (colorimetric) were made in a Coleman Universal Spectrophotometer, Model 11, at a wavelength of 710 mmu., using a red Pc-5 filter and 10 mm. depth of solution. The percentage of transmittance was read against a reference standard which was a sample of the test solution without the ferric sulfate. The moles of sulfhydryl per ml.

of egg suspension were determined by reading from a reference curve set up the same day (on same battery charge). The amount of egg protein in suspension (mg./ml.) was calculated from nitrogen determinations (Micro-Kjeldahl method) on a moisture-free basis. Per cent exposed sulfhydryl was calculated from milligrams sulfhydryl in the protein present in the suspension.

Total sulfhydryl was determined in the same manner except that the reaction mixture was allowed to react from three to four hours and the volume was made up to 100 ml.

The proportion of sulfhydryl groups exposed was calculated from per cent exposed and per cent total, and results are reported in per cent of total sulfhydryl content exposed.

Stability of egg-sugar foams

The relative stability of foams was determined by rate of drainage (Barmore, 1934, and Pyke and Johnson, 1940). Eighty grams of meringue was weighed into a six-inch funnel supported in a tared 100-ml. graduate cylinder. Small brass screen plugs were fitted into the angles of the funnels and served as support for the foams. These plugs were made of a brass ring, shaped like a cross section of a cone fitting into the angle of the funnel and covered with a platform of brass screen, 60 meshes to the inch. After the foams had stood for one hour at room temperature, the funnels were removed and the amount of liquid drained read directly from the graduate cylinder. The weight of material in the cylinder was determined by difference. Results are reported both in milliliters of liquid drained in one hour and grams of meringue drained in one hour, since frequently foam had seeped through the screen but had not reverted to liquid, thus confusing the measurement.

Specific gravity determinations

A tared standard household fourth cup measure was filled with the substance to be tested, and the measure was levelled by drawing the edge of a spatula across the top in one rapid stroke. The filled measure was then weighed to the nearest 0.1 gram and weight of material determined by difference. The specific gravity was calculated by dividing the weight in grams by the weight of an equal volume of water, or, in this instance, 59 grams. Results are reported in the calculated figures.

Foam temperature

The temperature of the finished meringue was determined by immersing a standard laboratory Centigrade thermometer in the foam and allowing it to come to maximum expansion. Results are reported in Centigrade units.

<u>pH determinations</u>

A Coleman pH Electrometer with glass electrode was used for determining the pH of egg magmas and cake batters. The samples were thoroughly stirred before they were put into the sample cup and were used without dilution. Acetone was used occasionally to wash the electrode free of possible fat film. The pH value was read directly and results are reported in pH units.

<u>Baking losses of cakes</u>

Baking losses were determined by difference between weight of cake batter and weight of cake cooled one hour. Results are reported in grams.

<u>Volume of cakes</u>

The seed displacement method described by Platt and Kratz (1933) was used to determine volume of cakes. The cooled cakes in baking tins of measured volume were covered with waxed paper to facilitate recovery of the seeds and a constant volume of seeds was allowed to pour onto the cake at a constant rate from a definite height. This was accomplished by filling a plugged funnel, supported on a ring stand, with seeds and then withdrawing the plug and allowing the seeds to drop by force of gravity. The seeds were levelled to the capacity of the tin by drawing the edge of a spatula across the top of the tin in two rapid strokes. The seeds were poured from the cake into a second funnel kept at a definite height above a 1000-ml. graduate cylinder, again allowing the seeds to drop at constant rate into the cylinder. The volume was read to the nearest five cubic centimeters and the volume of the cake was obtained by difference in the capacity of the pan and seeds added. Volume is reported in cubic centimeters of cake.

Tensile strength of cakes

Determinations of tensile strength were made the day after the cakes were baked. Cakes were sliced 0.5 inch thick using a knife with a serrated edge. Uniformity of slices was obtained by use of a miter box. The crust and end slice of the cake were discarded, the next three slices being used for tensile strength measurements. When cut, the slices were placed under bell jars to minimize drying until used. Cutting of the cakes required approximately one hour.
The slices were cut with a specially designed cutter in the shape of an hourglass. The width of the section to be torn measured 7/8 inch. The slices, 2-3/4 inches long, were clamped at each end in such a manner that a pulley, driven by electric motor, pulled on the cake, one end of which was clamped to a lever arm resting on a gram scale. The lever arm pushed onto the scale until released by the tearing of

the cake. The scale was set at zero before there was any pull on the cake, and the maximum pressure on the scale was read just as the break occurred. This reading was then divided by two to give tensile strength reading. Results are given in the average tensile strength of the three slices.

Palatability of cakes

Five food department staff members served as judges throughout the entire study. Cakes were cut in the miter box, and each slice was marked with the cake number and was wrapped separately in waxed paper. Each judge received a slice from the same position in the respective cakes.

The appearance of the cake was noted by the investigator and did not enter into the score. Scoring was done by weighted score card as follows (see appendix):

Crumb color	5
Texture and grain	35
Tenderness	30
Moistness	10
Flavor	20

Results were totalled and averages obtained for replications (five judges' scores) and for judges (five to seven replicate scores), the mean values being the same in either case. Results are reported by mean scores (details for all average scores in appendix).

Statistical analysis

The statistical method used in this study was an analysis of variance by Snedecor (1940) in which the unit of measurement was total scores of cakes given to each cake by each judge. This was done to include individual variations in total error. Total scores were selected for analysis rather than some other factor since it was felt that scores were the best indication of culinary value of the eggs. Objective measurements such as volume do not take into consideration the eating quality of the product.

The sources of variation used in the analysis were:

Replications
Treatments
Replications x treatments

Judges
Judges x replications
Judges x treatment
Judges x treatment x days

Total (total number of scores)

Computations were by machine method. Tables showing source of variation, degrees of freedom, and mean squares are given in the appendix.

Photographs

Photographs were made by the College Photographic Service. The method used was direct contact using a 1/2-inch slice, as described by Cathcart (1938). Each slice was a representative sampling of one of the experimental cakes.

RESULTS AND DISCUSSION

Cakes were baked in series of five to seven replications each and the results will be presented and discussed by single series. All replications of data are given in the appendix to which the reader is referred for details.

SERIES I. Cakes Made with Fresh and Aged Infertile Shell Eggs

Quality of eggs

Infertile eggs were chosen for this study since it was known that they were less subject to rot than are fertile eggs. They are also less subject to chemical deterioration (Funk, 1944) than are fertile eggs which may account for the fact that the findings here are not always consistent with those reported in the literature.

Although actual weight losses of eggs during storage at 25°C (77°F) were not determined, they may be calculated from the average weights of the eggs at the time of use, inasmuch as they were random selections from the same group of hens and a relatively large number of eggs were used for each replication in order to obtain a blend of the same general quality. The average weights of eggs for the various storage periods are shown in Table 3.

Table 3

Average Weights* of Fresh and Aged Infertile Shell Eggs

Replication	Days in Storage at 25°C					
	0	7	14	21	35	42
	gm.	gm.	gm.	gm.	gm.	gm.
1	55.4	53.6	54.9	53.6	47.8	47.0
2	57.4	54.6	54.7	53.6	49.2	44.8
3	55.4	53.4	56.1	54.9	51.8	40.5
4	56.9	56.8	54.1	51.6	50.4	44.5
5	56.3	56.0	54.9	52.8	49.6	50.8
6	57.3	54.2	49.3	55.2	49.7	50.2
7	57.7	55.3	54.4	54.2	56.1	49.4
Mean	56.7	54.8	54.1	53.7	50.7	46.8

*Each figure is an average of 6-12 eggs.

Hydrograph records kept for part of the storage period showed that the relative humidity of the storage cabinet was maintained at approximately 65 per cent. Under these conditions, the average loss of weight during a 42 day storage period at 25°C (77°F) was approximately 10 grams or 17 per cent. Pyke and Johnson (1941) had observed that during a 30 day storage period at 22-23°C (71.6-73.4°F) and relative humidity of 20-25 per cent, the eggs had lost considerable weight although the exact figures were not given. It would be expected, however, that the weight loss observed by these workers would be greater than was observed in this study since the relative humidity of the storage room was lower than the relative humidity used in this study.

There was a great variation noted in the amount of thick white and flattening of the yolk in eggs of the same storage period. In some cases it appeared that thinning had begun at the outside of the white and was progressing toward the yolk whereas in others a general thinning was observed. Very few of the yolks broke when the eggs were broken out of the shell and those that did break were of the 42 day storage period. Sharp (1937) had reported that yolks of eggs aged 20 days at 25°C (77°F) invariably broke when the eggs were removed from the shell. Photograph 1 shows the general trend encountered of thinning of the white and flattening of the yolk. Eggs of the same approximate weight were selected for the photograph and those shown are of 0, 21, and 42 day storage periods respectively.

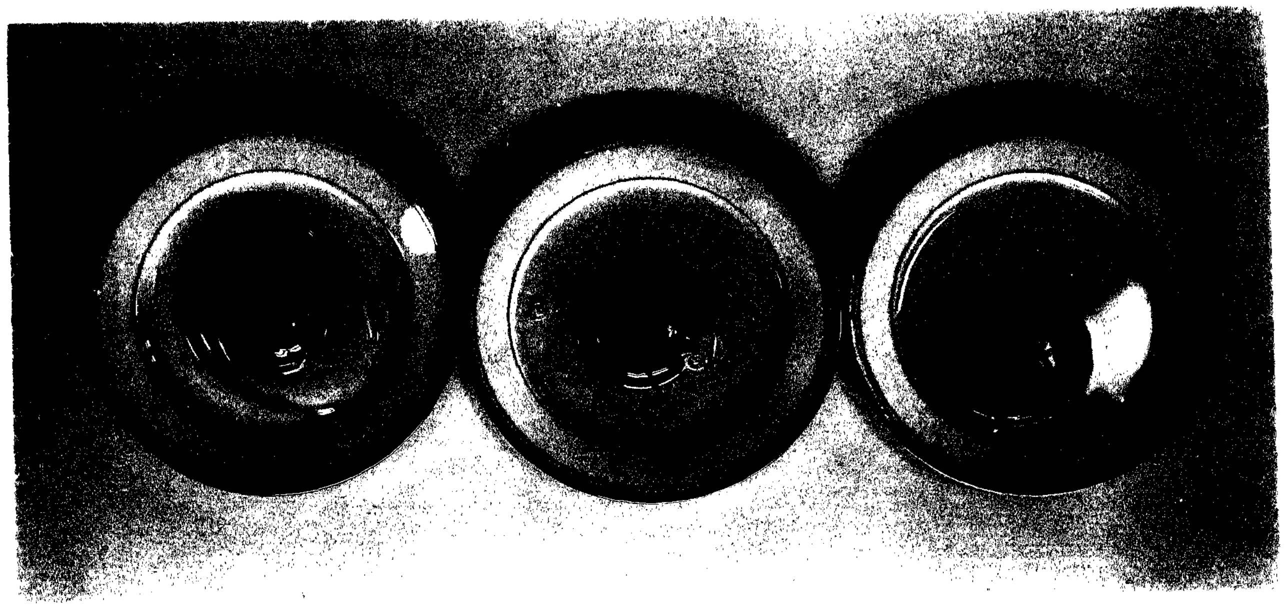
Quality of the eggs was determined objectively by Haugh unit. Here again considerable variation was encountered (see Table A-1 of appendix for ranges). The average Haugh units of the eggs used for the daily bakings are shown in Table 4.

Table 4

Average Haugh Units* of Fresh and Aged Infertile Eggs

Replication	Days in Storage at 25°C					
	0	7	14	21	35	42
1	78	60	47	41	32	36
2	81	58	44	33	22	18
3	77	56	45	35	27	19
4	78	58	50	37	30	23
5	75	49	40	38	38	32
6	80	52	49	43	44	32
7	85	56	43	47	26	27
Mean	79	56	46	39	31	27

*Each figure is an average of 6-12 eggs.



Photograph 1. Infertile Eggs Aged 0, 21, and 42 Days in the Shell at 25°C, Showing Progressive Thinning of the White and Flattening of the Yolk During Aging

The Haugh units were plotted against the days in storage and a curve drawn from the mean values, Figure 1. There was a gradual decrease in quality as determined by Haugh unit, the most rapid decrease occurring in the first seven days. Although not shown on the graph, the rate of decline in quality was found to be logarithmic after seven days. The curve shown (Figure 1) is similar to one presented by Funk (1944) in plotting albumen score of infertile eggs against days in storage at 21.1°C (70°F).

pH of egg magma and cake batters

The average values for pH of egg magma for the different storage periods and of cake batters are given in Table 5.

Table 5

Average pH of Egg Magma and Cake Batters Made with Fresh and Aged Infertile Shell Eggs

	Days in Storage at 25°C					
	0	7	14	21	35	42
Egg magma	7.22	7.55	7.55	7.63	7.58	7.59
Cake batter	5.18	5.15	5.18	5.18	5.22	5.26

The increase in pH from fresh to aged egg was surprisingly slight and was not appreciable after the first seven days in storage. The pH of fresh egg magma, 7.22, was somewhat higher than reported by King et al (1936), 7.09 and 7.14, for fresh egg magma from mature hens. This may have been due to the fact that these workers oil-dipped the eggs soon

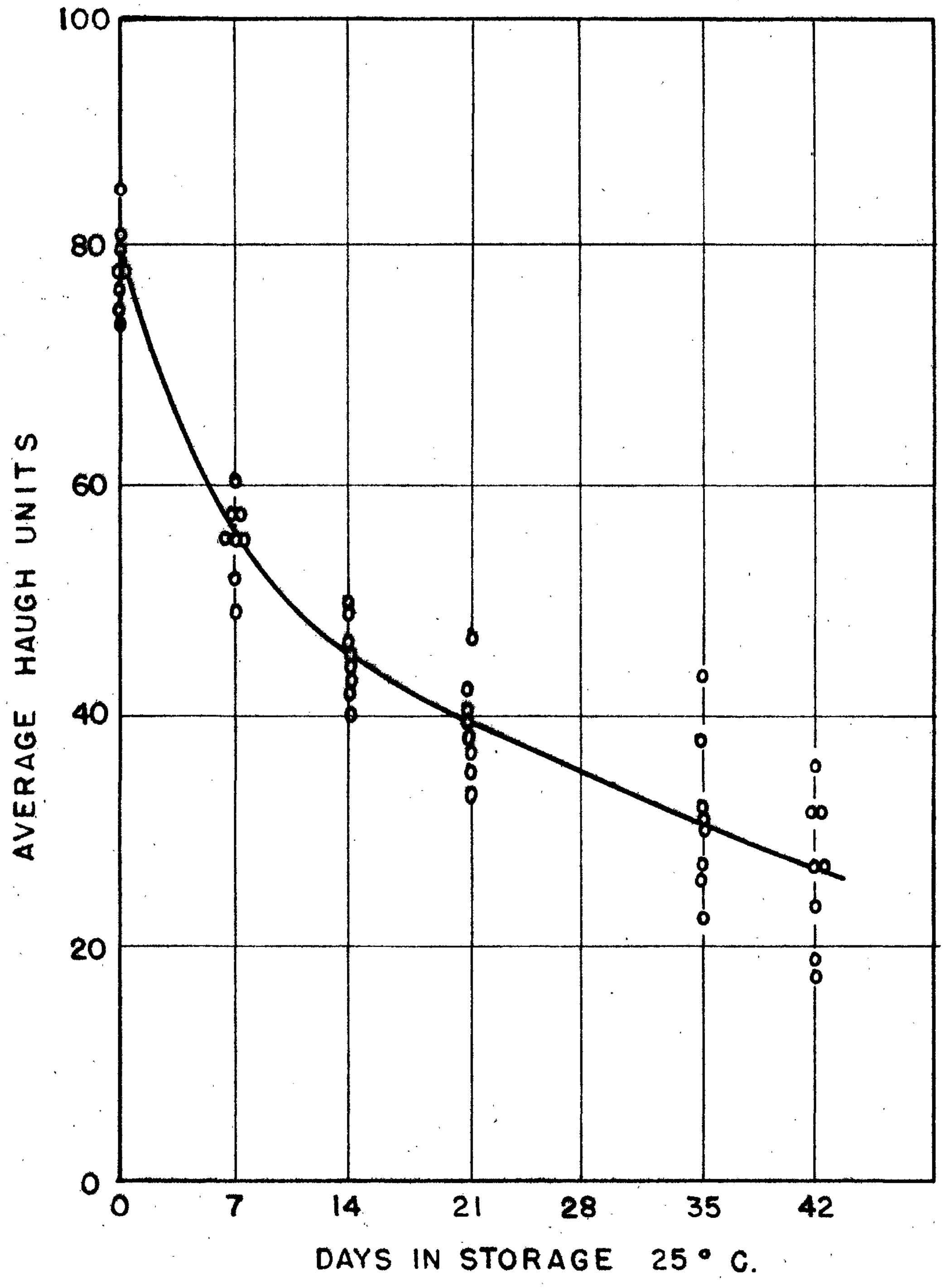


Fig.1. Average Haugh Units of Infertile Shell Eggs Aged at 25 °C. for Varying Periods of Time.

after they were laid so no loss of carbon dioxide occurred during the transport to the laboratory.

The pH of the cake batters showed little variation among the different storage periods of the eggs and did not seem to be closely related to the pH of the egg magma. The overall variation observed (Table B-1 in appendix) was 5.11 to 5.35, a difference of only 0.24 pH unit whereas King et al (1936) reported a range of 4.80 to 5.80 for batters in one series of fresh egg cakes with an average value of 5.33.

Foaming properties and foam stability

Pyke and Johnson (1941) stated that eggs of poor quality (stored) tended to foam more readily than eggs of good quality. The opposite effect was observed in this study as indicated by the average beating times required to reach a definite specific gravity of foam, shown in Table 6.

Table 6

Average Beating Times and Specific Gravities of Foams and Batters Made with Fresh and Aged Infertile Shell Eggs

	Days in Storage at 25°C					
	0	7	14	21	35	42
Total beating time, seconds	218	257	246	255	271	276
Specific gravity of foam	0.269	0.268	0.268	0.269	0.266	0.270
Specific gravity of batter	0.329	0.329	0.333	0.333	0.335	0.342

This difference in foaming properties may have been caused by the difference in type of acid used; Pyke and Johnson (1941) used cream of tartar, whereas citric acid (lemon juice) was used in this study. Barmore (1934) had reported that these acids do not have equivalent effects on egg white foams.

It may further be observed (Table 6) that with the same specific gravity of the foams, 0.27, the specific gravities of the batters tended to increase slightly with increased age of the eggs although all batters were mixed the same number of strokes in incorporating the flour. This would seem to indicate that the foams of the stored eggs were less stable than foams of the fresh eggs. It has been observed that fresh egg foams can stand more mechanical abuse than foams of lower quality eggs (Pyke and Johnson, 1941). However, if rate of drainage of foams is a criterion of foam stability, the fresh egg foams in this series were less stable than foams of stored eggs. This is apparent from the results shown in Table 7 and presented graphically in Figure 2; more liquid drained from fresh egg foams in one hour than from foams made with stored eggs.

Table 7

Average Milliliters of Liquid Drained in One Hour from Whole-Egg-Sugar Foams Made with Fresh and Aged Infertile Shell Eggs

Days in Storage at 25°C					
0	7	14	21	35	42
21.6	17.8	18.9	20.6	17.4	12.2

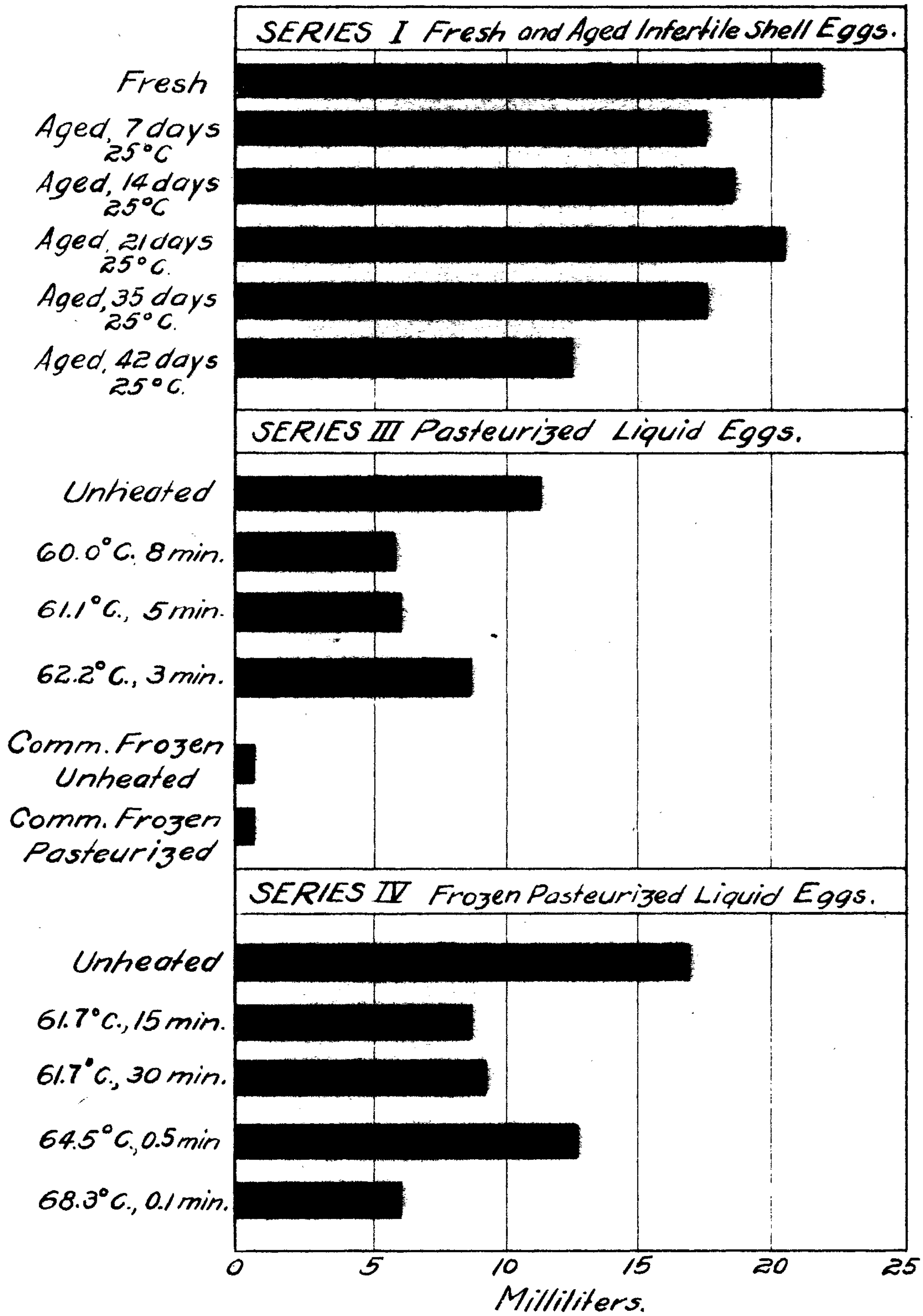


Fig. 2. Average Milliliters of Liquid Drained in One Hour from Whole-Egg-Sugar Foams.

In this study the volume of drained liquid has been assumed to give a better indication of foam stability than the weight of material drained inasmuch as considerable foam frequently seeped through the wire screens in some of the tests thereby increasing the weight of material drained without increasing the visible liquid.

Less liquid drained from foams made with eggs of the 42 day storage period than from other foams (Table 7, Figure 2). This may have been caused by a higher concentration of egg solids with resultant decrease in free water in the aged egg since it has been pointed out that loss of water had occurred during storage and was greatest for the 42 day period.

Volumes of cakes

The average volumes of cakes are shown in Table 8 and are presented graphically in Figure 3. Although there was some daily variation, the cakes made with eggs aged 35 and 42 days had consistently larger volumes than cakes from eggs stored for shorter periods of time.

Table 8

Average Volumes of Cakes Made with Fresh and Aged Infertile Shell Eggs

Days in Storage at 25°C					
0	7	14	21	35	42
cc.	cc.	cc.	cc.	cc.	cc.
682	686	692	694	732	746

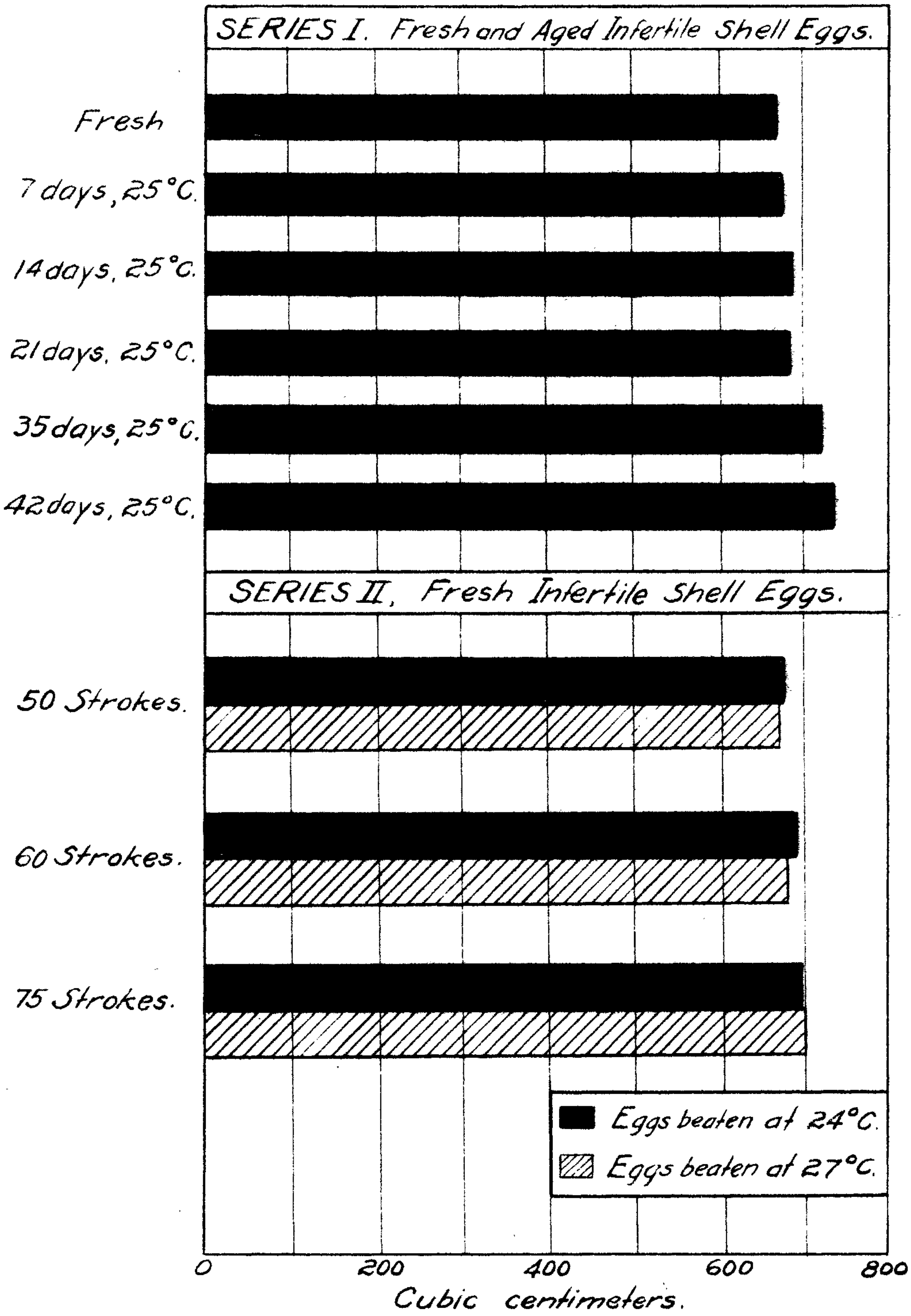


Fig. 3. Average Volumes of Cakes made with Infertile Shell Eggs.

These cake volume differences may be explained by the fact that the coagulation temperature of partially deteriorated eggs is higher than for eggs of good quality (fresh), as observed by Pyke and Johnson (1941), so that greater expansion of structural materials was possible before coagulation occurred. A slight collapse of the top of some of the cakes made with 55 and 42 day eggs occurred which might be attributed to overexpansion of the cakes. This is in keeping with the finding of Pyke and Johnson (1941) who stated that unless additional structural material (flour) was added, cakes made of poor quality eggs invariably collapse. They also predicted that this effect would be less severe at sea level; they were working at high altitudes.

Tensile strength of cakes

The average measurements for tensile strength for all cakes are shown in Table 9. It is apparent from the mean values that there is a direct relation between age of eggs and tensile strength, the relationship being inverse: decreased tensile strength with increased time in storage. This is consistent with the finding of Pyke and Johnson (1941) who reported that cakes made of stored eggs were more tender than cakes made with good quality eggs.

Table 9

Tensile Strength of Cakes Made with Fresh and Aged Infertile Shell Eggs

Replication	Days in Storage at 25°C					
	0	7	14	21	35	42
1	41	37	31	27	26	27
2	52	35	32	31	26	28
3	40	38	43	29	23	37
4	29	40	30	28	26	37
5	36	35	37	31	32	27
6	35	33	32	35	30	26
7	42	39	37	30	28	27
Mean	39	37	35	30	27	30

Apparently, aging increases the dispersion of egg proteins resulting in: 1) decrease in apparent viscosity as observed in the thinning of the white, 2) decrease in resistance to mechanical manipulation as shown by increased specific gravities of cake batters, and 3) decrease in resistance to stretching as indicated by volumes of cakes and lower tensile strength of cakes.

Palatability of cakes

In general, it was noted that all cakes were a pleasing brown color. Crusts of all cakes tended to be sticky when the humidity was high but cakes made with eggs aged 35 and 42 days seemed the most susceptible. Appearance does not enter into the judges' scores.

The average scores (7 replications) given all characteristics by each judge are shown in Table 10.

Table 10

Average Scores of Cakes Made with Fresh and Aged Infertile S Shell Eggs

Characteristic	Judge	Days in Storage at 25°C					
		0	7	14	21	35	42
Crumb Color (5)	1	5.0	5.0	5.0	5.0	5.0	5.0
	2	5.0	5.0	5.0	5.0	5.0	5.0
	3	5.0	5.0	5.0	5.0	5.0	5.0
	4	5.0	5.0	5.0	5.0	5.0	5.0
	5	5.0	5.0	5.0	5.0	5.0	5.0
	Mean	5.0	5.0	5.0	5.0	5.0	5.0
Texture and Grain (35)	1	29.2	29.2	30.7	31.3	32.1	31.4
	2	26.7	28.0	27.7	27.6	29.9	30.6
	3	28.0	27.7	27.7	27.0	29.6	29.7
	4	29.6	30.6	30.1	27.7	29.7	30.8
	5	27.7	28.1	28.8	27.7	26.7	28.6
	Mean	28.2	28.7	29.0	28.2	29.6	30.2
Tenderness (30)	1	26.0	26.1	25.8	27.4	27.1	27.3
	2	25.6	26.1	26.0	26.1	27.0	27.3
	3	23.4	23.9	22.7	24.0	25.1	23.4
	4	27.7	27.7	27.7	28.0	28.4	27.8
	5	27.7	28.1	28.1	28.0	28.6	28.4
	Mean	26.0	26.3	26.1	26.7	27.2	26.9
Moistness (10)	1	8.6	8.6	8.7	8.6	8.6	8.6
	2	8.8	9.0	9.0	9.0	8.8	8.3
	3	9.0	9.0	8.7	8.8	9.0	8.7
	4	8.0	8.0	8.0	8.0	8.0	7.8
	5	7.7	8.1	8.3	7.8	8.3	8.3
	Mean	8.4	8.5	8.5	8.4	8.5	8.4
Flavor (20)	1	17.7	17.3	16.3	15.0	14.3	11.6
	2	17.6	16.7	17.0	16.6	16.8	16.1
	3	17.4	18.1	18.0	18.0	16.8	17.1
	4	16.7	14.4	14.0	15.3	14.3	10.7
	5	15.8	17.4	17.4	16.8	16.4	16.7
	Mean	17.0	16.8	16.5	16.4	15.7	14.4
Total Scores (100)	1	86.6	86.3	86.6	87.3	87.1	83.8
	2	83.8	84.8	84.7	84.4	87.4	87.3
	3	82.8	83.6	82.1	82.1	85.6	84.0
	4	87.0	85.1	84.6	84.0	85.4	82.3
	5	83.7	86.8	87.7	85.0	85.0	87.0
	Mean	84.8	85.3	85.1	84.6	86.1	84.8

Although the final eating quality of a cake is reflected by the total score, it is also of interest to consider the various characteristics that entered into that total score, Figure 4. There were no differences in scores for crumb color or moisture but there was a slight increase in tenderness score with increasing age of the eggs. Tenderness is negatively correlated with tensile strength of cakes, the objective measurement of tenderness, and the correlation is shown in Figure 5. Tenderness scores were plotted in decreasing order so that the correlation might be seen more readily.

Texture scores also increased with increasing age of the eggs (Table 10, Figure 4), the cakes made with stored eggs tending to have increasingly finer cell walls and more uniform texture. Whereas texture and tenderness scores gradually increased with increased storage time of the eggs, flavor scores declined (Figure 4). This divergence of scores of the various characteristics caused a smoothing of the curve for total scores and it is apparent that storage age of the eggs did not affect cake quality as shown by total judges' scores.

The textures of the cakes may be observed from Photographs 2 to 7 inclusive. It is apparent from the photographs that the texture becomes more delicate and more uniform with increasing age of the eggs.

Since Sharp (1936) had reported wide variation among judges in their sensitivity to various flavors in eggs, a comparison was made of the five judges' flavor scores in this study. Figure 6 (Table 10) shows the average flavor scores

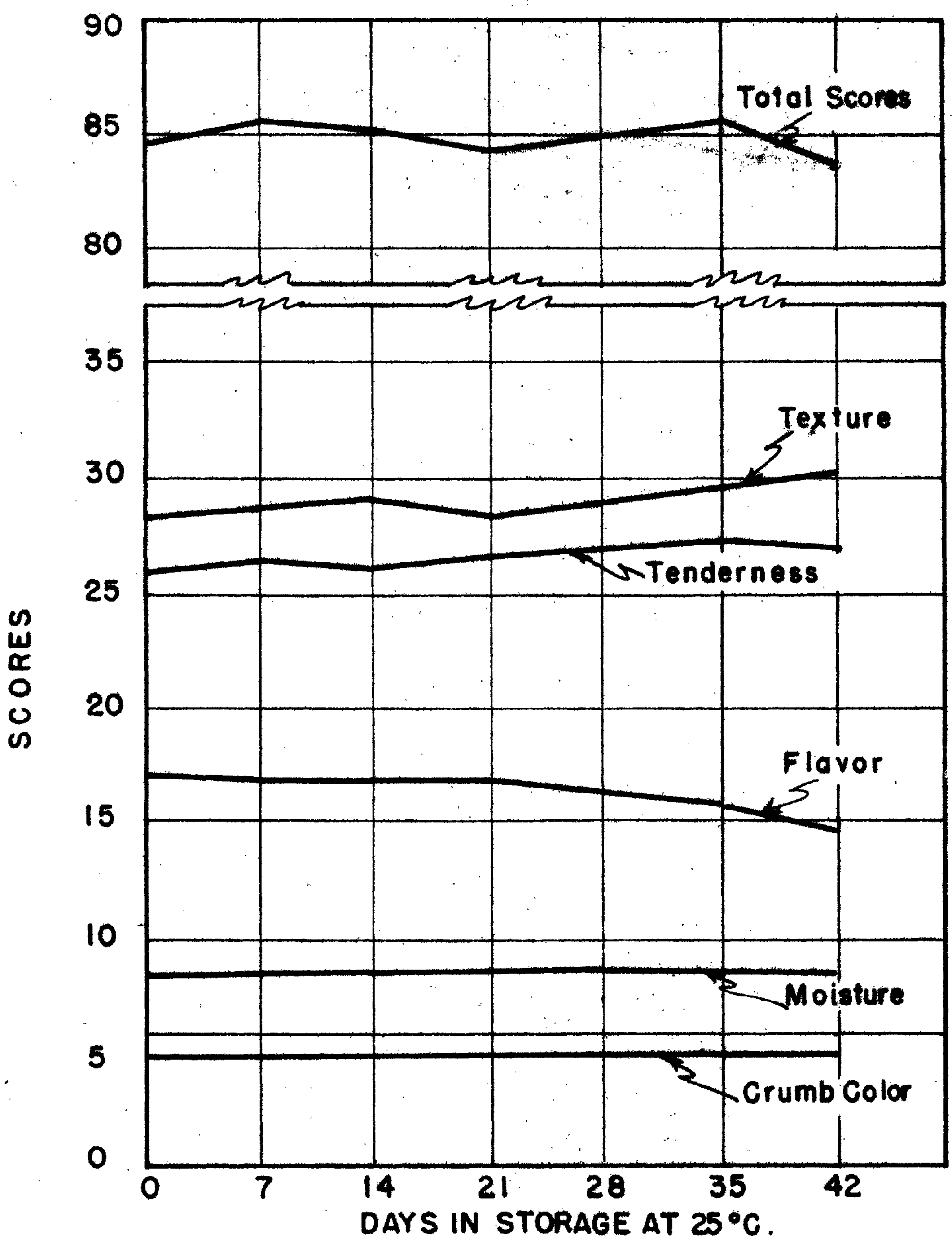


Fig. 4. Mean Scores of Cakes Made with Fresh and Aged Infertile Shell Eggs.

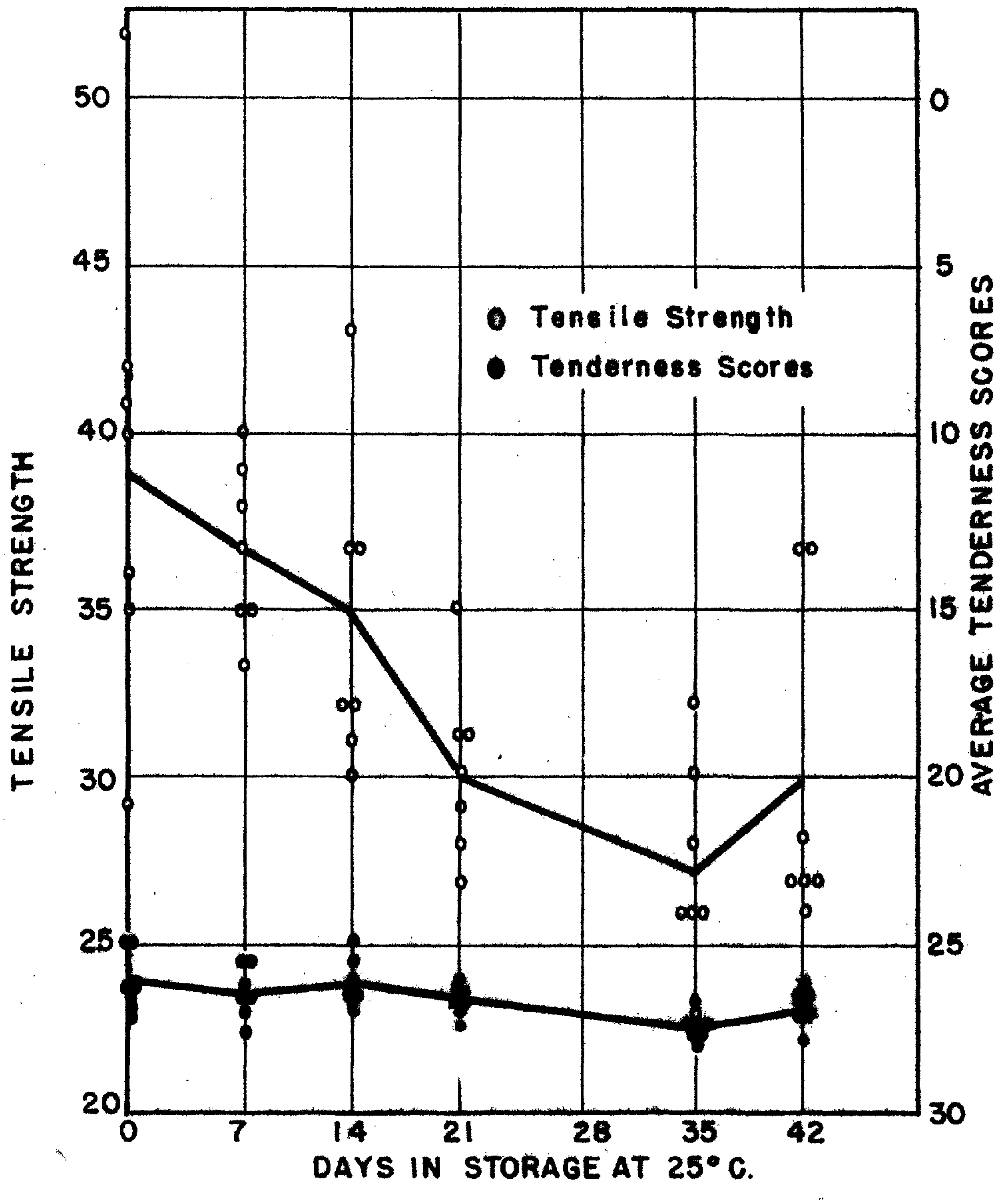
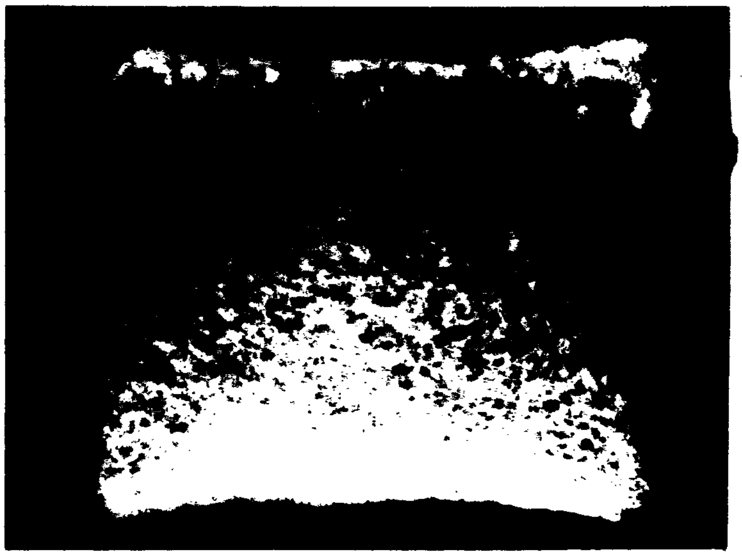
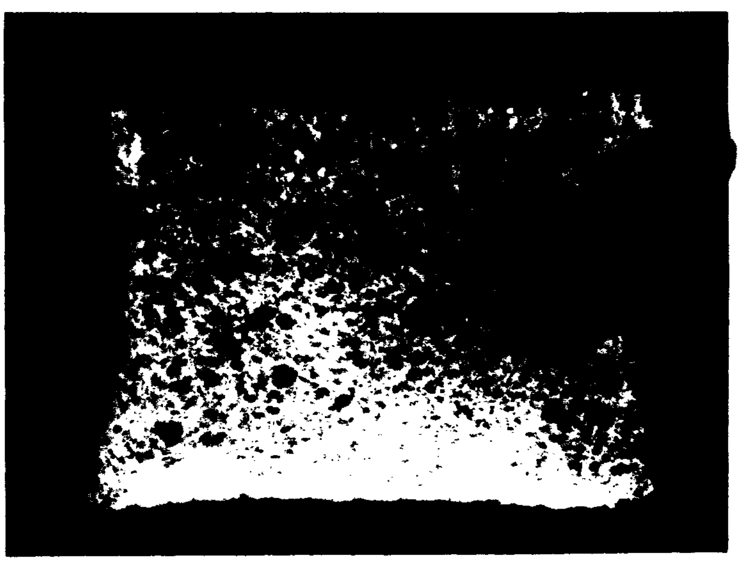


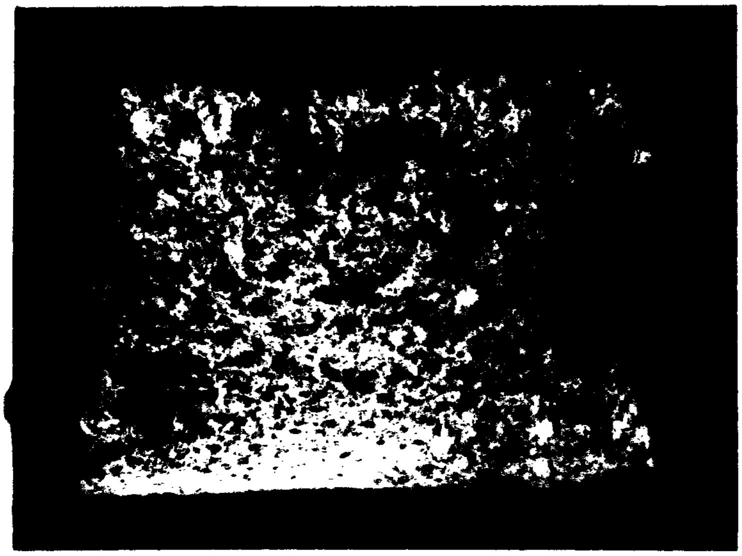
Fig. 5. Tensile Strength and Average Tenderness Scores for Cakes Made with Fresh and Aged Infertile Shell Eggs.



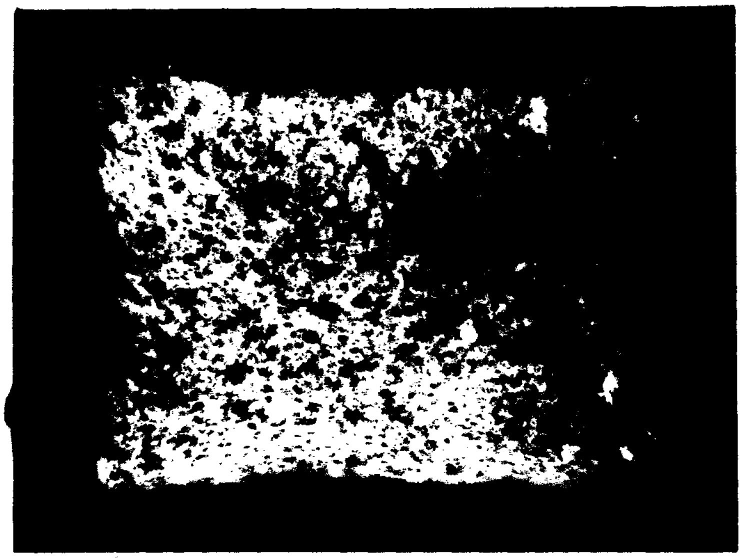
Photograph 2. Cake Made with Fresh Infertile Shell Eggs



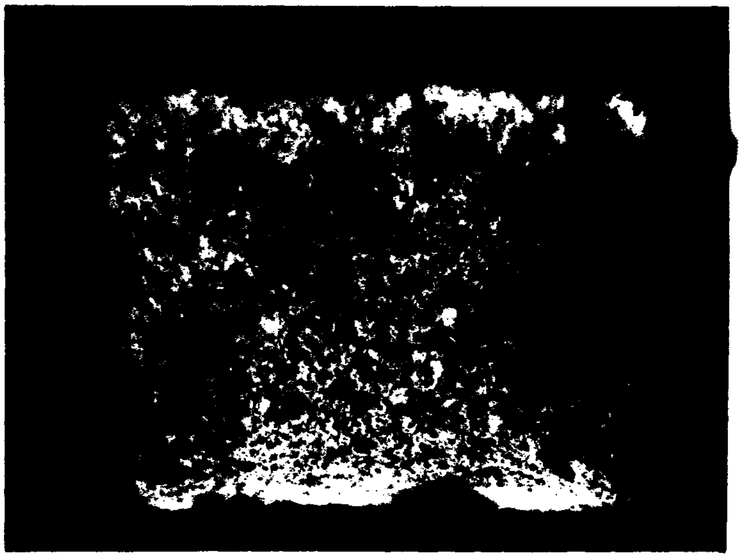
Photograph 3. Cake Made with Infertile Shell Eggs Stored 7 Days at 25°C



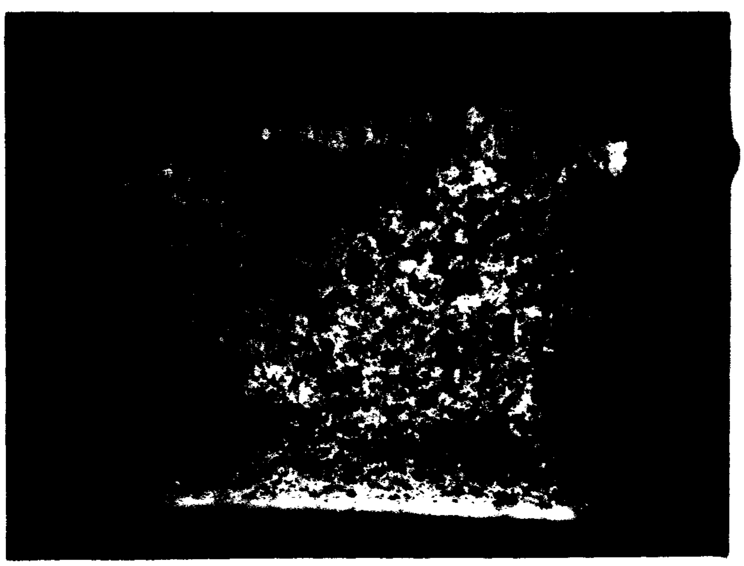
Photograph 4. Cake Made with Infertile Shell Eggs Stored 14 Days at 25°C



Photograph 5. Cake Made with Infertile Shell Eggs Stored 21 Days at 25°C



Photograph 6. Cake Made with Infertile Shell Eggs Aged 35 Days at 25°C



Photograph 7. Cake Made with Infertile Shell Eggs Aged 42 Days at 25°C

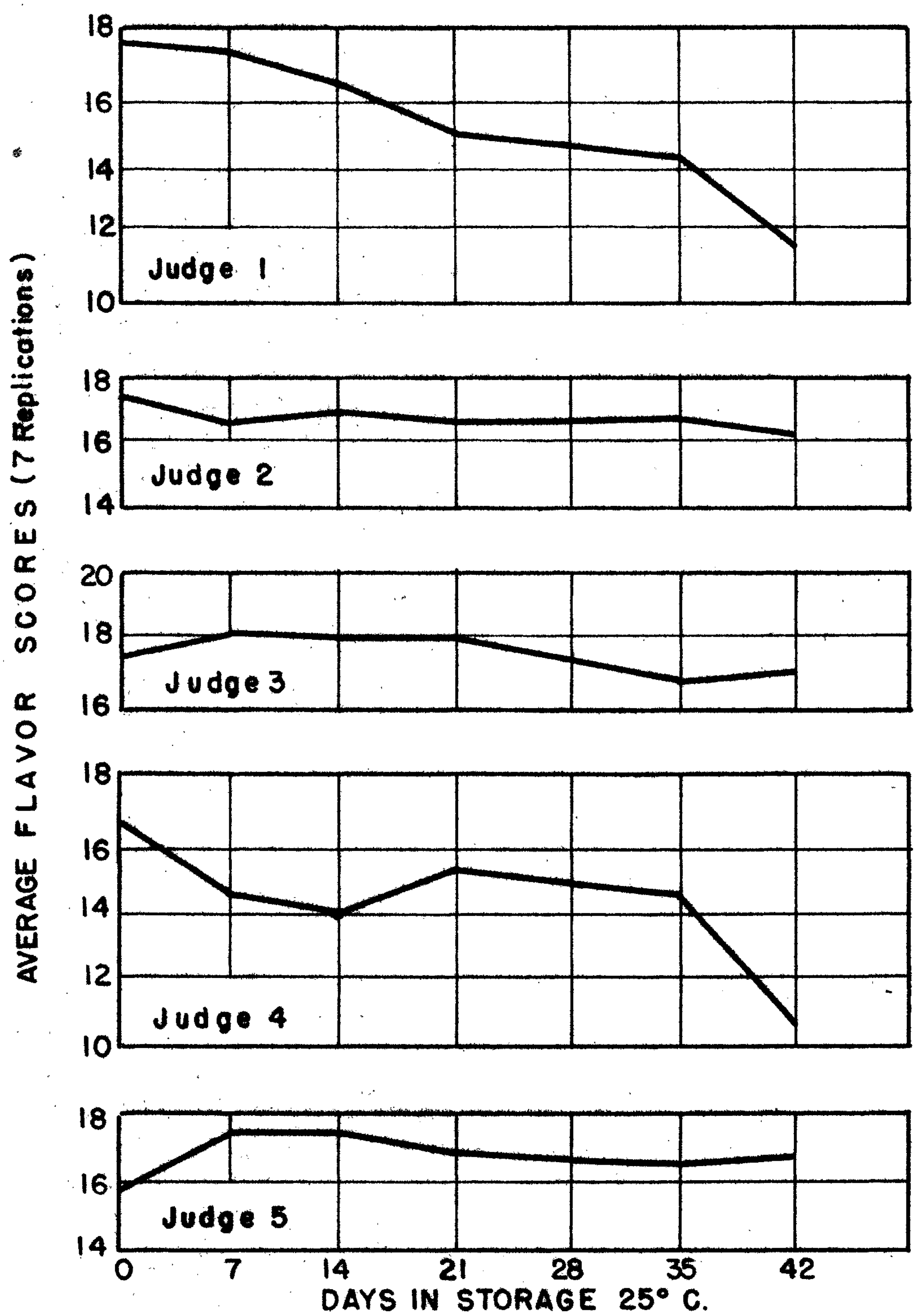


Fig. 6. Individual Judge's Sensitivity to Flavor Differences Due to Chemical Changes in Stored Shell Egg.

for each judge. It is apparent that only two of the five judges detected deteriorative flavors in cakes made with stored eggs.

SERIES II. Cakes Made with Fresh Infertile Shell Eggs Beaten at 24°C and 27°C and the Foam Combined with the Flour in 50, 60, and 75 Strokes

This experiment was undertaken because the textures of the fresh egg cakes in Series I were coarse and inferior to textures of cakes made with aged eggs. The most feasible explanation seemed to lie in insufficient mixing in incorporating the flour since the specific gravities of the foams were exactly the same as those obtained for aged eggs. The following facts were considered:

1) The technique of using 50 strokes to incorporate the flour was developed in the preliminary investigation in which so-called fresh eggs from the foods storeroom were used. The few cases in which Haugh unit had been determined indicated that these eggs were similar in quality to eggs stored at 25°C (77°F) for seven days, that is, a Haugh unit of approximately 55.
2) Butter cakes that have been insufficiently mixed show coarse cell walls, large cells and bready texture; with more mixing the grain of the cake is finer and the cell walls thinner (Lowe, 1943).
3) Butter cakes may show increased volume with increased mixing (Lowe, 1943).

Quality of the eggs

No objective measurement of quality of the eggs was made in this series. It was noted that all eggs had upstanding yolks and a large percentage of thick white. They were from the same group of hens in the same laying cycle as the eggs in Series I and were used no later than 24 hours after they were laid.

pH of egg magma and cake batters

The average pH, 7.29, of the egg magma was approximately the same as the pH of the fresh egg magma in Series I, 7.22. The pH of the batters, 5.18, was the same as in Series I, 5.18.

Foaming properties and foam stability

Eggs foamed readily whether beaten at 24°C (75.2°F) or at 27°C (80.6°F) but the desired lightness was attained more quickly when beaten at 27°C (80.6°F). The average total beating times required to reach a specific gravity of foam of 0.25 were 301 and 286 seconds respectively. Sufficient foam was beaten each time to make three cakes. After the desired lightness of foam was attained, it was divided into three equal parts and combined with the flour in 50, 60, and 75 strokes.

Rates of drainage of the foams were not investigated. Specific gravities of the batters differed little in spite of the difference in amount of mixing. The average specific gravities of batters are shown in Table 11.

Table 11

Specific Gravities of Sponge Cake Batters Made with Fresh Infertile Shell Eggs Beaten at 24°C and 27°C and the Foams Combined with the Flour in 50, 60, and 75 Strokes

Strokes	24°C	27°C
50	0.312	0.304
60	0.311	0.311
75	0.309	0.312

Pyke and Johnson (1941) obtained a definite specific gravity of batter by varying the amount of mixing. This study shows that the extent of mixing has a definite effect on the finished cake.

Volumes of cakes

There was a slight but definite increase in volume of cake caused by the increased mixing but no difference in volume attributable to temperature of eggs. The average volumes of cakes are given in Table 12 and are shown graphically in Figure 3 on the same Figure as volumes of cakes for Series I. Comparing the volumes for the two series (Figure 3), it is apparent that the optimum amount of mixing of foam and flour for maximum volume of cake, varies with the quality of the eggs.

Table 12

Average Volumes of Cakes Made with Fresh Infertile Shell Eggs Beaten at 24°C and 27°C and the Foam Combined with the Flour in 50, 60, and 75 Strokes

Strokes	24°C	27°C
	cc.	cc.
50	687	689
60	700	695
75	707	713

Tensile strength of cakes

There was no appreciable difference in tenderness of cakes as shown by tensile strength measurements. The value obtained was approximately 40 units which was similar to the value for tensile strength of cakes made with fresh eggs in Series I.

Palatability of cakes

All cakes had a pleasing shape and color although those mixed 50 strokes tended to have slightly spotty crusts. The average scores (5 judges, 5 replications) for all characteristics are given in Table 13. A gradual improvement in cakes due to increased mixing of the foam and flour is reflected in increased tenderness, texture, flavor, and total scores. The analysis of variance, however, showed that differences obtained were not of statistical significance.

Table 13

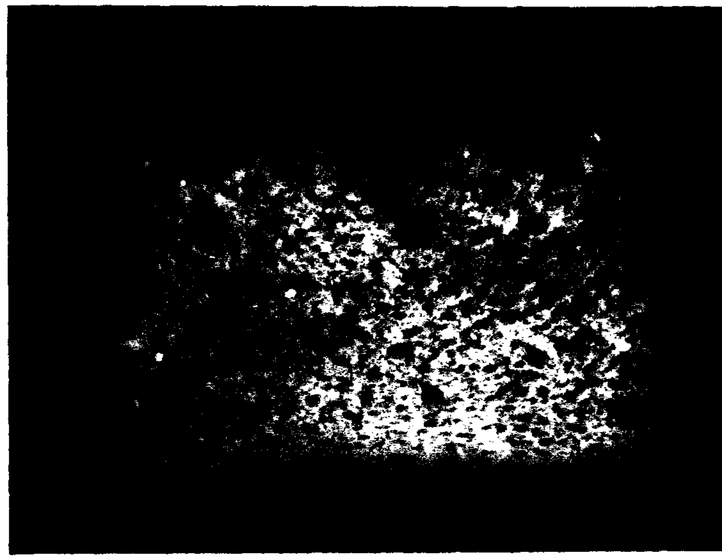
Average Scores of Cakes Made with Fresh Infertile Shell Eggs Beaten at 24°C and 27°C and the Foam Combined with the Flour in 50, 60, and 75 Strokes

Characteristic	24°C			27°C		
	Strokes			Strokes		
	50	60	75	50	60	75
Crumb Color (5)	5.0	5.0	5.0	5.0	5.0	5.0
Texture and Grain (35)	28.0	28.8	29.4	27.2	28.7	29.1
Tenderness (30)	25.8	26.0	26.4	26.3	26.0	26.6
Moistness (10)	8.3	8.4	8.5	8.5	8.3	8.4
Flavor (20)	17.2	17.6	17.9	17.4	17.5	17.8
Total Scores (100)	84.3	85.8	87.1	84.4	85.5	86.9

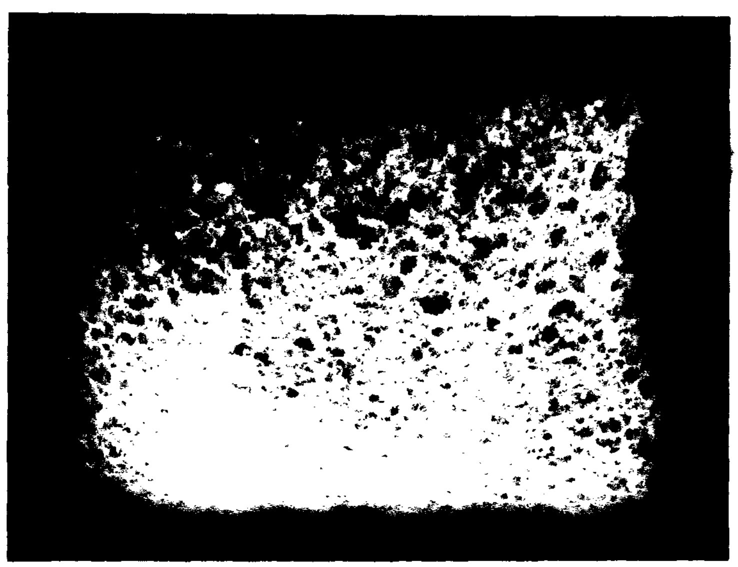
The improvement in texture with increased mixing of the batter is recorded in Photographs 8 to 13 inclusive. It is readily observed that the cakes mixed with 75 strokes have the most delicate texture. Further work needs to be done to ascertain whether or not the best conditions observed here are the optimum conditions for making cakes by whole-egg meringue method with strictly fresh eggs.

SERIES III. Cakes Made with Unheated and Pasteurized Liquid Whole Egg and Unheated and Pasteurized Commercially Frozen Egg

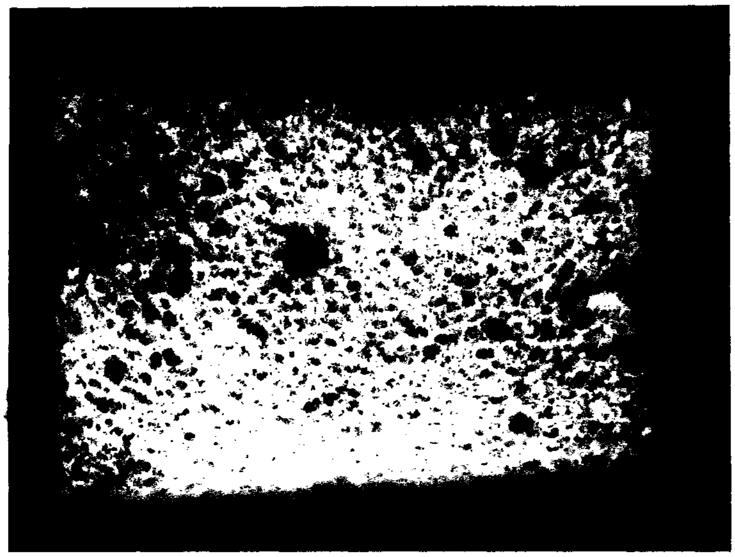
The eggs used in this series were from two sources: 1) shell eggs of known history obtained from the College



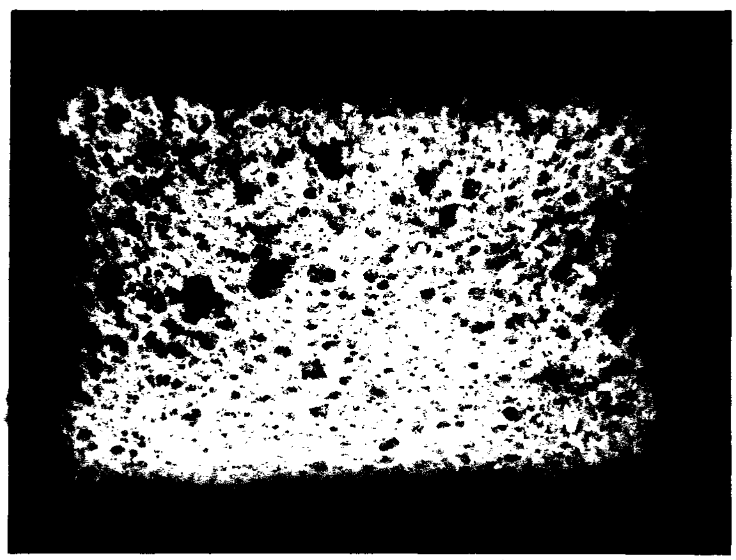
Photograph 8. Cake Made with Fresh Infertile Shell Eggs Beaten at 24°C and Foam Combined with Flour in 50 Strokes



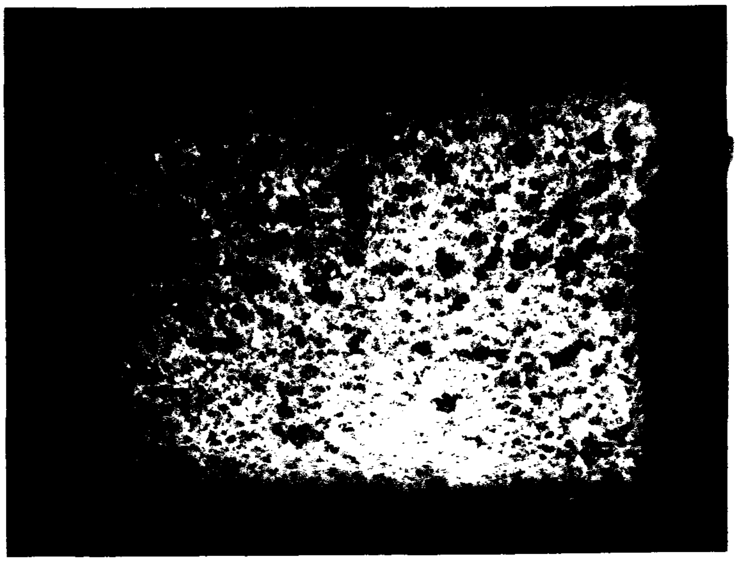
Photograph 9. Cake Made with Fresh Infertile Shell Eggs Beaten at 27°C and Foam Combined with Flour in 50 Strokes



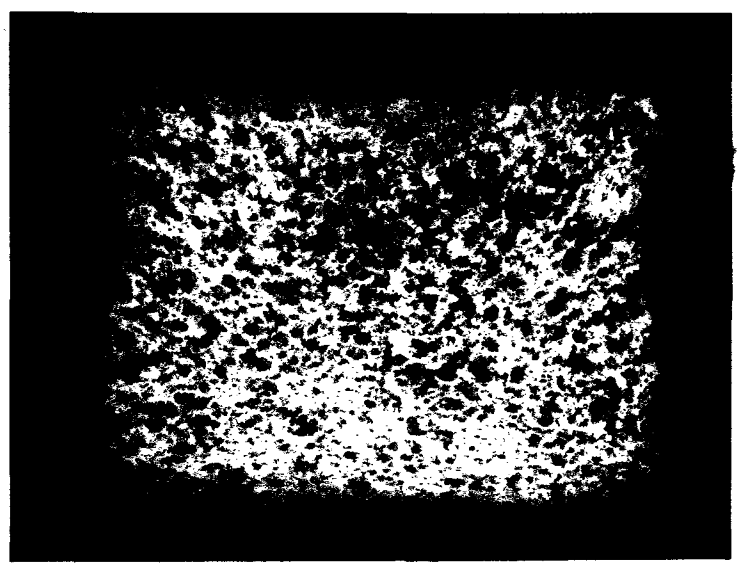
Photograph 10. Cake Made with Fresh Infertile Shell Eggs Beaten at 24°C and Foam Combined with Flour in 60 Strokes



Photograph 11. Cake Made with Fresh Infertile Shell Eggs Beaten at 27°C and Foam Combined with Flour in 60 Strokes



Photograph 12. Cake Made with Fresh Infertile Shell Eggs Beaten at 24°C and Foam Combined with Flour in 75 Strokes



Photograph 13. Cake Made with Fresh Infertile Shell Eggs Beaten at 27°C and Foam Combined with Flour in 75 Strokes

Poultry Farm, and 2) commercially frozen eggs of unknown history obtained on the open market. When prepared for use, the shell eggs were broken out of the shell, blended in a household homogenizer, and strained. A portion of the magma was set aside to serve as unheated control whereas portions of the remainder were heated as follows:

60.0°C (140°F) 8 minutes
61.1°C (142°F) 5 minutes
62.2°C (144°F) 3 minutes.

The commercially frozen egg was thawed and a portion set aside to serve as unheated control and the remainder heated to 61.7°C (143°F) for 30 minutes.

Quality of the eggs

Quality of the shell eggs at the time of use was assessed by Haugh unit. The range of average Haugh units of replicates was 45-56 with an average of 52. No objectivement measurement of quality was made on the commercially frozen eggs. It was noted that the magma was viscous and dark yellow in color.

pH of egg magma and cake batters

The average pH values of egg magma and cake batters are found in Table 14. Heating of the egg magma seemed to increase pH slightly. The pH of cake batters tended to remain constant, however. Apparently, pH of egg magma was not closely related to the pH of cake batters.

Table 14

Average pH of Egg Magma and Cake Batters Made with Unheated and Pasteurized Liquid Whole Egg and Unheated and Pasteurized Commercially Frozen Egg

	Pasteurized Liquid Whole Egg				Com. Frozen Egg	
	Control Unheated	60.0°C 8 Min.	61.1°C 5 Min.	62.2°C 3 Min.	Control Unheated	Pasteurized
Egg Magma	7.65	7.78	7.71	7.77	7.48	7.63
Cake Batter	5.07	5.05	5.08	5.09	5.06	5.05

Foaming properties and foam stability

The two samples of commercially frozen eggs foamed less readily than did the samples prepared from shell eggs, but foams of the desired lightness were obtained in approximately three minutes of fast beating. The average total beating times and specific gravities of foams and batters are shown in Table 15. The unheated control of the samples prepared from shell eggs required less time for beating than the heated samples whereas the opposite was true for the samples prepared from commercially frozen eggs.

The specific gravity of the batters made with the commercially frozen eggs were slightly greater than those of the other egg treatments indicating that there was less water available in the foams for absorption by the flour. The batters appeared drier and more viscous than those of the other egg treatments.

Table 15

Average Total Beating Times and Specific Gravities of Foams and Batters Made with Unheated and Pasteurized Liquid Whole Egg and Unheated and Pasteurized Commercially Frozen Egg

	Pasteurized Liquid Whole Egg				Com. Frozen Egg	
	Control Unheated	60.0°C 8 Min.	61.1°C 5 Min.	62.2°C 3 Min.	Control Unheated	Pasteurized
Total Beating Time, Sec.	328	375	342	342	450	402
Specific Gravity of Foam	0.259	0.265	0.263	0.265	0.258	0.261
Specific Gravity of Batter	0.315	0.326	0.318	0.324	0.331	0.332

The foam drainage tests showed that there was less free water in the foams made from the commercially frozen eggs than from the other egg treatments; the amount of liquid drained in one hour was not appreciable. The average volume of liquid drained from foams in this series is given in Table 16 and illustrated graphically in Figure 2.

Table 16

Average Milliliters of Liquid Drained in One Hour from Egg-Sugar Foams Made with Unheated and Pasteurized Liquid Whole Egg and Unheated and Pasteurized Commercially Frozen Egg

Pasteurized Liquid Whole Egg				Com. Frozen Egg	
Control Unheated	60.0°C 8 Min.	61.1°C 5 Min.	62.2°C 3 Min.	Control Unheated	Pasteurized
11.1	5.5	5.7	8.7	0.3	0.3

Comparing the average volumes of liquid drained for all samples, Figure 2, it is apparent that the unheated control of the samples prepared from shell eggs was the least stable;

pasteurization seemed to increase stability.

Pyke and Johnson (1940) had reported that foams which drained rather rapidly produced the best sponge cakes since water was readily available for absorption by the flour resulting in a more stable batter.

Volumes of cakes

Heating to the pasteurization times and temperatures used in this series apparently had no effect on the volumes of the cakes made from egg magma prepared from shell eggs. Also, in this group there was no apparent correlation between cake volume and rate of drainage of foam. The pasteurized sample of the commercially frozen egg, however, produced a cake of larger volume than did the unheated sample. Average volumes of all cakes are given in Table 17 and are shown graphically in Figure 7.

Table 17

Average Volumes of Cakes Made with Unheated and Pasteurized Liquid Whole Egg and Unheated and Pasteurized Commercially Frozen Egg

Pasteurized Liquid Whole Egg				Com. Frozen Egg	
Control Unheated	60.0°C 8 Min.	61.1°C 5 Min.	62.2°C 3 Min.	Control Unheated	Pasteurized
cc.	cc.	cc.	cc.	cc.	cc.
709	703	723	716	614	651

Neither of the commercially frozen egg samples gave cakes of volume equivalent to that made with other egg treatments. Apparently there was less free water in the batter and

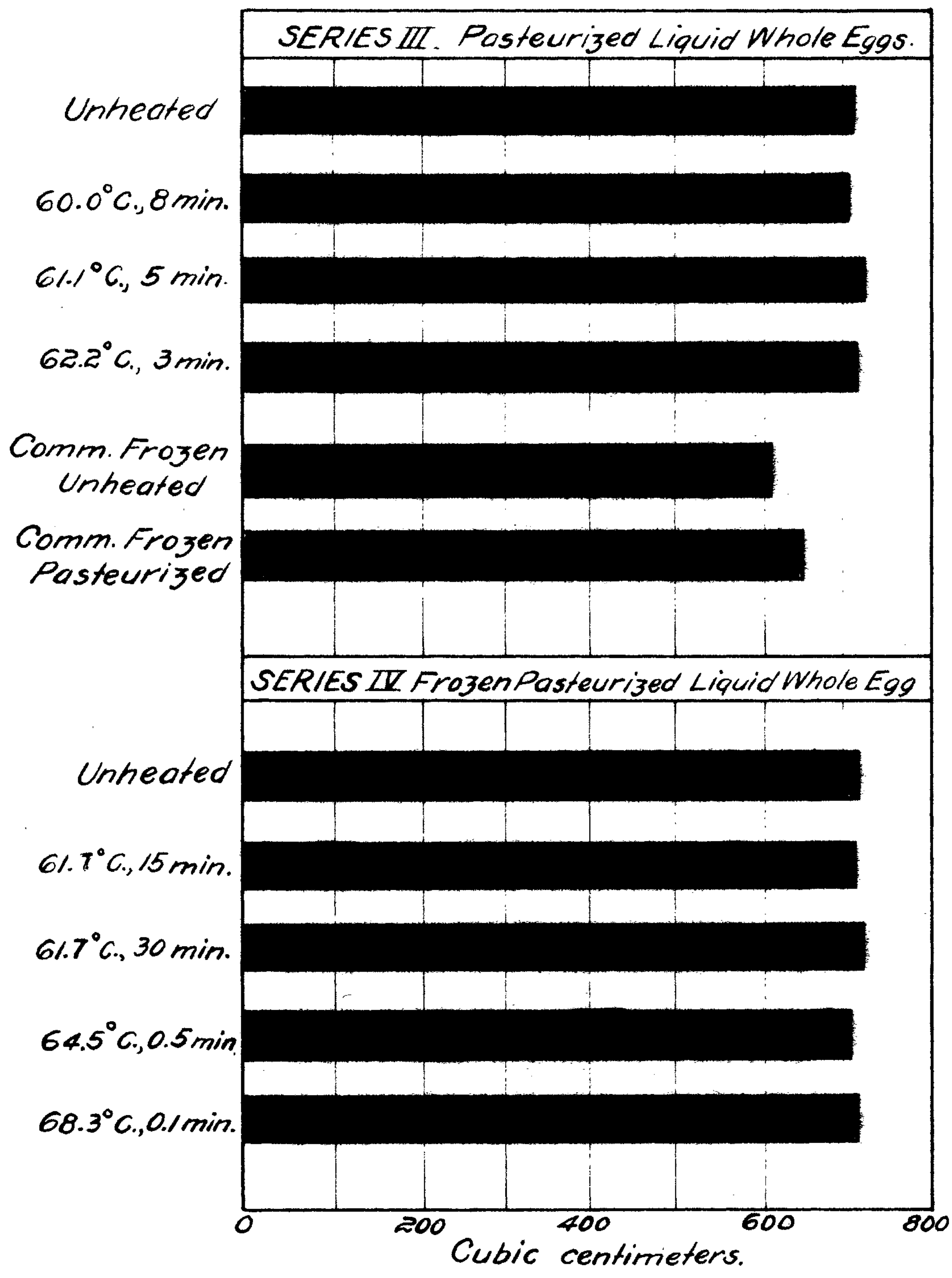


Fig. 7. Average Volumes of Cakes made with Unfrozen and Frozen Liquid Whole Eggs.

consequently less steam formed for leaven since the difference in entrapped air, as indicated by specific gravities of batters, was not appreciable and it is known that steam leavens more than air.

Tensile strength of cakes

Cakes made with pasteurized egg magma tended to be more tender, as measured by tensile strength, than the unheated controls. The average tensile strength values are shown in Table 18.

Table 18

Average Tensile Strength of Cakes Made with Unheated and Pasteurized Liquid Whole Egg and Unheated and Pasteurized Commercially Frozen Egg

Pasteurized Liquid Whole Egg				Com. Frozen Egg	
Control Unheated	60.0°C 8 Min.	61.1°C 5 Min.	62.2°C 3 Min.	Control Unheated	Pasteurized
39	39	33	32	38	32

The average tensile strength of cakes made with egg magma prepared from shell eggs correlated negatively with cake volume as did the tensile strength of cake made with commercially frozen eggs, but the correlation was not consistent between the two groups. That is, the two unheated controls had the same tensile strength but considerable volume difference, 709 and 614 cc.

The average tensile strength of cakes made with unheated magma prepared from shell eggs was the same as the tensile strength of cakes made from fresh eggs in Series I, 39 units.

Palatability of cakes

A pleasing appearance in color, crust, and shape was obtained in cakes from all egg treatments. The average scores (5 judges, 6 replications) for all characteristics are shown in Table 19.

Table 19

Average Scores of Cakes Made with Unheated and Pasteurized Liquid Whole Egg and Unheated and Pasteurized Commercially Frozen Egg

Characteristic	Pasteurized Liquid Whole Egg				Com. Frozen Egg	
	Control Unheated	60.0°C 8 Min.	61.1°C 5 Min.	62.2°C 3 Min.	Control Unheated	Pasteurized
Crumb Color (5)	5.0	5.0	5.0	5.0	5.0	5.0
Texture and Grain (35)	29.6	29.8	29.9	29.6	27.7	27.7
Tenderness (30)	26.9	27.2	27.3	27.1	25.8	26.8
Moistness (10)	8.4	8.7	8.6	8.6	8.2	8.5
Flavor (20)	17.4	17.5	17.6	17.1	15.2	15.6
Total Scores (100)	87.5	88.3	88.6	87.6	81.7	83.6

Cakes of both samples of commercially frozen egg were scored lower for texture, tenderness, and flavor than cakes made with other egg treatments. Analysis of variance showed that cake quality was affected by egg treatment but only insofar as egg samples originated from shell eggs or from commercially frozen eggs and not within these two groups.

SERIES IV. Cakes Made from Frozen Unheated and Frozen Pasteurized Liquid Whole Egg

Eggs for this series were obtained from the College Poultry Farm and stored seven days at room temperature. When prepared for use, they were broken out of the shell, blended in a household homogenizer, strained and a portion of the magma was set aside to serve as unheated control. Portions of the remainder were heated to the following times and temperatures:

61.7°C (143°F) for 15 minutes
61.7°C (143°F) for 30 minutes
64.5°C (148°F) for 0.5 minute
68.3°C (155°F) for 0.1 minute.

These treatments gave two variables in each of hold and flash pasteurization temperatures. All samples were subsequently quick-frozen and kept in the frozen state until the following day when baking tests were made.

Quality of eggs

Eggs were obtained from the same source during the same laying cycle and were stored the same length of time as the shell eggs in Series III so were assumed to be of the same quality, that is, a Haugh unit of approximately 50.

Thawed magmas of the pasteurized samples seemed more viscous and slightly darker in color than the unheated control.

pH of egg magma and of cake batters

The average pH values for egg magma and cake batters are found in Table 20.

Table 20

Average pH of Egg Magma and Cake Batters Made with Frozen Unheated and Frozen Pasteurized Liquid Whole Egg

	Control Unheated	61.7°C 15 Min.	61.7°C 30 Min.	64.5°C 0.5 Min.	68.3°C 0.1 Min.
Egg Magma	7.64	7.69	7.78	7.63	7.67
Cake Batter	5.17	5.19	5.17	5.19	5.17

The slight increase in pH of egg magma caused by heating of the eggs, observed in Series III, is less noticeable in this series. The pH of the unheated samples in each series, 7.64, was the same from which it is assumed that freezing had no effect on pH of egg magma.

There was no appreciable difference in pH of cake batters. They were slightly higher than was observed in Series III (approximately 5.07).

Foaming properties and foam stability

All egg samples appeared to foam readily although the pasteurized samples required nearly twice as much fast beating to reach a definite specific gravity as was required by the unheated control. Average total beating times and the specific gravities of foams and batters are found in Table 21.

Table 21

Average Total Beating Times and Specific Gravities of Foams and Batters Made with Frozen Unheated and Frozen Pasteurized Liquid Whole Egg

	Control Unheated	61.7°C 15 Min.	61.7°C 30 Min.	64.5°C 0.5 Min.	68.3°C 0.1 Min.
Total Beating Time, Sec.	202	267	256	234	304
Specific Gravity of Foam	0.264	0.269	0.268	0.264	0.269
Specific Gravity of Batter	0.326	0.334	0.334	0.328	0.336

There was no difficulty in incorporating the flour in any foam indicating that water was readily available for absorption by the flour in all samples. A comparison of the rate of drainage of the foams, however, showed that unheated samples drained more rapidly than heated samples. Average volumes of liquid drained in one hour from foams are found in Table 22 and are illustrated graphically with other foam drainage tests in Figure 2.

Table 22

Average Milliliters of Liquid Drained in One Hour from Egg-Sugar Foams Made with Frozen Unheated and Frozen Pasteurized Liquid Whole Egg

Control Unheated	61.7°C 15 Min.	61.7°C 30 Min.	64.5°C 0.5 Min.	68.3°C 0.1 Min.
16.4	8.2	9.3	12.7	6.1

Foams made with frozen eggs, Series IV, drained more rapidly than foams made with unfrozen eggs, Series III; and in both series the unheated samples drained more rapidly than pasteurized samples.

Volumes of cakes

The replicate cakes varied more in volume than did the cakes from different egg treatments. The average volumes obtained are shown in Table 23 and are illustrated in Figure 7.

Table 23

Average Volumes of Cakes Made with Frozen Unheated and Frozen Pasteurized Liquid Whole Egg

Control Unheated	61.7°C 15 Min.	61.7°C 30 Min.	64.5°C 0.5 Min.	68.3°C 0.1 Min.
cc.	cc.	cc.	cc.	cc.
714	709	715	702	716

There was no apparent relationship between rate of drainage of foams and volumes of cakes. Comparing the volumes of cakes made with unfrozen egg magma with the volumes obtained with the frozen magma, Figure 7, it is apparent that freezing had no effect on cake volumes. In both Series III and IV pasteurized eggs produced cakes of volume equivalent to the unheated control samples.

Tensile strength of cakes

The slight variation in tenderness of the cakes, as shown by tensile strength measurements, did not seem to be related to any known factor. The average values observed were as follows:

Unheated control. 34
61.7°C, 15 min. 32
61.7°C, 30 min. 32
64.5°C, 0.5 min.. 34
68.3°C, 0.1 min.. . . . . . .38.

Palatability of cakes

All cakes were of equally pleasing appearance. They browned well and the crusts were thin and fine. The average scores (5 judges, 5 replications) for all characteristics are given in Table 24.

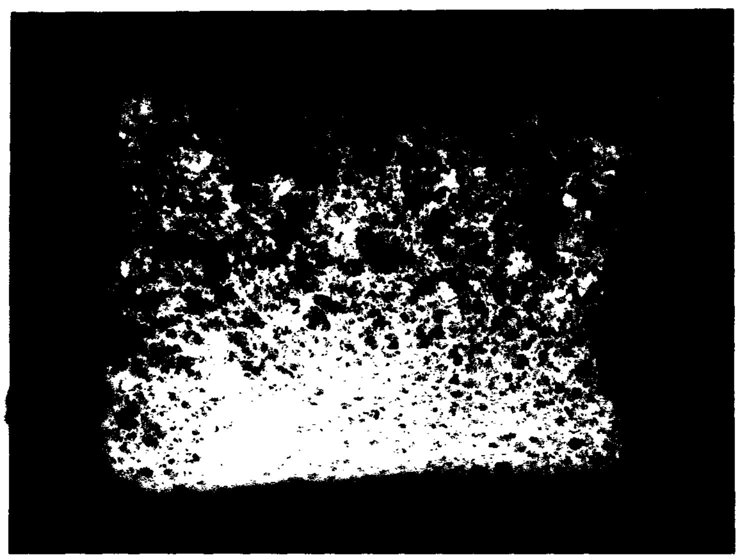
Table 24

Average Scores of Cakes Made with Frozen Unheated and Frozen Pasteurized Liquid Whole Egg

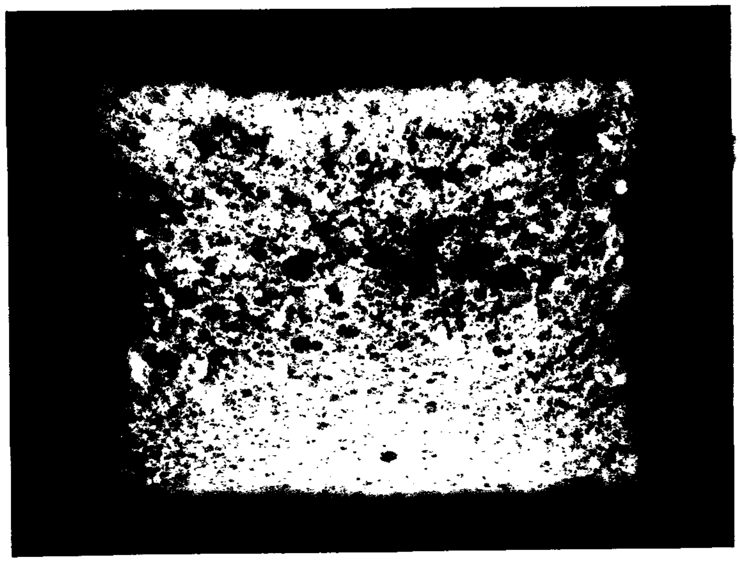
Characteristic	Control Unheated	61.7°C 15 Min.	61.7°C 30 Min.	64.5°C 0.5 Min.	68.3°C 0.1 Min.
Crumb Color (5)	5.0	5.0	5.0	5.0	5.0
Texture and Grain (35)	28.6	30.5	30.7	28.2	30.3
Tenderness (30)	26.0	25.6	25.7	25.1	25.7
Moistness (10)	8.8	8.6	8.6	8.6	8.6
Flavor (20)	17.0	16.9	16.1	17.3	17.3
Total Scores (100)	85.5	86.7	86.1	84.2	86.9

There were no appreciable differences for any of the characteristics among the cakes made from different egg treatments; and it is apparent that there were no differences in quality of cake due to egg treatment as shown by judges' total scores.

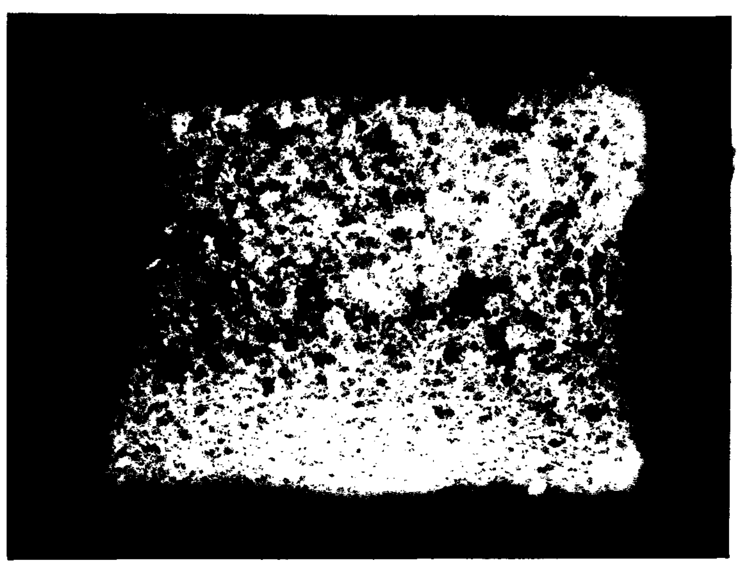
Textures of the cakes are recorded in Photographs 14 to 18 inclusive. Uniformity of texture and fineness of cell wall are observable in all cakes.



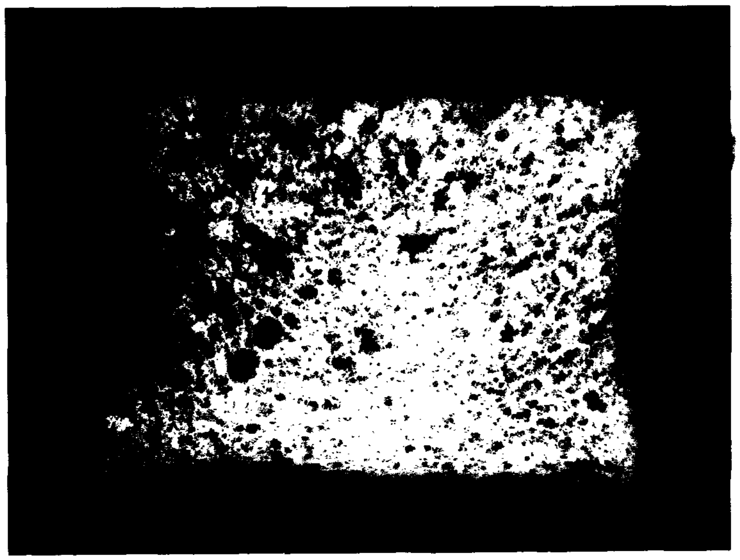
Photograph 14. Cake Made with Frozen Unheated Liquid Whole Egg



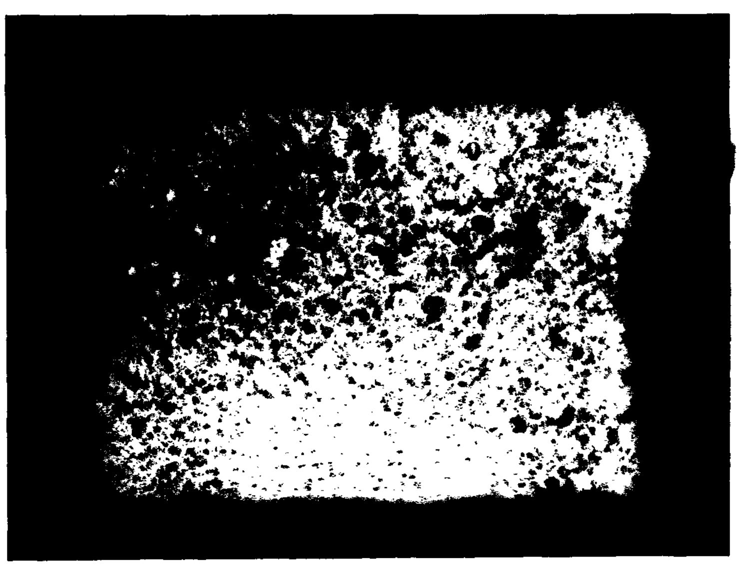
Photograph 15. Cake Made with Frozen Pasteurized (61.7°C, 15 Min.) Liquid Whole Egg



Photograph 16. Cake Made with Frozen Pasteurized (61.7°C, 30 Min.) Liquid Whole Egg



Photograph 17. Cake Made with Frozen Pasteurized (64.5°C, 0.5 Min.) Liquid Whole Egg



Photograph 18. Cake Made with Frozen Pasteurized (68.3°C, 0.1 Min.) Liquid Whole Egg

SERIES V. Cakes Made with Spray-dried (0.5% moisture) Whole Egg

This study was undertaken to determine whether whole eggs dried to a very low moisture (0.5 per cent) content, retained their beating properties. The addition of grated lemon rind was done to observe to what extent dried egg flavors could be masked in sponge cake. Bennion, Hawthorne, and Bate-Smith (1942) had reported that the unpleasant flavor in scrambles made with dried eggs was not noticeable in the finished sponge cakes. Baking powder was used as a secondary leavening agent to determine whether cake quality in this instance was improved.

Quality of eggs

The container of egg powder had been opened previous to the time of this study and the powder had absorbed sufficient moisture to be of 4.41 per cent moisture at the time the cakes were made. The moisture content was not taken into consideration, however, in reconstituting the eggs.

The powder was tan in color and appeared somewhat granular. A determination of the proportion of exposed sulfhydryl groups as an estimate of the extent of denaturation of egg proteins, gave a value of 18 per cent. No figures were available for evaluation of this result but one would assume that it is reasonably low especially since the eggs had had to undergo severe treatment to attain a moisture content as low as 0.5 per cent by spray-drying methods.

pH of reconstituted egg magma and cake batters

The pH of the reconstituted egg magma was 8.38. The average pH values for cake batters were:

Control.	4.86
Flavored	4.86
Baking powder added.	5.56.

The pH for batters without baking powder was somewhat lower than was observed in batters made with liquid egg in the previous series although the pH of the reconstituted egg magma was higher. It thus appeared that the eggs had suffered a loss of buffering ability as a result of the drying treatment.

The pH of the cake batter with baking powder added was noted to be considerably higher than batters without baking powder. This is consistent with the finding of Stamberg and Bailey (1939) who reported that variations in the amount of baking powder affected the pH of white and yellow layer cakes more than any other common ingredient. The alkaline residue as well as the greater amount of stretching of the proteins owing to increase in volume, would be expected to have a tendering effect on the cakes.

Foaming properties and foam stability

Preheated egg-sugar mixes beaten at 45°C (113°F) foamed less readily than the liquid eggs in previous series but the desired lightness was obtained in approximately five minutes of fast beating. Sufficient meringue was prepared at one time for the three cakes, and divided into equivalent portions by weight. Foams appeared drier and more viscous than foams from liquid egg and 60 strokes were used to incorporate the flour. The average specific gravity of the foams was 0.238. The average specific gravities of the batters were:

Control.	0.325
Flavored	0.338
Baking powder added.	0.324.

A slight increase in specific gravity of the flavored batter over the control batter was noted.

Volumes of cakes

The average volumes of cakes are found in Table 25 and are shown graphically in Figure 8.

Table 25

Average Volumes of Cakes Made with Spray-dried (0.5% Moisture) Egg

Control	Flavored	Baking Powder Added
cc.	cc.	cc.
592	564	636

Although there was some variation among replicates, the order of volume sizes was consistently: baking powder added, control, flavored. There was approximately a 9 per cent increase in volume due to added baking powder.

Pyke and Johnson (1940) had stated that lemon juice and rind were detrimental to foam structure and if used should always be added when mixing is complete. It may be that the

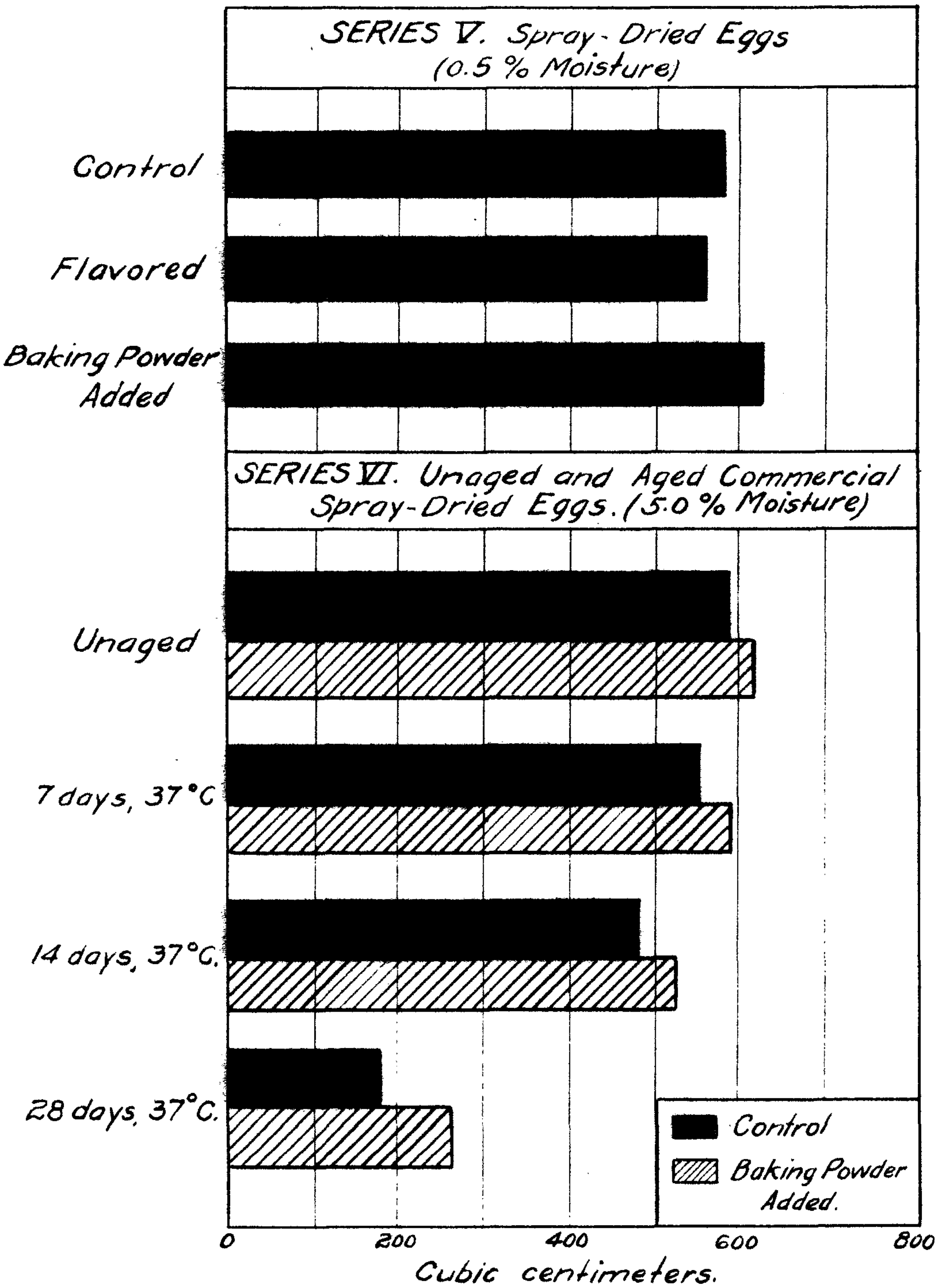


Fig. 8. Average Volumes of Cakes made with Spray-Dried Whole Egg with and without Baking Powder.

antagonistic substance is in the rind portion since cakes in this series with the same amount of lemon juice but no rind were superior to those containing rind. In this study the grated rind was added as the final 12 blending strokes were begun.

Tensile strength of cakes

Tensile strength measurements of cakes tended to correlate negatively with volumes of cakes. Cakes with added baking powder were more tender than cakes without baking powder as was expected from the higher pH of cake batter and larger volume of cake. The average values for tensile strength of cakes were:

Control.	42
Flavored	45
Baking Powder Added. . . .	37

Palatability of cakes

There were no observable differences in appearances of cakes. All browned well, had slightly rounded tops and thin crusts. The color of the cakes was tan in contrast to the bright yellow of the cakes made with liquid eggs. The average scores (5 judges, 5 replications) for all characteristics are given in Table 26. Scores for texture as well as tenderness were higher for the cakes with baking powder added than cakes without so that total scores were somewhat higher. The addition of lemon rind improved the flavor of the cakes as shown by judges' scores. Baking powder apparently improved the flavor slightly when no rind was present.

Table 26

Average Scores of Cakes Made with Spray-dried (0.5% Moisture) Egg

Characteristic	Control	Flavored	Baking Powder Added
Crumb Color (5)	4.9	4.7	4.8
Texture and Grain (35)	23.2	21.7	25.6
Tenderness (30)	22.9	22.3	23.9
Moistness (10)	8.3	8.3	8.0
Flavor (20)	14.4	16.2	15.0
Total Scores (100)	73.6	73.3	77.4

It is evident from the analysis of variance that there was no difference in quality of cakes owing to added baking powder or lemon rind as shown by judges' total scores.

SERIES VI. Cakes Made with Unaged and Aged Commercial Spray-dried (5.0% Moisture) Whole Egg

This series was undertaken to determine to what extent the beating properties of commercial spray-dried whole egg were retained during storage and whether or not a secondary leavening agent was desirable.

Quality of eggs

Samples of eggs were taken from the same lot and were put into tin containers and sealed. The containers were then stored at 37°C (98.6°F) for 0, 7, 14, and 28 days. The actual moisture contents were determined at the time the eggs were opened for use and were:

0 days, 37°C (98.6°F).	5.52%
7 days, 37°C (98.6°F).	5.46
14 days, 37°C (98.6°F).	5.57
28 days, 37°C (98.6°F).	5.32

An extimate of the extent of denaturation of the egg proteins expressed in per cent sulfhydryl groups exposed was as follows:

0 days, 37°C (98.6°F).	7% of total
7 days, 37°C (98.6°F).	37
14 days, 37°C (98.6°F).	51
28 days, 37°C (98.6°F).	67

Although no figures were available for evaluation of the results, they indicate a progressive denaturing of the proteins during storage, and it is apparent that quality decreased with increased storage time. McNally and Dizikes (1944) stated that it was necessary to measure the content of native undenatured protein of dried whole egg to obtain a useful measure of functional properties of the powder as beating, binding, or lifting power.

It was noted that the intensity of color of the powder increased with increased time in storage, the change being slight for the first seven days. Eggs stored 14 and 28 days had a strong odor.

pH of reconstituted egg magma and cake batters

The pH values of reconstituted egg magma and the average pH of cake batters are given in Table 27.

Table 27

pH of Egg Magma and Average pH of Cake Batters Made with Unaged and Aged Commercial Spray-dried (5% Moisture) Whole Egg

Days in Storage at 37°C	Egg Magma	Cake Batters Control	Cake Batters Baking Powder
0	8.36	4.89	5.49
7	8.12	4.85	5.41
14	7.67	4.81	5.48
28	7.26	4.79	5.41

The decrease in pH of egg magma with aging was in accordance with what has been reported in the literature (Stewart, Best, and Lowe, 1943; and others). The pH of cake batters also decreased due to aging of the eggs but less rapidly. The loss of buffering action of eggs during drying was noted here as in Series V; that is, egg magma had higher pH than egg magma in the liquid egg series but the pH of cake batters was lower.

The addition of baking powder increased the pH of all batters. This is in keeping with results reported in the literature (Stamberg and Bailey, 1939) and with the observation in Series V.

Foaming properties and foam stability

Egg-sugar mixes reconstituted and preheated to 68°C (154.4°F) did not foam when beaten at 45°C (113°F) as they did in Series V. Foams were obtained, however, in samples aged 0, 7, and 14 days when the preheated mixes were beaten at 80°C (176°F), but no foam was obtained in the samples aged 28 days even on prolonged beating at high speed and at high temperatures. Lemon juice in this series seemed to be inhibitory to foam formation.

The average total beating times and specific gravities of foams and batters are given in Table 28.

Table 28

Average Total Beating Times and Specific Gravities of Foams and Batters Made with Unaged and Aged Commercial Spray-dried (5% Moisture) Whole Egg

Days in Storage at 37°C	Total Beating Time, Seconds	Specific Gravity of Foam	Specific Gravity of Batters	
			Control	Baking Powder
0	360	0.231	0.361	0.361
7	383	0.242	0.350	0.343
14	588	0.294	0.437	0.426
28	(1200)*	(0.976)*	0.992	0.941

*No foam was obtained.

It is obvious that the longer the storage period, the longer the time required to beat eggs to a light foam. A foam was obtained from the sample aged 14 days with difficulty and it was impossible to obtain the desired lightness. A comparison of the beating times required and the resultant specific gravities of the foams is presented graphically in Figure 9.

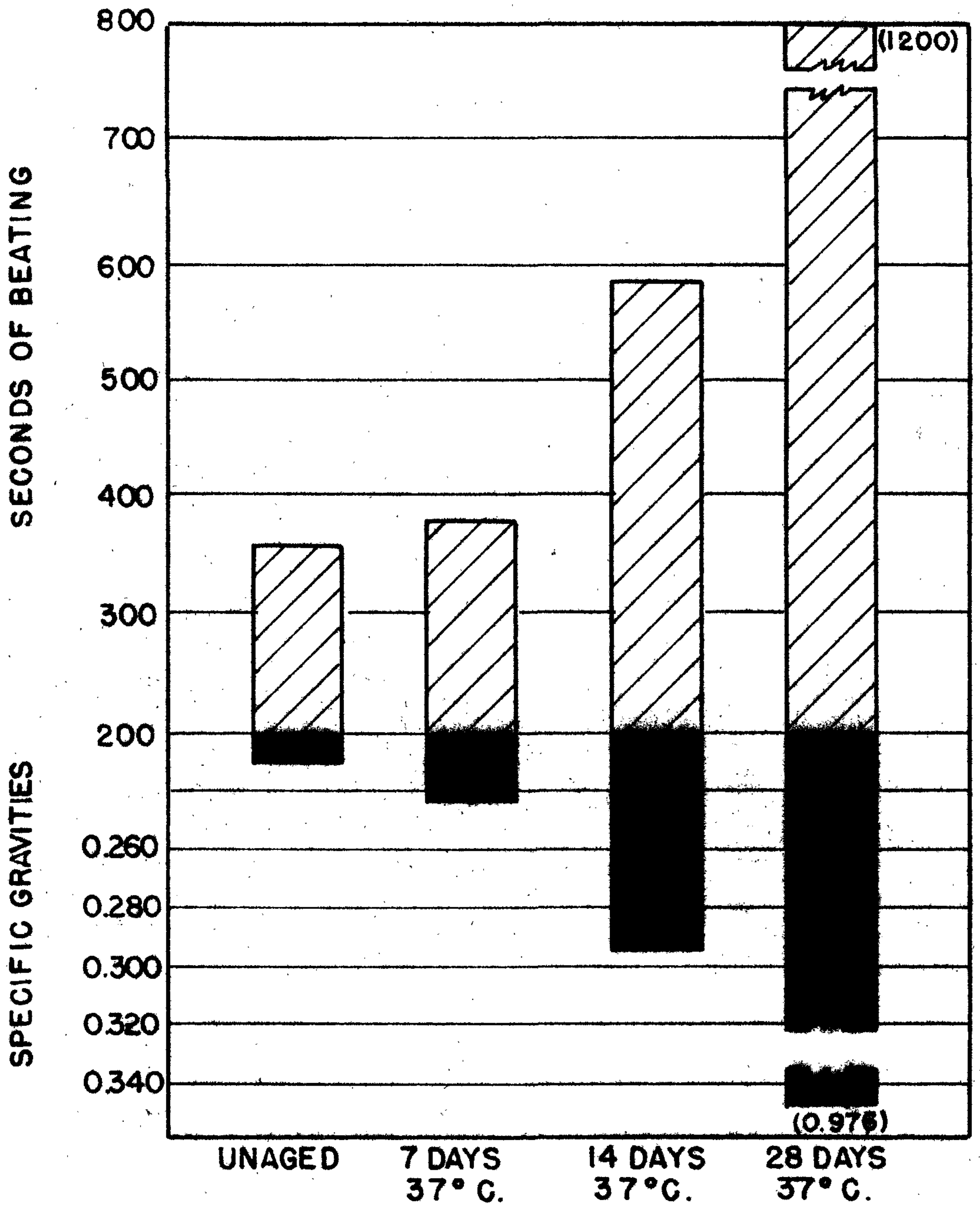


Fig. 9. Seconds of Beating and Specific Gravities of Foams Made with Unaged and Aged Commercial Spray-Dried Whole Egg (5 % Moisture).

Although Pyke and Johnson (1940) recommended cooling foams before adding the flour, foams in this study were not cooled and in this series were approximately 45°C (113°F) when the flour was added. The foams appeared drier and more viscous than foams from liquid eggs and 60 strokes were used to incorporate the flour in each cake. No drainage tests of foams were made.

<u>Volumes of cakes</u>

Volumes of cakes decreased with increased storage time of the egg powder. The average volumes of cakes are given in Table 29 and are shown graphically in Figure 9.

Table 29

Average Volumes of Cakes Made with Unaged and Aged Commercial Spray-dried (5% Moisture) Whole Egg

Days in Storage at 37°C	Control	Baking Powder Added
	cc.	cc.
0	591	624
7	564	591
14	479	525
28	185	265

The volumes of replicate cakes were consistently in the same order as shown by the averages. The volume increase owing to addition of the secondary leavening agent was slight but tended to become more effective with increased time in storage. A comparison of the unaged sample in this series with the control cake in Series V (Figure 8), indicates that cakes of equal volume were obtained from the different egg powders and that baking powder had the same effect on each.

Tensile strength of cakes

Cakes made with baking powder were more tender than the control cakes in each storage period but there was no apparent relation between storage time and tenderness as shown by tensile strength. The average tensile strength values are found in Table 30.

Table 30

Average Tensile Strength of Cakes Made with Unaged and Aged Commercial Spray-dried (5% Moisture) Whole Egg

Days in Storage at 37°C	Control	Baking Powder
0	40	33
7	34	28
14	44	40
28	--	--

The tendering effect of the baking powder was no doubt due to the increased expansion during baking and the peptizing action of the alkaline residue on the proteins.

Palatability of cakes

The general appearance of cakes made from powder stored 0 and 7 days was excellent; all had a good shape, thin crust, and delicate brown color. Cakes made with egg powder aged 14 days did not brown readily and tended to have thick soggy crusts. The average scores (5 judges, 5 replications) for all characteristics are shown in Table 31.

Table 31

Average Scores of Cakes Made with Unaged and Aged Commercial Spray-dried (5% Moisture) Whole Egg

Characteristic	Days in Storage at 37°C							
	0		7		14		28	
	Control	Baking Powder	Control	Baking Powder	Control	Baking Powder	Control	Baking Powder
Crumb Color (5)	5.0	4.9	4.6	4.7	3.4	3.9	1.0	1.0
Texture and Grain (35)	26.6	24.8	24.6	24.4	17.6	20.3	0.4	6.8
Tenderness (30)	24.3	23.8	23.8	24.1	20.5	21.6	4.0	7.4
Moistness (10)	8.5	7.8	8.0	8.2	7.4	7.7	2.8	2.6
Flavor (20)	14.2	13.9	13.6	13.5	9.8	10.9	2.8	3.0
Total Scores (100)	78.4	75.2	74.5	74.8	58.8	64.4	11.0	20.8

In general, scores for all factors tended to decrease with increasing storage time although the decrease in seven days was not appreciable. Cakes made with powder aged 14 days were unpalatable and cakes made with powder aged 28 days were inedible.

The effect of baking powder on palatability varied; in cakes made with unaged powder the baking powder seemed to have an adverse effect since all factors were scored lower. There was no appreciable difference in any of the characteristics of the cakes made with eggs aged seven days whereas baking powder improved cakes made with powder aged 14 days in all respects. Since egg powder aged 28 days had lost its foaming power, only single cakes were baked although several attempts to obtain a foam were made. Neither cake was edible.

It is evident from analysis of variance that cake quality was affected by aging of the egg powder as shown by judges' total scores but cake quality was not affected by the addition of baking powder.

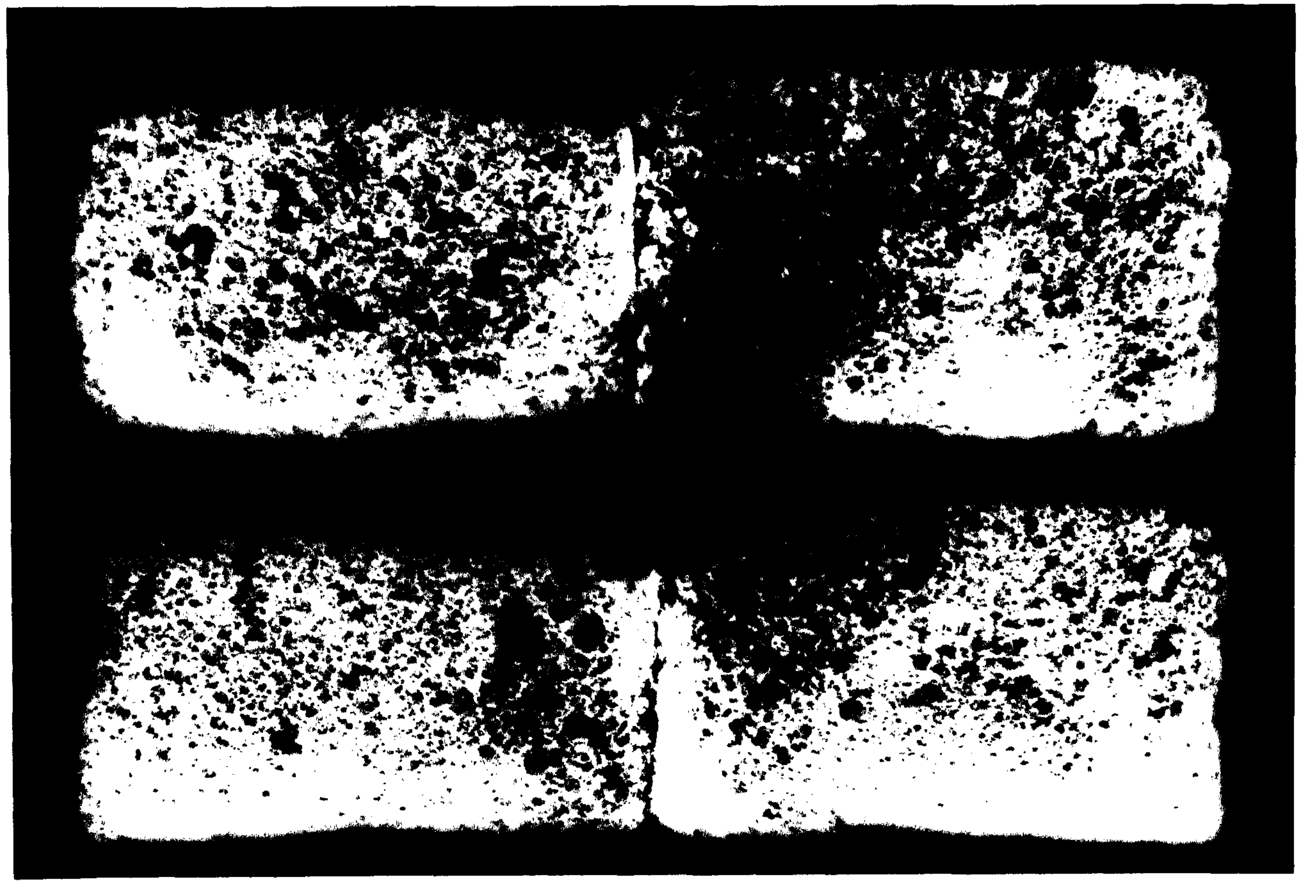
Cake texture is recorded in Photographs 19 and 20. The decrease in volume as well as the increase in compactness of texture with increased storage time of the egg powder is readily seen.

SERIES VII. Cakes Made with Unaged Spray-dried Whole Egg from Different Plants

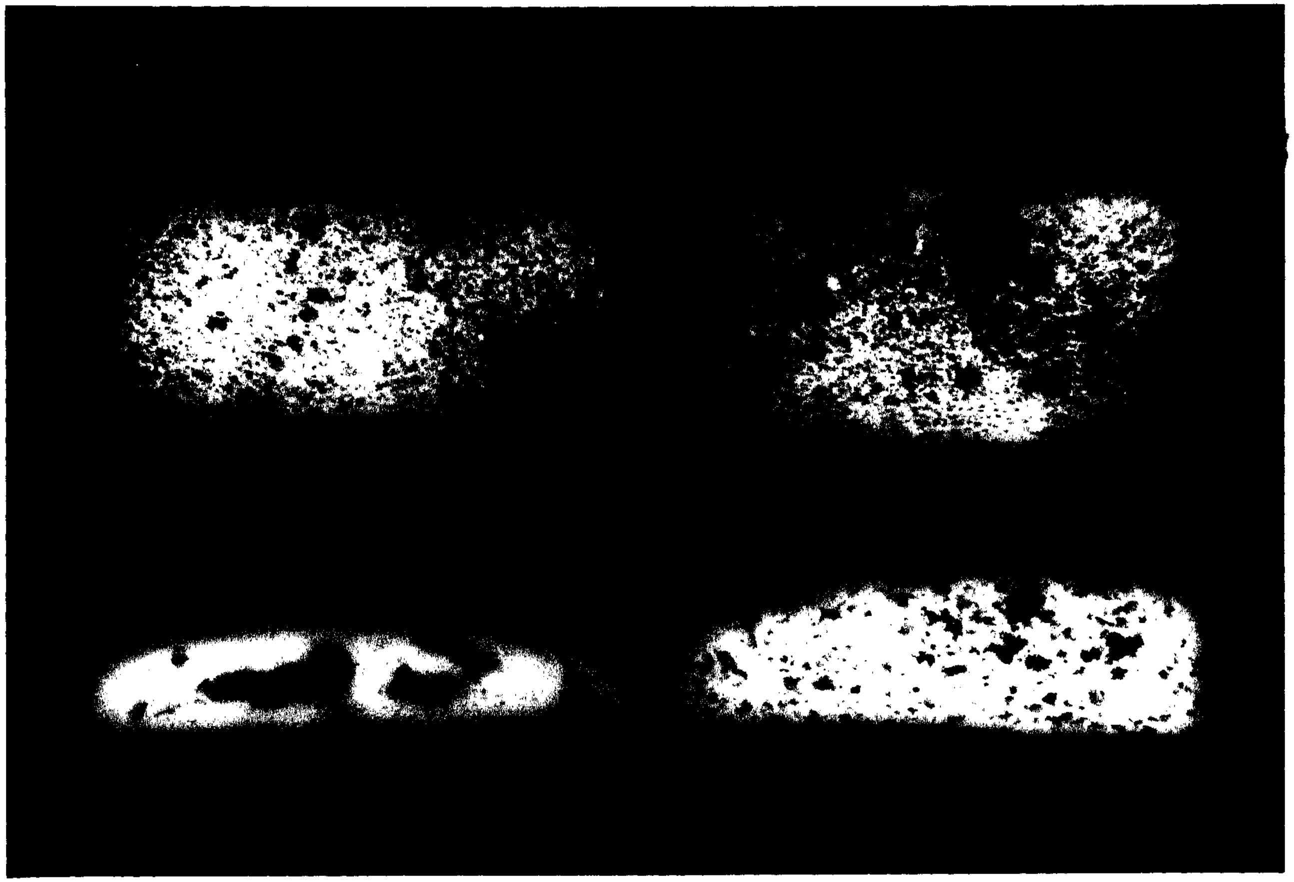
This study was prompted by the reports of other investigators (White and Thistle, 1943; Dawson et al, 1945) that egg powders from different plants differed in initial quality. Unaged samples were obtained from three plants operated by one firm. A sample of vacuum-dried whole egg and market shell eggs were used as controls.

Quality of eggs

The moisture contents of the egg powders were determined as soon as the hermetically sealed containers in which they



Photograph 19. Cakes Made with Commercial Spray-dried Whole Egg (5% Moisture)
Upper: Unaged Powder, Control and Baking Powder Added (right)
Lower: Powder Aged 7 Days at 37°C, Control and Baking Powder Added (right)



Photograph 20. Cakes Made with Commercial Spray-dried Whole Egg (5% Moisture)

Upper: Powder Aged 14 Days at 37°C, Control and Baking Powder Added (right)

Lower: Powder Aged 28 Days at 37°C, Control and Baking Powder Added (right) were received were opened. The moisture contents were:

Plant 1	1.6%
Plant 2	1.7
Plant 3	0.7
Vacuum-dried.	3.39

Powder from Plant 2 had a slightly better color and odor than the other powders but none was offensive. An estimate of the extent of denaturation of egg proteins as a measure of quality was made by determining the proportion of exposed sulfhydryl groups. The sulfhydryl exposed as per cent of total sulfhydryl found was:

Plant 1	13%
Plant 2	4
Plant 3	22
Vacuum-dried.	1

Powder from Plant 2 had less denatured proteins than powders from the other plants and was therefore indicated to be of better quality.

No objective measure of the quality of shell eggs used in this series was made. It was noted that they were similar in appearance to the eggs aged seven days in Series I.

pH of reconstituted egg magma and cake batters

All samples of egg powder had pH values higher than that of magma from shell eggs. This is consistent with the findings of other investigators and also with the findings of the previous series of this study.

The pH of cake batter was lower in the cakes made with egg powder than in the cake made with shell eggs. This also is consistent with what has already been observed in previous series.

The pH of reconstituted egg magma and the average pH of cake batters are given in Table 32.

Table 32

pH of Egg Magma and Average pH of Cake Batters Made with Unaged Spray-dried Whole Egg from Different Plants

	Controls		Spray-dried Egg		
	Shell Egg	Vacuum-dried	Plant 1	Plant 2	Plant 3
Egg Magma	7.87	8.72	8.25	8.36	8.36
Cake Batters	5.22	5.02	5.03	5.04	5.04

<u>Foaming properties and foam stability</u>

The reconstituted egg-sugar mixes warmed to 68°C (154.4°F) when whipped at 45°C (113°F) foamed readily although it was noted that lemon juice tended to inhibit foam formation in vacuum-dried samples. The desired lightness of foam was obtained as quickly with powder from Plant 2 as with magma from shell eggs, the vacuum-dried sample requiring the longest beating time. The average total beating times and specific gravities of foams and batters are found in Table 33.

The increase in specific gravity from foam to batter due to the incorporation of flour, was least for foams made with magma from shell eggs and with powder from Plant 2. This indicated that foams made with magma from shell eggs and with powder from Plant 2 were more stable than foams from the other egg powders.

Table 33

Average Total Beating Times and Specific Gravities of Foams and Batters Made with Unaged Spray-dried Whole Egg from Different Plants

	Controls		Spray-dried Egg		
	Shell Egg	Vacuum-dried	Plant 1	Plant 2	Plant 3
Total Beating Time, Sec.	195	396	264	192	253
Specific Gravity of Foam	0.262	0.257	0.264	0.240	0.253
Specific Gravity of Batter	0.329	0.353	0.360	0.319	0.346

Volumes of cakes

Largest volumes in cakes were produced with magma from shell eggs although these were closely approximated by cakes made with powder from Plant 2. Table 34 shows the average volumes obtained and these are illustrated graphically in Figure 10.

Table 34

Average Volumes of Cakes Made with Unaged Spray-dried Whole Egg from Different Plants

Controls		Spray-dried Egg		
Shell Egg	Vacuum-dried	Plant 1	Plant 2	Plant 3
cc.	cc.	cc.	cc.	cc.
701	653	610	681	629

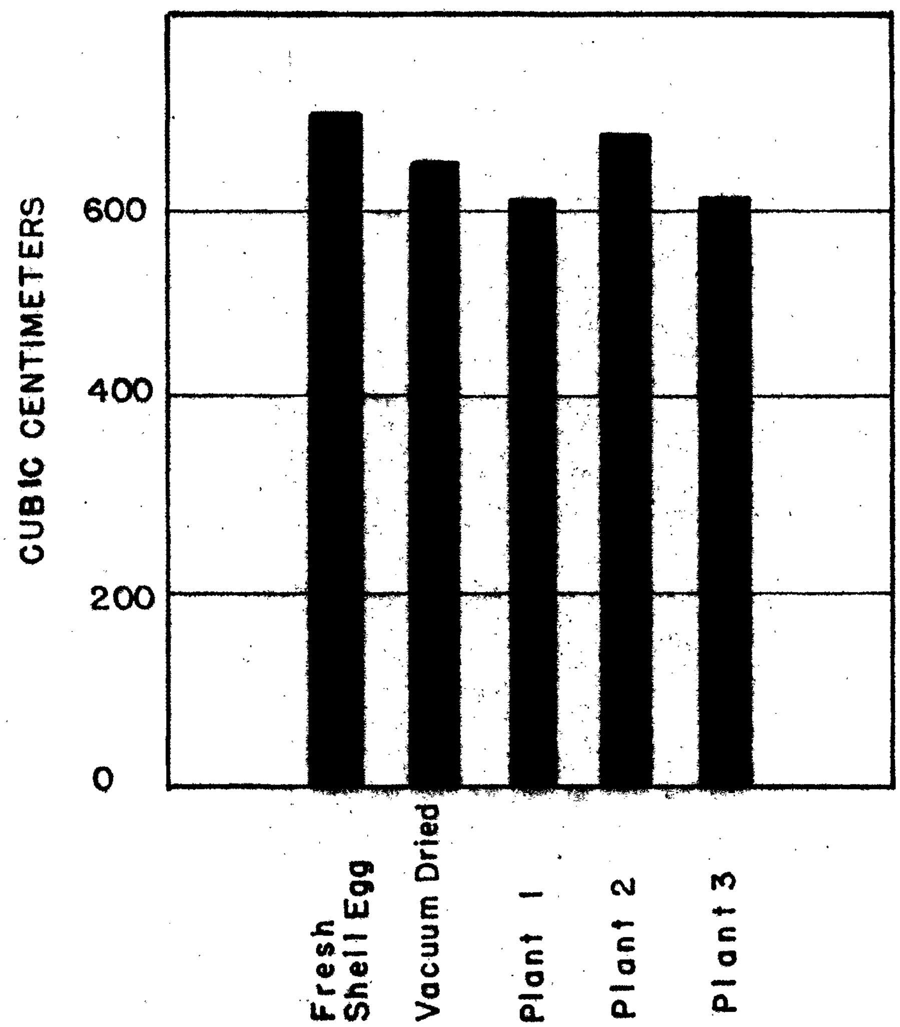


Fig. 10. Average Volume of Cakes Made with Freshly Dried Eggs from Different Plants.

Tensile strength of cakes

Cakes made with vacuum-dried egg and with egg powder from Plant 2 were the most tender as indicated by average tensile strength measurements. The average values observed were:

Plant 2	40
Vacuum-dried.	40
Shell Egg	44
Plant 3	44
Plant 1	47

Palatability of cakes

The appearance of all cakes was good; they had slightly rounded tops, thin crusts, and delicate brown color. The average scores (5 judges, 5 replications) for all characteristics are shown in Table 35.

Table 35

Average Scores of Cakes Made with Unaged Spray-dried Whole Egg from Different Plants

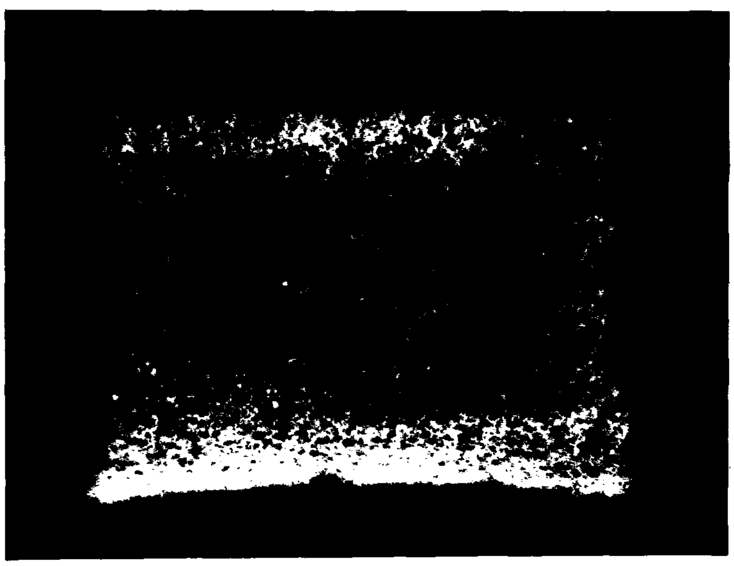
Characteristic	Controls		Spray-dried Egg		
	Shell Egg	Vacuum-dried	Plant 1	Plant 2	Plant 3
Crumb Color (5)	4.8	5.0	5.0	5.0	5.0
Texture and Grain (35)	29.1	28.5	26.4	27.6	27.0
Tenderness (30)	25.9	25.4	24.5	25.8	24.8
Moistness (10)	8.5	8.4	8.2	8.3	8.3
Flavor (20)	16.7	15.7	14.3	16.5	15.0
Total Scores (100)	84.9	82.9	78.5	83.2	80.5

The scores for cakes made with egg powder from Plant 2 were higher for all characteristics than for cakes made with egg powder from the other plants, the scores approximating those for cakes made with shell eggs. Tenderness scores were negatively correlated with tensile strength measurements. The cakes made with shell eggs were scored slightly higher for texture and flavor than for the other cakes.

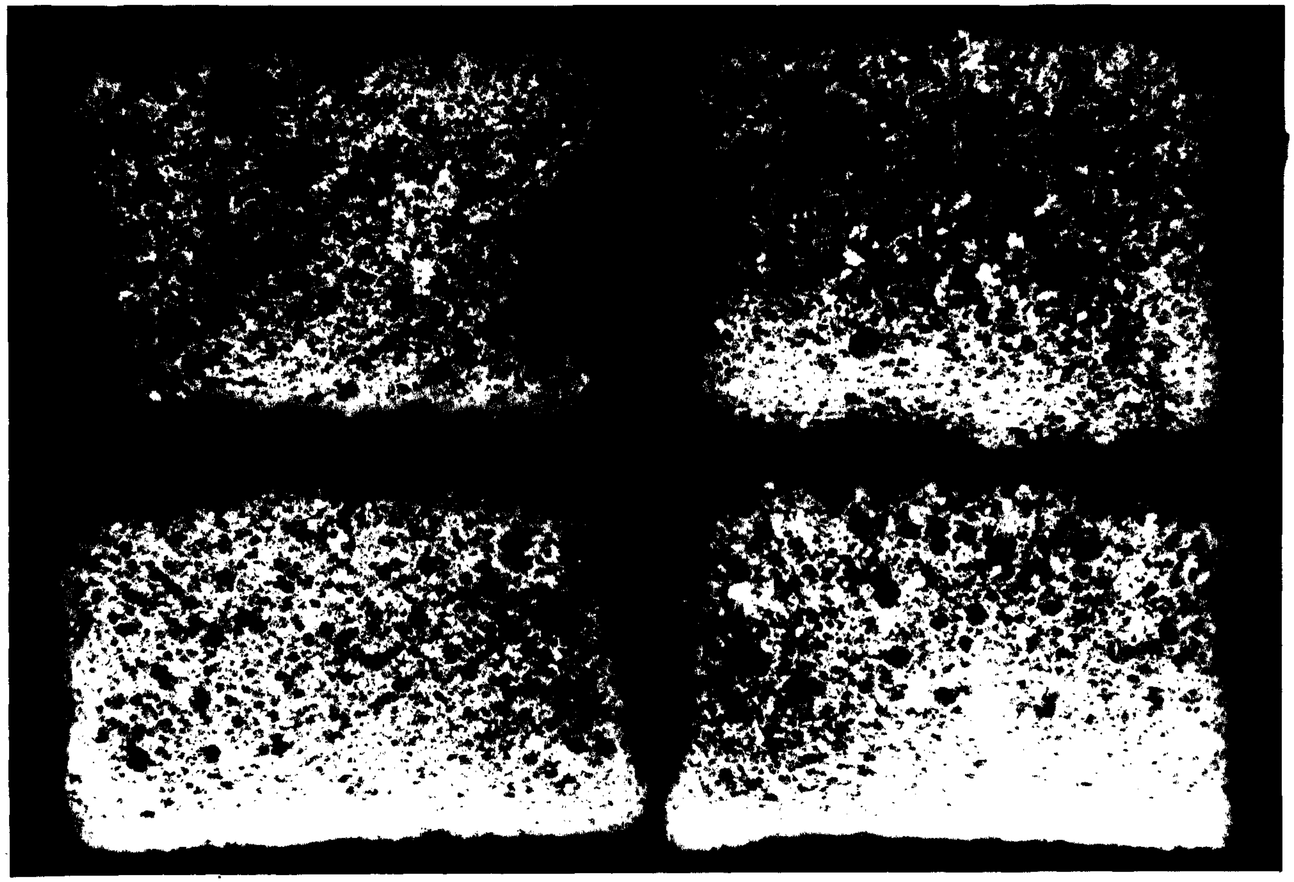
The flavor scores for the cakes made with spray-dried powders were in the order expected from the odor of the egg powders. The individual judge's scores for flavors showed the same sensitivity to flavor defects as they did in Series I. The two judges who detected flavor defects in the cakes made with stored eggs, scored cakes made with powder from Plants 1 and 3 lower than the other cakes in this series. The other three judges made little difference in flavor scores.

It is evident from the statistical analysis that cake quality was affected by egg treatment as shown by judges' total scores. There was no appreciable difference in treatment means for cakes made with shell eggs (84.9), vacuum-dried egg (82.9), or powder from Plant 2 (83.2); all were significantly higher than scores for cakes made with egg powders from Plant 1 (78.5) and Plant 3 (80.5).

The superior texture of cakes of highest treatment means is evident in Photographs 21 and 22.



Photograph 21. Cake Made with Shell Egg



Photograph 22. Cakes Made with Dried Whole Egg from Different Plants

Upper left: Vacuum-dried Control

Lower left: Powder from Plant 1

Upper right: Powder from Plant 2

Lower right: Powder from Plant 3

SERIES VIII. Cakes Made with Shell Eggs, Fresh and Aged; Frozen Pasteurized Egg, Hold and Flash; and Dried Egg, Vacuum-dried and Spray-dried (0.5% Moisture)

It was the object of this series to compare at one time the three main treatments of eggs studied in the preceding series, namely, shell eggs of varying quality, frozen pasteurized liquid whole egg of two pasteurization methods, and whole egg powders dried by two different methods.

Quality of eggs

The quality of shell eggs was assessed by Haugh unit; the values observed were:

Fresh.	80
Stored 7 days, 37°C (98.6°F) . .	49

The Haugh unit for fresh eggs was the same as that for fresh eggs in Series I; the Haugh unit for stored eggs was similar to that of eggs stored 14 days at 25°C (77°F) in Series I, 46. The stored eggs in this series, however, had mold growth and smelled musty.

No objective method was used to assess the quality of the frozen pasteurized eggs. They were similar in origin, storage, and pasteurization treatment to two samples in Series IV. The times and temperatures used for pasteurization in this series were:

Hold	62.2°C (144°F), 30 Min.
Flash.	71.1°C (160°F), 20 Sec.

The pasteurized magma was frozen and when used was thawed by immersing the containers in cold water. Both samples had a smooth appearance but a viscous consistency; there were no foreign odors.

The spray-dried powder was the same as that used in Series V, dried originally to 0.5 per cent moisture. The vacuum-dried sample was of the same origin and general quality as in Series VII. The moisture content was 2.68 per cent. The estimate of extent of denaturation of egg proteins by per cent of total sulfhydryl content exposed showed that the vacuum-dried sample had undergone no appreciable denaturation. The values observed were:

Vacuum-dried 1%
Spray-dried 18

The vacuum-dried powder is thus indicated to be of better quality than the spray-dried powder. Baking powder was used in cake batters made with spray-dried egg in this series because it improved the quality characteristics as shown by judges' scores in Series V.

pH of reconstituted egg magma and cake batters

The average pH of egg magma and cake batters is shown in Table 36. It is apparent that pH of egg magma increased with storage of shell egg, pasteurization, or drying. The decrease in pH from egg magma to batter was least in shell egg samples. The pH of cake batters tended to remain constant unless baking powder was added. The increase in pH of cake batter owing to the addition of baking powder was noted here as in previous series (Series V and VI.).

Table 36

Average pH of Egg Magma and Cake Batters Made with Shell Eggs, Fresh and Aged; Frozen Pasteurized Egg, Hold and Flash; and Dried Egg, Vacuum-dried and Spray-dried (0.5% Moisture)

	Shell		Pasteurized		Dried	
	Fresh	Aged	Hold	Flash	Vacuum	Spray
Egg Magma	7.29	7.54	7.81	7.61	8.70	8.36
Cake Batters	5.04	5.02	4.95	5.00	4.92	5.60*

*Baking powder added

Foaming properties and foam stability

Foams of sufficient lightness for sponge cake were obtained with all egg samples although the time required to reach a definite specific gravity of foam varied. The average total beating times and specific gravities of foams and batters are given in Table 37 and the average beating times and specific gravities of foams are illustrated in Figure 11. The foams made of pasteurized eggs were not quite so light as with other egg samples but were well within the range for satisfactory sponge cakes.

It was noted here as in Series I that fresh eggs required less time to produce a light foam than was required by stored eggs. The pasteurized egg samples required longer beating time than either shell egg sample; this is consistent with the observation in Series IV that the pasteurized samples required longer beating than the unheated control. In this series the vacuum-dried sample was treated in the same manner

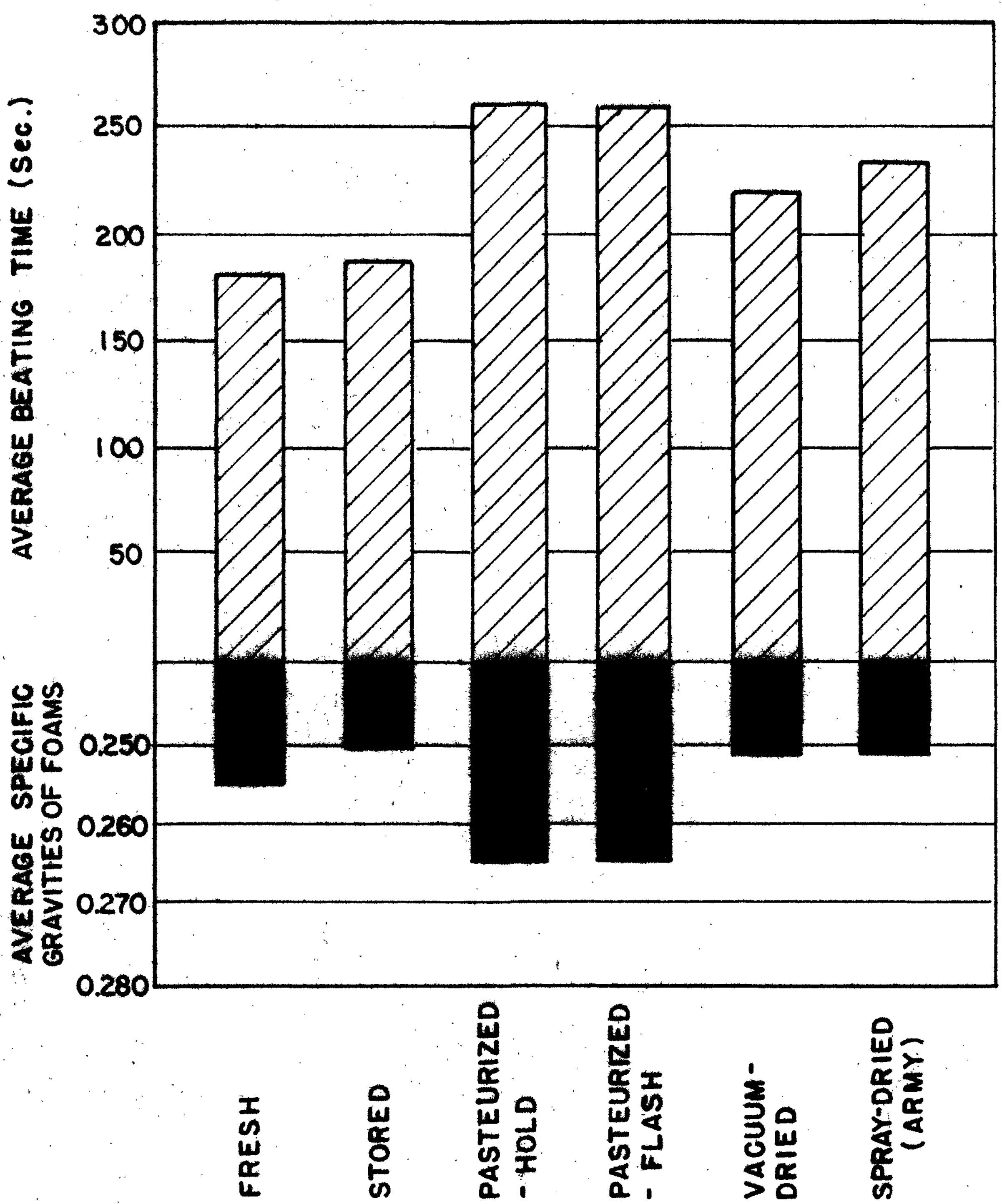


Fig. 11. Beating Time and Specific Gravities of Egg - Sugar Foams From Eggs of 6 Different Treatments.

Table 37

Average Total Beating Times and Specific Volumes of Foams and Batters Made with Shell Egg, Fresh and Stored; Frozen Pasteurized Egg, Hold and Flash; and Dried Whole Egg, Vacuum-dried and Spray-dried

	Shell		Pasteurized		Dried	
	Fresh	Aged	Hold	Flash	Vacuum	Spray
Total Beating Time, Seconds	182	190	261	261	222	236
Specific Gravity of Foam	0.255	0.251	0.265	0.264	0.252	0.252
Specific Gravity of Batter	0.316	0.314	0.340	0.337	0.339	0.308

as spray-dried eggs, that is, the reconstituted egg-sugar mix was preheated to 68°C (154.4°F) and was beaten at 45°C (113°F). The spray-dried egg required slightly longer time to reach a definite specific gravity of foam than was required by the vacuum-dried egg. The preheated vacuum-dried egg mix required less time for beating than the sample in Series VII that was not preheated. No drainage tests of foams were made.

The increase in specific gravity due to incorporation of flour was greatest in the foam made from vacuum-dried egg indicating a less stable foam was obtained.

Volumes of cakes

Largest volumes in cakes were produced by the shell eggs the fresh eggs in this series producing cakes of average volume equivalent to the aged eggs. The volume of the cake made with fresh eggs in this series, 710 cc., was similar to that obtained under the same conditions (incorporating the flour into the foam in 75 strokes) in Series II, 713 cc. Average volumes of cakes are given in Table 38 and are shown graphically in Figure 12.

Table 38

Average Volumes of Cakes Made with Shell Egg, Fresh and Stored; Frozen Pasteurized Egg, Hold and Flash; and Dried Whole Egg, Vacuum-dried and Spray-dried

Shell		Pasteurized		Dried	
Fresh	Aged	Hold	Flash	Vacuum	Spray
cc.	cc.	cc.	cc.	cc.	cc.
710	710	676	686	647	688

In this series somewhat higher temperatures were used for hold and flash pasteurization of liquid whole egg than were used in Series IV and the volumes of cakes were less although the specific gravities of the batters were very similar. The volumes obtained in each series were:

Pasteurization Method	Series	Sp. Gr. Batter	Cake Volume
Hold (61.7°C, 30 Min.)	IV	0.334	715 cc.
Hold (62.2°C, 30 Min.)	VIII	0.340	676 cc.
Flash (68.3°C,0.1 Min.)	IV	0.336	716 cc.
Flash (71.1°C,0.3 Min.)	VIII	0.337	686 cc.

No doubt some denaturation of egg proteins had occurred in pasteurization in this series which caused them to resist stretching during baking.

Vacuum-dried egg produced the least volume in cakes in this series. No doubt optimum conditions for use of vacuum-dried egg were not used in this study.

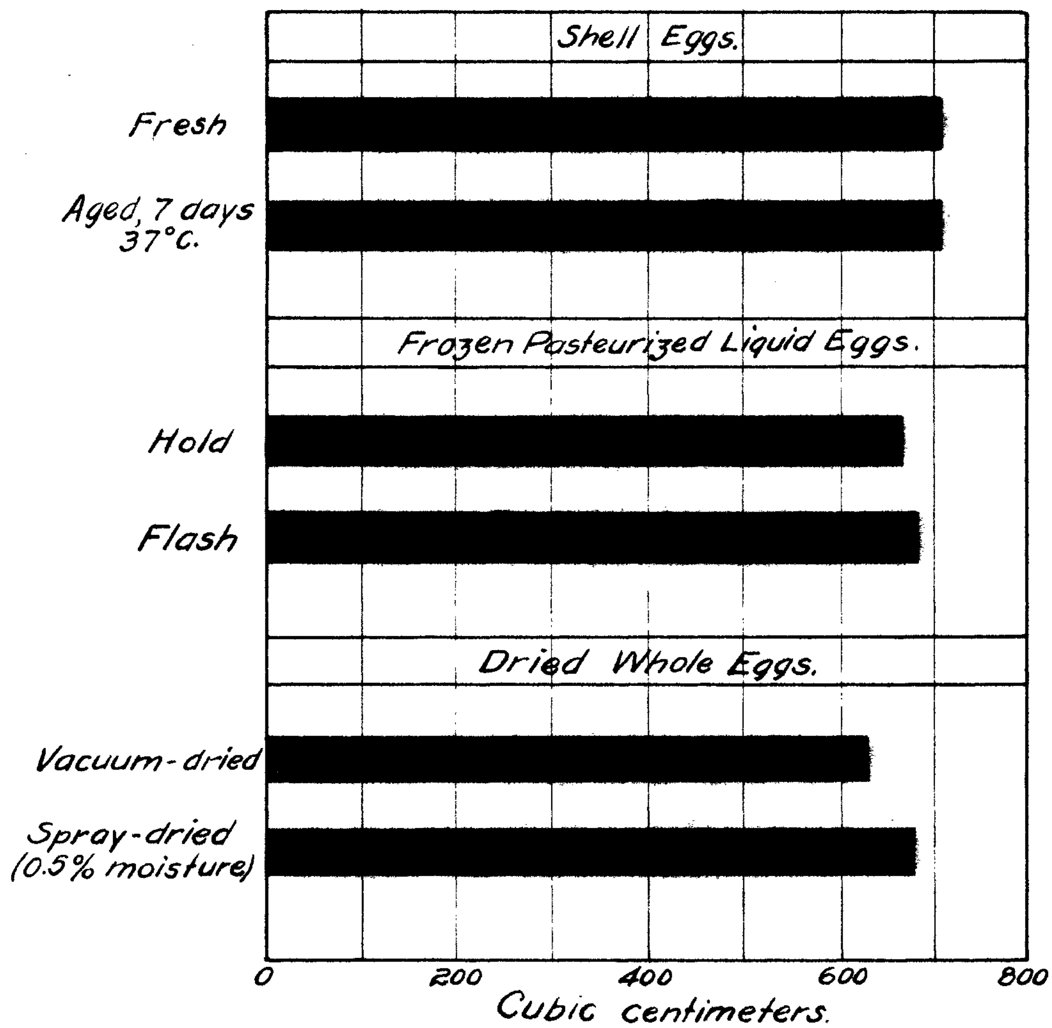


Fig. 12. SERIES VIII Average Volumes of Cakes made with Shell Eggs, Frozen Pasteurized Eggs, and Dried Whole Eggs.

Tensile strength of cakes

The average tensile strength measurements showed that the stored shell egg produced the most tender cakes. In order that comparisons might be made between the tensile strength of cakes in this series and that of cakes made with similar egg treatments in other series, the average values shown in Table 39 are from this and previous series.

Table 39

Average Tensile Strength of Cakes Made with Shell Eggs, Fresh and Stored; Frozen Pasteurized Egg, Hold and Flash; and Dried Whole Egg, Vacuum-dried and Spray-dried

Egg Treatment	Series	Tensile Strength
Fresh Shell Egg	II	40
Fresh Shell Egg	VIII	39
Aged Shell Egg (25°C, 14 days; Haugh Unit, 46)	I	35
Aged Shell Egg (37°C, 7 days; Haugh Unit, 49)	VIII	29
Pasteurized, Hold (61.7°C, 30 Min.)	IV	32
Pasteurized, Hold (62.2°C, 30 Min.)	VIII	33
Pasteurized, Flash (68.3°C, 0.1 Min.)	IV	38
Pasteurized, Flash (71.1°C, 0.3 Min.)	VIII	40
Vacuum-dried (not preheated)	VII	40
Vacuum-dried (mix preheated)	VIII	42
Spray-dried, Baking Powder	V	37
Spray-dried, Baking Powder	VIII	37

The values obtained for cakes made with similar egg products in the different series were very similar except for the eggs that were aged in the shell.

Palatability of cakes

All cakes had a pleasing shape, crust, and color. No difference in browning was observed. The average scores (5 judges, 5 replications) for all characteristics are shown in Table 40.

Table 40

Average Scores of Cakes Made with Shell Eggs, Fresh and Stored; Frozen Pasteurized Eggs, Hold and Flash; and Dried Whole Dried Egg, Vacuum-dried and Spray-dried

Characteristic	Shell		Pasteurized		Dried	
	Fresh	Stored	Hold	Flash	Vacuum	Spray*
Crumb Color (5)	5.0	4.9	5.0	5.0	4.9	4.7
Texture and Grain (35)	28.9	27.8	29.7	28.9	26.6	28.9
Tenderness (30)	26.1	26.5	26.1	26.0	25.3	26.0
Moistness (10)	8.3	8.3	8.3	8.4	7.9	8.3
Flavor (20)	17.6	15.8	16.1	17.5	17.2	14.0
Total Scores (100)	85.9	83.3	85.1	85.8	82.0	82.0

*Baking Powder Added

The tenderness scores tended to correlate negatively with tensile strength measurements, cakes from vacuum-dried eggs received the lowest score for tenderness and contributed most to tensile strength.

Cakes varied in flavor as shown by judges' flavor scores. One of the judges, shown to be less sensitive to certain flavors in other series, consistently detected a rubber flavor in the cake made with egg pasteurized by the hold method. This was not noted by the other judges. There was no doubt that the flavor was present since the liquid egg had been in rubber tubing during a 30 minute heating period in the pasteurization treatment. This judge was also the only one to consistently detect the musty flavor of the cake made with stored shell egg.

It is evident from the statistical analysis that the egg treatments did affect the quality of the cakes as shown by judges' total scores. The three of highest treatment means:

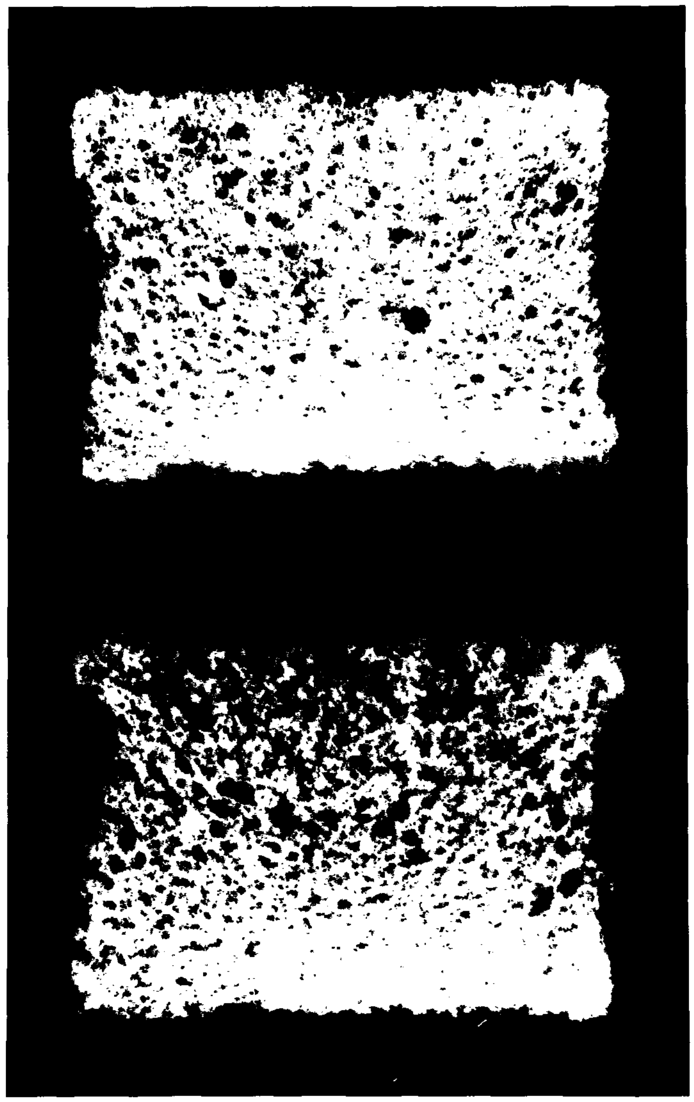
Fresh Shell Egg.	.85.9
Pasteurized Egg, Flash	.85.8
Pasteurized Egg, Hold.	.85.1

differed significantly from the three of lowest treatment means:

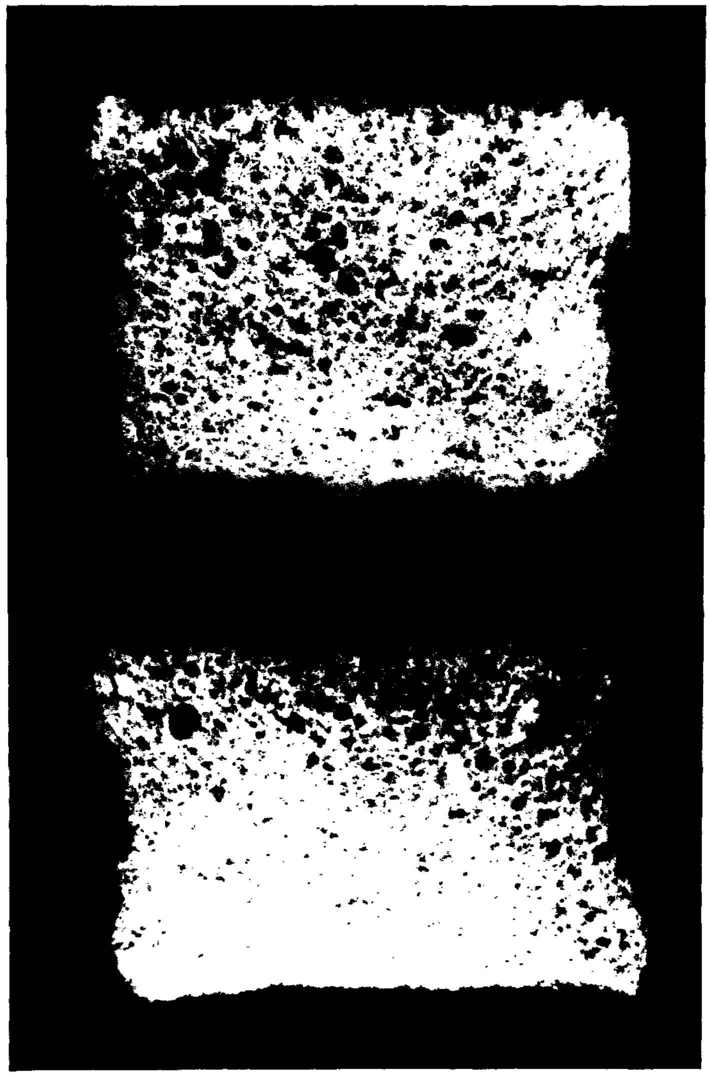
Stored Shell Egg.	83.3
Vacuum-dried Egg.	82.0
Spray-dried Egg	82.0

but there was no difference within these groupings (Table 40).

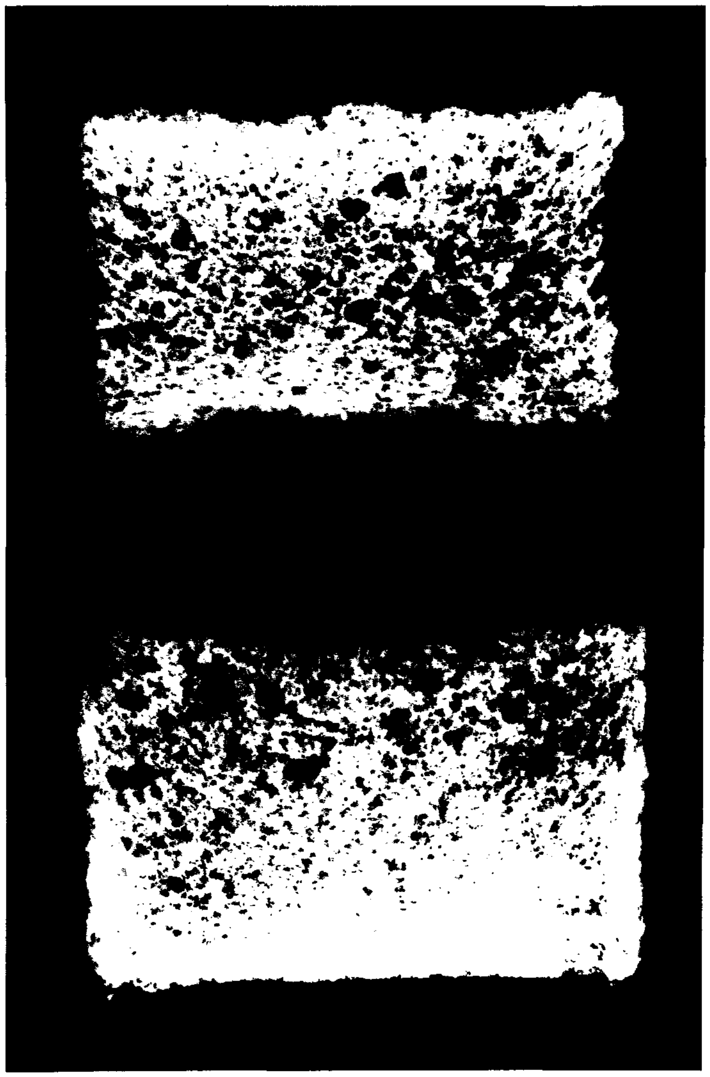
The textures of the cakes are recorded in Photographs 23 to 25 inclusive. The cakes made from dried eggs had less delicate cell walls and more compact texture than cakes made from liquid eggs.



Photograph 23. Cakes Made with Infertile Shell Eggs
Upper: Fresh
Lower: Stored 7 Days at $37^{\circ}C$



Photograph 24. Cakes Made with Frozen Pasteurized Liquid Egg
Upper: Hold (62.2°C, 30 Min.)
Lower: Flash (71.1°C, 0.3 Min.)



Photograph 25. Cakes Made with Dried Whole Egg
Upper: Vacuum-dried
Lower: Spray-dried (with Baking Powder)

GENERAL DISCUSSION AND CONCLUSIONS

Foam Temperatures

The temperatures of the finished foams when eggs were beaten at room temperature were noted to be consistently the same in all series and were slightly below room temperature. They varied only with the variations in temperature and were approximately 23°C (73.4°F). When egg powder mixes were beaten at 45°C (113°F), the resultant foams were approximately 35°C (95°F). All data are given in the appendix, pages 172 to 180.

Baking Losses of Cakes

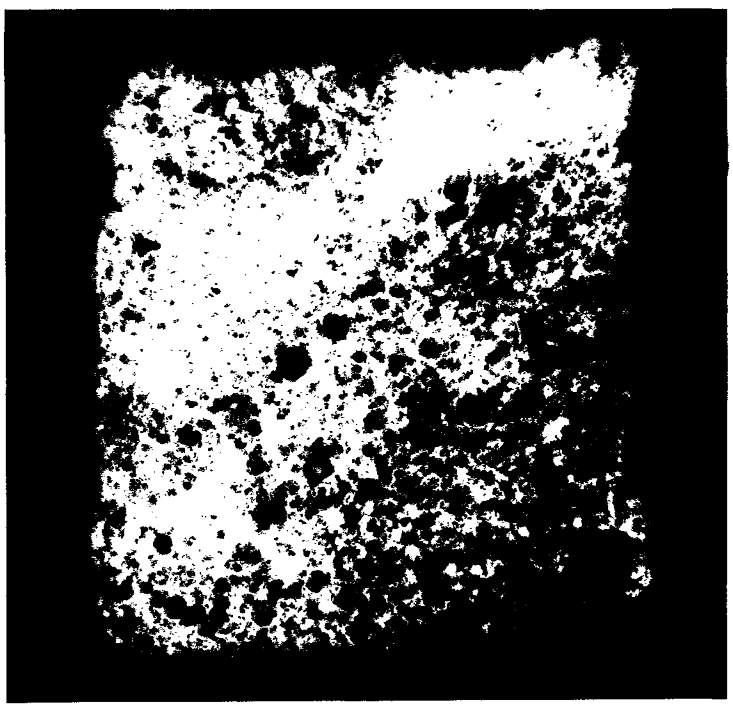
The losses in weight during baking were small and approximately constant for all series, tending to vary only with variations in oven temperature. The approximate average loss was 16 grams or 11 per cent of the batter weight. Data are given in the appendix, Tables F, 1-8.

Application of Results to "Family-size" Cakes

The "family-size" cakes made at the end of each series (single test) showed that the results obtained in the experiment could be expected to hold for ordinary-size cakes. In general, the foams required slightly longer beating time than in the experimental cakes, but the same specific gravity of foam was obtained. Eighty strokes were used in incorporating the flour. Volume measurements were not made, but the comparative volumes appeared the same as in the experiment. The large cakes were more porous in texture than the experimental cakes with subsequent lower tensile strength. Large-size cakes were flavored with lemon rind, and it was apparent from the increase in flavor scores that the flavoring substance masked flavor defects of eggs to some extent. On the whole, large cakes received a higher total score than did experimental cakes, but they were ranked in the same order within the series. A slice from a large cake made with fresh egg is shown in Photograph 26. It was more difficult to cut thin slices of uniform thickness from a large cake than from those of experimental size, which fact accounts for the dense portion appearing in the photograph.

Application of Results to a Household Situation

Although acceptable "family-size" cakes were obtained with all of the egg samples producing satisfactory cakes in the experiments, this should not be assumed to indicate that comparable results would be obtained in a household situation. In this study all beating was done by an electric mixer (KitchenAid), which maintains a constant rate of beating even



Photograph 26. Cake Made with Fresh Infertile Shell Eggs in "Family Size" Recipe

with a heavy load. The consistency of the resultant meringues was uniform throughout. It was noted in a single trial of beating foam with a hand-operated rotary egg beater that the foam was not uniform and a cake of poor texture and volume was produced although specific gravities of foams and batters were comparable to those obtained when an electric mixer was used. Two students in special problems class used rotary beaters to obtain whole-egg meringues for sponge cakes. They found that pasteurized liquid eggs required considerably longer beating than the unheated control to produce a foam of the desired lightness. All cakes were coarse in texture and relatively tough as shown by tensile strength measurements. More work needs to be done to determine whether satisfactory sponge cakes can be made by whole-egg meringue method using a rotary beater. Beating at higher temperatures might hasten the formation of foam, or cream of tartar, a common household acid, might be more effective as a stabilizer than lemon juice. It seems logical to assume that if a satisfactory procedure is developed for shell egg by whole-egg meringue method, it would be applicable to the use of pasteurized liquid whole egg.

Whole egg powders do not seem adaptable for making sponge cake in the household, either. It has been shown in this study and was reported by others that a relatively high temperature of beating is required to obtain satisfactory lightness of foam. Furthermore, Bennion et al. (1942) found that a small-size electric mixer was inadequate for foam formation; a large-size beater was required. A study of the use of a rotary beater in producing foams of egg powders might be practical and desirable.

Reproducibility of Results

Whether the results of this study could be reproduced or not would depend upon how closely the conditions of the experiment could be duplicated. Variations encountered in eggs as was shown by variations in Haugh unit observed in eggs of the same origin, and of the same storage age are unavoidable, and some variations in results can be expected. However, it was shown in Series VIII that the results of objective measurements could be closely approximated when cakes were prepared under the same conditions.

Throughout the study it was observed that replicate cakes varied somewhat no matter how careful the manipulation. This observation was also reported by King *et al*. (1936), who stated that variations were unavoidable in a set of six cakes made at one time. This variation was reflected in volume determinations in which differences in replicate cakes were not correlated with any other known factor. It was hoped that five to seven replications were sufficient to absorb the replicate variations although it was recognized that a larger sampling would have been desirable. A large number of replications would also absorb individual judge's variations from day to day.

Objective and Subjective Testing of Cakes

Although the results of objective tests are useful in obtaining an indication of the quality of sponge cake and hence the quality of the eggs used, they cannot be used as the sole criterion since flavor cannot be measured objectively and yet is very important in the eating quality of a food product. Objective tests are usually more reproducible than subjective tests. On the other hand, subjective tests are more easily evaluated if supplemented with objective tests. In some instances the trained judges in this study were shown, by analysis of variance, to be inconsistent in their ranking of replicate cakes. This was accepted as indicating that no real differences in cake quality existed in that series and not as indicating unreliability of the subjective test.

A comparison of the objective and subjective tests used in this study may be made from Table 41. Volume and tensile strength of cakes reflect the comparative tenderness and textures of cakes, whereas the comparative eating quality is best shown by average flavor and total scores of cakes by judges.

Table 41

Average Volumes, Tensile Strength Measurements, Flavor Scores, and Total Scores of Cakes in Eight Series with Three to Six Egg Treatments in Each

Series and Treatment	Volume (cc.)	Tensile strength	Flavor (20)	Total score (100)
I. Fresh and aged infertile shell eggs				
Held 0 days, 25°C	682	39	17.0	84.8
7	686	37	16.8	85.3
14	692	35	16.5	85.2
21	694	30	16.4	84.6
35	732	27	15.7	86.1
42	746	30	14.4	84.8
II. Fresh infertile shell eggs				
Beaten at 24°C				
Mixed 50 strokes	687	41	17.2	84.3
60	700	41	17.6	85.8
75	707	40	17.9	87.1
Beaten at 27°C				
Mixed 50 strokes	689	36	17.4	84.4
60	695	42	17.5	85.5
75	713	40	17.8	86.9
III. Pasteurized liquid whole egg				
Unheated control	709	39	17.1	87.5
60.0°C, 8 min.	703	40	17.3	88.3
61.1°C, 5 min.	723	33	17.3	88.6
62.2°C, 3 min.	716	33	16.9	87.6
Com. frozen unheated control	614	38	14.7	81.7
Com. frozen pasteurized	651	32	15.1	83.6

(Continued)

Table 41 (Continued)

Series and Treatment	Volume (cc.)	Tensile strength	Flavor (20)	Total score (100)
IV. Frozen pasteurized liquid whole egg				
Unheated control	714	34	17.0	85.5
61.7°C, 15 min.	709	32	16.9	86.7
61.7°C, 30 min.	715	32	16.1	86.1
64.5°C, 0.5 min.	702	34	17.3	84.2
68.3°C, 0.1 min.	716	38	17.3	86.9
V. Spray-dried egg, 0.5% moisture				
Control	592	42	14.4	73.6
Lemon rind added	564	45	16.2	73.3
Baking powder added	636	37	15.0	77.4
VI. Unaged and aged com. spray-dried egg, 5% moisture				
0 days, 37°C. Control	591	40	14.2	78.4
Bk. powder	624	33	13.9	75.2
7 days, 37°C. Control	564	34	13.6	74.5
Bk. powder	591	28	13.5	74.8
14 days, 37°C. Control	479	44	9.8	58.8
Bk. powder	525	40	10.9	64.4
28 days, 37°C. Control	185	--	2.8	11.0
Bk. powder	265	--	3.0	20.8
VII. Unaged spray-dried egg from different plants				
Plant 1	610	47	14.3	78.5
2	681	40	16.5	83.2
3	629	44	15.0	80.5
Vacuum-dried, control	653	40	15.7	82.9
Shell egg, control	701	44	16.7	84.9
VIII. Shell eggs, frozen pasteurized eggs, and dried eggs				
Fresh shell egg, 0 days	710	39	17.6	85.9
Shell egg, 7 days, 37°C	710	29	15.8	83.3
Hold pasteurized 61.7°C, 30 min.	676	33	16.1	85.1
Flash pasteurized 71.1°C, 20 sec.	686	40	17.5	85.8
Vacuum-dried	647	42	17.2	82.0
Spray-dried, bk. powder	688	37	14.0	82.0

In general, volume seemed to be closely related to total score of cakes, whereas flavor was not related to any other factor.

It is also recognized that subjective scoring as a tool is useful only insofar as the judges are representative of the population, since individual preferences govern results. The larger the number of judges, the better the chance of having a true sampling of the population. On the other hand, limitations are imposed by availability of a large number of people throughout a long experimental period. Since there were five constant judges and five to seven replications were made in this study, final scores are averages of 25 to 35 scores. These serve as the basis on which most of the conclusions were made.

Conclusions

It was concluded from the results obtained in this study that:

1) shell eggs may be kept for reasonably long periods at room temperature without deleterious effects on foaming properties or sponge cake quality;
2) sponge cake batters made from eggs of high Haugh unit (75 or more) require more mixing in combining the flour with a whole-egg meringue to produce maximum volume and cakes of uniform texture and fine cell walls than do batters made from eggs of low Haugh unit;

3) homogenized liquid whole egg may be heated to pasteurization temperatures and times used in this study without deleterious effect on foaming properties or quality of sponge cakes made therefrom;

4) homogenized liquid whole egg pasteurized at times and temperatures used in this study may be quick-frozen without deleterious effects on foaming properties or quality of sponge cakes made therefrom;

5) whole eggs subjected to spray-drying procedures suffer some loss of buffer action during the drying process;

6) the pH of egg magma is increased by (a) storage of shell egg, (b) pasteurization of liquid whole egg, and (c) drying of whole egg;

7) the pH of sponge cake batters is not closely related to the pH of the egg magma under the conditions used in this study;

8) unaged spray-dried whole egg powders of good quality produce stable foams under the following conditions:

    a) mixing sugar with egg powder and then reconstituting the egg at room temperature,

    b) preheating the egg-sugar mix slowly to 68°C (154.4°F) and whipping at 45°C (113°F) with a KitchenAid electric mixer;

9) the quality of sponge cakes made from unaged spray-dried whole egg under the conditions used in this study varies with the initial quality of the egg powder;

10) unaged spray-dried egg powders may vary in initial quality

according to the conditions prevailing in the drying plant;

11) sulfate-phosphate baking powder used as a secondary leavening agent in sponge cake batters made with spray-dried whole eggs has no appreciable effect on the quality of the cake as shown by judges' scores, under the conditions of this experiment;

12) sulfate-phosphate baking powder leaves an alkaline residue in sponge cake batter as used in this study; it increases the volume and tenderness of the cake;

13) under the conditions of this experiment the quality of spray-dried whole egg powder of 5 per cent moisture, and the quality of sponge cakes made therefrom, decrease with increased time in storage at 37°C (98.6°F);

14) under the conditions used in this study, eggs may be stored in the shell for reasonable periods of time, may be pasteurized, frozen, dried, or subjected to a combination of these treatments without destroying their foaming powers.

SUMMARY

The culinary value of eggs after various storage, pasteurization, and drying treatments was investigated. The eggs were made into sponge cakes under standardized conditions, and the quality of the cakes by objective and subjective tests was used as the criterion of egg quality. Eight series of cakes with from three to six egg treatments in each were replicated five to seven times. Data were obtained on:

1) the interior quality of fresh and aged shell eggs by Haugh unit,
2) the quality of whole egg powder by an estimate of the extent of denaturation of egg proteins,
3) the time required to whip whole egg-sugar mixes to a definite specific gravity of foam,
4) comparative stability of egg-sugar foams by rate of drainage of foams,
5) pH of egg magmas and sponge cake batters,
6) specific gravities of foams and batters,
7) weight losses of cakes during baking,
8) volumes of cakes,
9) tenderness of cakes by tensile strength tests, and
10) palatability of cakes by weighted scores of five trained judges.

It was found that the quality of shell eggs decreased progressively with increased storage time at 25°C (77°F), and that the quality of whole egg powder of 5 per cent moisture

decreased progressively with increased time in storage at 37°C (98.6°F).

The beating time required to obtain foams of definite specific gravity varied with the quality of the eggs and with the egg treatments. Rate of drainage of egg-sugar foams varied with different egg treatments but was not closely related to cake quality under the conditions of this experiment.

The pH of egg magma was found to increase on storage of shell eggs at 25°C (77°F), on heating of homogenized magma to pasteurization times and temperatures used in this study, and on drying of eggs. pH of cake batters in this experiment were not closely related to pH of egg magma and tended to remain constant at pH 5.0 $\pm$0.2.

It was found that under the conditions of this experiment stored shell eggs produced cakes of larger volume and more tender structure than fresh shell eggs. This was attributed to a higher gelation temperature of the proteins of the partially deteriorated stored eggs. Batters made with fresh shell egg required more manipulation in incorporating the flour into the whole-egg meringue to produce optimum volumes and delicate texture of cakes than did batters made with stored shell eggs.

Under the conditions of this experiment it was found that the quality of cakes made with spray-dried whole eggs varied directly with the initial quality of the egg powder and that spray-dried whole egg powders from different plants varied in initial quality. A storage temperature of 37°C (98.6°F) for more than seven days was deleterious to the foaming properties of commercial spray-dried whole egg of 5 per cent moisture as shown by volumes of cakes and judges' total scores. A sulfate-phosphate baking powder used as a secondary leavening agent in certain cakes made with spray-dried whole egg caused an increase in pH of cake batter, in volume of cake, and in the tenderness of cake but had no appreciable effect on the eating quality of the cakes as shown by judges' total scores.

Cakes made with fresh shell eggs had the best flavor as compared to cakes of other egg treatments in this study as shown by judges' average flavor scores.

It was concluded that under the conditions of this experiment the lifting power of eggs subjected to the storage, pasteurization, freezing, or drying treatments used in this study was retained and that the eating quality of the sponge cakes was dependent upon the initial quality of the eggs used.

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APPENDIX

Table A-1. HAUGH UNITS OF EGGS

Series I. Fresh and Aged Infertile Shell Eggs

Replication	Days of storage at 25°C																	
	0			7			14			21			35			42		
	No. eggs	Range	Av.	No. eggs	Range	Av.	No. eggs	Range	Av.	No. eggs	Range	Av.	No. eggs	Range	Av.	No. eggs	Range	Av.
1	12	48-93	78	12	42-74	60	12	20-57	47	12	10-68	41	10	12-52	32	8	0-71	36
2	12	68-89	81	11	47-72	58	11	33-62	44	12	10-73	33	10	5-43	22	12	0-40	18
3	12	68-91	77	12	35-67	56	12	30-61	45	12	17-60	35	9	17-47	27	6	0-42	19
4	12	53-90	78	12	40-72	58	11	37-71	50	12	21-45	37	12	0-46	30	8	0-65	23
5	11	60-87	75	10	25-64	49	10	22-52	40	11	22-55	38	11	15-63	38	9	10-43	32
6	12	72-92	80	11	40-72	52	9	38-60	49	11	20-55	43	9	15-69	44	11	15-50	32
7	11	70-90	85	10	45-67	56	11	25-62	43	11	30-66	47	10	5-47	26	9	10-35	27
Mean			79			56			46			39			31			27

Table A-2. HAUGH UNITS OF EGGS

Series III. Eggs for Pasteurization (Held 7 Days at 27°C)

Repli-cation	No. eggs	Haugh Units	
		Range	Average
1	35	15-75	54
2	35	22-72	49
3	36	10-75	51
4	36	36-77	56
5	36	32-72	54
6	36	20-64	45
Mean			52

Table A-3. HAUGH UNITS OF EGGS

Series VIII. Fresh and Aged Infertile Shell Eggs

Repli-cation	Fresh			Aged 7 days at 37°C		
	No. eggs	Range	Av.	No. eggs	Range	Av.
1	6	67-88	87	5	49-72	56
2	6	58-85	79	5	43-71	54
3	6	73-84	79	5	35-55	45
4	6	62-88	79	5	36-68	49
5	10	60-88	78	9	0-79	43
Mean			80			49

Table B-1. pH OF EGG MAGMA AND OF CAKE BATTERS

Series I. Fresh and Aged Infertile Shell Eggs

Repli- cation	Days in storage at 25°C					
	0	7	14	21	35	42
			Egg magma			
1	7.35	7.76	7.67	7.83	7.82	7.82
2	7.15	7.45	7.52	7.60	7.60	7.53
3	7.32	7.52	7.60	7.68	7.59	7.53
4	7.20	7.60	7.56	7.63	7.60	7.64
5	7.18	7.49	7.45	7.58	7.48	7.55
6	7.20	7.55	7.52	7.52	7.44	7.49
7	7.17	7.45	7.53	7.55	7.55	7.56
Mean	7.22	7.55	7.55	7.63	7.58	7.59
			Batters			
1	5.21	5.09	5.24	5.16	5.30	5.30
2	5.15	5.12	5.21	5.15	5.18	5.18
3	5.21	5.11	5.18	5.23	5.22	5.31
4	5.18	5.19	5.23	5.19	5.29	5.35
5	5.16	5.19	5.14	5.20	5.15	5.24
6	5.20	5.17	5.14	5.19	5.17	5.19
7	5.15	5.15	5.15	5.16	5.23	5.27
Mean	5.18	5.15	5.18	5.18	5.22	5.26

Table B-2. pH OF EGG MAGMA AND OF CAKE BATTERS

Series II. Fresh Infertile Shell Eggs

Replication	Egg magma	Batters
1	7.35	5.22
2	7.23	--
3	--	5.05
4	7.20	5.16
5	7.39	5.11
Mean	7.29	5.14

Table B-3. pH OF EGG MAGMA AND OF CAKE BATTERS

Series III. Unheated and Pasteurized Liquid Whole Eggs and Unheated and Pasteurized Commercially Frozen Eggs

Replication	Laboratory				Commercially Frozen	
	Unheated	140°F 8 min.	142°F 5 min.	144°F 3 min.	Unheated	Pasteurized
			Egg magma			
1	7.75	7.81	7.81	7.81	--	--
2	7.59	7.66	7.69	7.76	6.99	7.55
3	7.61	7.85	7.69	7.69	7.59	7.61
4	7.54	7.85	7.68	7.76	7.66	7.67
5	7.69	7.72	7.65	7.79	7.50	7.60
6	7.71	7.81	7.76	7.81	7.64	7.70
Mean	7.65	7.78	7.71	7.77	7.48	7.63
			Batters			
1	5.11	5.04	5.11	5.11	--	--
2	5.11	5.11	5.11	5.11	5.02	5.06
3	5.02	5.02	5.04	5.09	5.11	5.05
4	5.02	5.00	5.02	5.05	5.06	5.06
5	5.06	5.01	5.06	5.10	5.02	5.06
6	5.09	5.09	5.12	5.09	5.09	5.04
Mean	5.07	5.04	5.08	5.09	5.06	5.05

Table B-4. pH OF EGG MAGMA AND OF CAKE BATTERS

Series IV. Frozen, Unheated and Pasteurized Liquid Whole Eggs

Replication	Unheated	143°F 15 min.	143°F 30 min.	148°F 0.5 min.	155°F 0.1 min.
			Egg magma		
1	7.79	7.75	7.75	7.74	7.75
2	7.68	7.75	7.87	7.70	7.71
3	7.78	7.81	7.81	7.71	7.81
4	7.41	7.58	7.66	7.51	7.51
5	7.42	7.55	7.81	7.49	7.56
Mean	7.64	7.69	7.78	7.63	7.67
			Batters		
1	5.15	5.21	5.20	5.20	5.20
2	5.21	5.20	5.15	5.22	5.20
3	5.23	5.23	5.23	5.23	5.23
4	5.13	5.18	5.13	5.15	5.09
5	5.15	5.12	5.15	5.17	5.15
Mean	5.17	5.19	5.17	5.19	5.17

Table B-5. pH OF EGG MAGMA AND OF CAKE BATTERS

Series V. Spray-dried (0.5% Moisture) Eggs

Replication	Egg magma	Batters		
		Control	Flavored	Baking powder
1	8.36	4.87	4.87	5.59
2	--	4.85	4.89	5.48
3	--	4.84	4.80	5.62
4	--	4.86	4.86	5.50
5	--	4.88	4.86	5.59
Mean	8.36	4.86	4.86	5.56

Table B-6. pH OF EGG MAGMA AND OF CAKE BATTERS

Series VI. Unaged and Aged Commercial Spray-dried (5.0% Moisture) Eggs

Replication	Days in storage at 37°C							
	0		7		14		28	
	Control	Baking powder	Control	Baking powder	Control	Baking powder	Control	Baking powder
	Egg magma							
--	8.36		8.12		7.67		7.26	
	Batters							
1	4.88	5.45	--	--	4.78	5.35	4.79	5.41
2	4.90	5.52	4.85	5.49	4.85	5.39	--	--
3	4.85	5.37	4.82	5.41	4.79	5.40	--	--
4	4.90	5.51	4.87	5.65	4.79	5.61	--	--
5	4.92	5.62	4.90	5.52	4.85	5.63	--	--
Mean	4.89	5.49	4.85	5.41	4.81	5.48	4.79	5.41

Table B-7. pH OF EGG MAGMA AND OF CAKE BATTERS

Series VII. Unaged Spray-dried Eggs from Different Plants

Repli-cation	Controls		Dried eggs		
	Shell egg	Vacuum-dried (Lab.)	Plant 1	Plant 2	Plant 3
			Egg magma		
--	7.87	8.72	8.25	8.36	8.36
			Batters		
1	5.23	5.09	5.00	5.02	5.00
2	5.21	5.00	5.06	5.03	5.05
3	5.21	5.03	5.01	5.05	5.06
4	5.23	4.98	5.00	5.06	5.02
5	5.21	4.98	5.07	5.05	5.05
Mean	5.22	5.02	5.03	5.04	5.04

Table B-8. pH OF EGG MAGMA AND OF CAKE BATTERS

Series VIII. Shell Eggs, Fresh and Aged; Frozen Pasteurized Eggs, Hold and Flash; and Dried Eggs, Vacuum-dried and Spray-dried (0.5% Moisture).

Repli-cation	Shell		Pasteurized		Dried	
	Fresh	Aged	Hold	Flash	Vacuum	Spray
			Egg magma			
1	7.20	7.38	7.72	7.65	8.70	8.36
2	7.32	7.49	7.88	7.60	--	--
3	7.38	7.50	7.81	7.55	--	--
4	7.30	7.51	7.70	7.61	--	--
5	7.27	7.80	7.92	7.65	--	--
Mean	7.29	7.54	7.81	7.61	8.70	8.36
			Batters			
1	5.00	4.99	4.90	4.99	4.95	5.59*
2	4.99	5.03	5.01	5.00	4.91	5.62*
3	5.17	5.01	4.96	4.98	5.00	5.60*
4	5.00	5.05	4.90	5.03	4.90	5.65*
5	5.06	5.06	5.00	5.00	4.90	5.55*
Mean	5.04	5.02	4.95	5.00	4.93	5.60*

*Baking powder added.

Table C-1. MILLILITERS OF LIQUID DRAINED IN ONE HOUR FROM EGG-SUGAR FOAMS

Series I. Foams Made with Fresh and Aged Infertile Shell Eggs

Repli-cation	Days in storage at 25°C					
	0	7	14	21	35	42
	ml.	ml.	ml.	ml.	ml.	ml.
1	25.0	12.0	29.0	19.0	10.0	6.5
2	27.0	5.0	21.0	23.0	26.0	8.0
3	23.0	25.0	13.0	23.0	20.0	7.5
4	8.0	19.0	13.0	17.5	15.0	12.5
5	20.0	21.5	20.0	28.0	10.0	17.0
6	28.0	21.5	15.0	14.0	18.0	19.0
7	20.5	20.5	21.5	20.0	23.0	15.0
Mean	21.7	17.9	18.9	20.7	17.3	12.2

Table C-2. MILLILITERS OF LIQUID DRAINED IN ONE HOUR FROM EGG-SUGAR FOAMS

Series III. Foams Made with Unheated and Pasteurized Liquid Whole Eggs and Unheated and Pasteurized Commercially Frozen Eggs

Repli-cation	Laboratory				Commercially frozen	
	Un-heated	140°F 8 min.	142°F 5 min.	144°F 3 min.	Un-heated	Pasteur-ized
	ml.	ml.	ml.	ml.	ml.	ml.
1	13.5	5.5	10.0	11.5	--	--
2	10.0	4.5	10.0	10.5	1.0	0.0
3	7.5	3.1	2.5	6.5	0.1	0.7
4	14.5	3.0	1.5	7.0	0.1	0.0
5	6.0	7.7	9.0	7.5	0.0	0.5
6	15.0	9.5	1.0	9.5	0.5	0.0
Mean	11.1	5.7	5.7	8.7	0.3	0.2

Table C-3. MILLILITERS OF LIQUID DRAINED IN ONE HOUR FROM EGG-SUGAR FOAMS

Series IV. Foams Made from Frozen Unheated and Pasteurized Eggs

Repli-cation	Un-heated	143°F 15 min.	143°F 30 min.	148°F 0.5 min.	155°F 0.1 min.
	ml.	ml.	ml.	ml.	ml.
1	22.5	6.0	1.5	12.0	5.0
2	1.5	5.0	4.5	20.0	10.0
3	12.0	4.0	12.0	14.0	2.5
4	27.0	11.0	24.0	8.0	12.5
5	19.0	15.0	4.5	9.5	0.5
Mean	16.4	8.2	9.3	12.7	6.1

Table D-1. GRAMS OF LIQUID DRAINED IN ONE HOUR FROM EGG-SUGAR FOAMS

Series I. Foams Made with Fresh and Aged Infertile Shell Eggs

Replication	Days in storage at 25°C					
	0	7	14	21	35	42
	gm.	gm.	gm.	gm.	gm.	gm.
1	30.1	28.0	37.1	24.1	26.3	25.0
2	35.2	32.9	27.0	29.0	36.2	25.0
3	24.6	24.8	32.5	37.8	27.6	20.2
4	40.6	29.1	31.4	23.0	25.0	21.5
5	30.5	26.2	26.9	35.5	39.3	23.0
6	32.8	34.6	27.6	41.8	22.0	32.5
7	33.9	32.8	31.8	32.8	30.6	42.9
Mean	32.5	29.8	30.6	32.0	29.5	27.2

Table D-2. GRAMS OF LIQUID DRAINED IN ONE HOUR FROM EGG-SUGAR FOAMS

Series III. Foams Made with Unheated and Pasteurized Liquid Whole Eggs and Unheated and Pasteurized Commercially Frozen Eggs

Replication	Laboratory				Commercially frozen	
	Unheated	140°F 8 min.	142°F 5 min.	144°F 3 min.	Unheated	Pasteurized
	gm.	gm.	gm.	gm.	gm.	gm.
1	16.2	15.2	11.5	15.0	--	--
2	29.5	20.0	14.1	12.5	1.0	15.1
3	25.0	6.3	3.5	10.7	0.1	0.7
4	17.0	17.5	25.7	9.8	0.1	--
5	35.2	9.1	11.7	11.1	0.0	0.3
6	20.4	10.3	30.4	18.4	0.4	6.8
Mean	23.9	13.1	16.2	12.7	0.3	3.8

Table D-3. GRAMS OF LIQUID DRAINED IN ONE HOUR FROM EGG-SUGAR FOAMS

Series IV. Foams Made from Frozen Unheated and Pasteurized Eggs

Replication	Unheated	143°F 15 min.	143°F 30 min.	148°F 0.5 min.	155°F 0.1 min.
	gm.	gm.	gm.	gm.	gm.
1	27.6	8.3	30.7	19.2	6.4
2	29.8	6.0	6.1	24.3	20.6
3	40.2	30.6	13.9	15.5	31.2
4	34.0	23.0	16.7	36.2	14.7
5	27.3	7.5	4.2	11.0	5.9
Mean	31.8	15.5	14.3	21.2	15.8

Table E-1. BEATING TIMES, FOAM TEMPERATURES, AND SPECIFIC GRAVITIES OF FOAMS AND BATTERS

Series I. Cakes Made with Fresh and Aged Infertile Shell Eggs*

Replication	Days in storage at 25°C					
	0	7	14	21	35	42
	Total beating time (approx. 2 min. at speed 1)					
1	210 sec.	260 sec.	245 sec.	240 sec.	285 sec.	345 sec.
2	220	270	230	270	240	325
3	215	295	265	240	265	270
4	230	270	235	285	275	230
5	225	235	230	250	245	240
6	210	235	275	230	315	285
7	220	230	240	273	275	235
Mean	218	257	246	255	271	276
	Foam temperature					
1	22.7°C	21.8°C	22.1°C	21.9°C	23.0°C	21.8°C
2	22.0	21.8	23.0	21.9	22.2	21.8
3	23.0	23.0	22.0	23.0	23.0	23.0
4	21.5	21.5	22.0	21.3	21.5	21.5
5	21.5	21.5	21.5	21.5	21.5	21.5
6	21.5	21.5	22.2	22.0	--	21.5
7	22.0	21.5	21.8	21.7	22.0	21.5
Mean	22.0	21.8	22.1	21.9	22.2	21.8
	Specific gravity of foam					
1	0.267	0.264	0.266	0.271	0.256	0.263
2	0.271	0.263	0.264	0.264	0.263	0.271
3	0.271	0.271	0.271	0.271	0.266	0.271
4	0.266	0.274	0.271	0.269	0.266	0.273
5	0.269	0.271	0.274	0.274	0.274	0.271
6	0.274	0.263	0.263	0.271	0.271	0.271
7	0.266	0.273	0.269	0.267	0.267	0.271
Mean	0.269	0.268	0.268	0.269	0.266	0.270
	Specific gravity of batter					
1	0.326	0.332	0.333	0.333	0.318	0.337
2	0.339	0.325	0.328	0.333	0.339	0.343
3	0.335	0.335	0.342	0.333	0.335	0.356
4	0.322	0.339	0.332	0.330	0.337	0.353
5	0.325	0.330	0.342	0.347	0.342	0.333
6	0.333	0.315	0.323	0.326	0.335	0.340
7	0.323	0.325	0.330	0.328	0.339	0.330
Mean	0.329	0.329	0.333	0.333	0.335	0.342

*Eggs brought to 24°C and beaten at room temperature, 23-24°C.

Table E-2. BEATING TIMES, FOAM TEMPERATURES, AND SPECIFIC GRAVITIES OF FOAMS AND BATTERS

Series II. Cakes Made with Fresh Infertile Shell Eggs Beaten at 24° and 27°C and Mixed with 50, 60, and 75 Strokes

Replication	24°C			27°C		
	Strokes			Strokes		
	50	60	75	50	60	75
	Total beating time (approx. 2 min. at speed 1)					
1	270 sec.			285 sec.		
2	295			293		
3	345			300		
4	285			---		
5	310			275		
Mean	301			286		
	Foam temperature					
1	22.0°C			22.0°C		
2	22.0			22.2		
3	22.2			23.0		
4	22.8			23.0		
5	22.0			23.0		
Mean	22.2			22.6		
	Specific gravity of foam					
1	0.259			0.241		
2	0.263			0.264		
3	0.263			0.256		
4	0.247			0.247		
5	0.251			0.251		
Mean	0.256			0.252		
	Specific gravity of batter					
1	0.323	0.306	0.312	0.293	0.302	0.302
2	0.318	0.322	0.323	0.316	0.313	0.325
3	0.322	0.310	0.313	0.303	0.313	0.305
4	0.295	0.303	0.298	0.296	0.303	0.315
5	0.300	0.315	0.300	0.313	0.325	0.313
Mean	0.312	0.311	0.309	0.304	0.311	0.312

Table E-3. BEATING TIMES, FOAM TEMPERATURES, AND SPECIFIC GRAVITIES OF FOAMS AND BATTERS

Series III. Cakes Made with Unheated and Pasteurized Liquid Whole Eggs and Unheated and Pasteurized Commercially Frozen Eggs*

Replication	Laboratory				Commercially frozen	
	Unheated	140°F 8 min.	142°F 5 min.	144°F 3 min.	Unheated	Pasteurized
	Total beating time (approx. 4 min. at speed 1)					
1	315 sec.	330 sec.	330 sec.	315 sec.	---	---
2	330	330	330	330	420 sec.	390 sec.
3	360	540	360	405	465	450
4	345	375	370	360	450	390
5	300	345	330	330	465	390
6	315	330	330	315	450	390
Mean	327	375	342	342	450	402
	Foam temperature					
1	22.0°C	22.0°C	22.0°C	22.5°C	--	--
2	22.2	22.5	--	--	22.7°C	23.0°C
3	23.0	23.0	23.0	23.0	22.8	22.8
4	21.5	21.7	21.7	21.5	21.8	21.8
5	21.7	21.3	21.5	21.5	21.5	21.5
6	22.2	22.0	22.0	22.6	22.0	22.5
Mean	22.1	22.1	22.0	22.0	22.0	22.1
	Specific gravity of foam					
1	0.263	0.263	0.263	0.271	---	---
2	0.254	0.271	0.263	0.263	0.264	0.261
3	0.259	0.264	0.264	0.263	0.254	0.257
4	0.266	0.267	0.266	0.263	0.254	0.263
5	0.259	0.266	0.264	0.266	0.263	0.264
6	0.256	0.261	0.256	0.266	0.257	0.263
	Specific gravity of batter					
1	0.313	0.322	0.313	0.330	---	---
2	0.310	0.325	0.322	0.315	0.339	0.330
3	0.308	0.330	0.310	0.322	0.322	0.325
4	0.330	0.330	0.333	0.325	0.330	0.326
5	0.320	0.322	0.322	0.325	0.330	0.339
6	0.312	0.325	0.306	0.328	0.333	0.337
Mean	0.315	0.326	0.318	0.324	0.331	0.332

*Egg magma warmed to 27°C; beaten at room temperature, 23-24°C.

Table E-4. BEATING TIMES, FOAM TEMPERATURES, AND SPECIFIC GRAVITIES OF FOAMS AND BATTERS

Series IV. Cakes Made with Frozen Unheated and Pasteurized Liquid Whole Eggs*

Repli-cation	Un-heated	143°F 15 min.	143°F 30 min.	148°F 0.5 min.	155°F 0.1 min.
	Total beating time (1 min., speed 1)				
1	190 sec.	280 sec.	270 sec.	260 sec.	355 sec.
2	195	320	315	245	300
3	195	210	225	225	280
4	200	220	230	200	260
5	228	305	240	240	325
Mean	202	267	256	234	304
	Foam temperature				
1	23.0°C	23.0°C	--	23.0°C	22.0°C
2	23.5	23.5	22.0°C	23.5	23.0
3	23.0	23.0	23.0	23.2	22.8
4	23.0	23.0	23.0	23.0	23.2
5	23.0	23.0	22.2	22.2	22.2
Mean	23.1	23.1	22.6	23.0	22.6
	Specific gravity of foam				
1	0.271	0.269	0.269	0.266	0.267
2	0.263	0.269	0.271	0.263	0.271
3	0.257	0.269	0.266	0.259	0.269
4	0.261	0.266	0.271	0.271	0.266
5	0.269	0.271	0.264	0.261	0.271
Mean	0.264	0.269	0.268	0.264	0.269
	Specific gravity of batter				
1	0.323	0.330	0.335	0.330	0.330
2	0.330	0.346	0.342	0.330	0.337
3	0.322	0.326	0.332	0.322	0.344
4	0.322	0.330	0.340	0.335	0.330
5	0.333	0.340	0.323	0.325	0.339
Mean	0.326	0.334	0.334	0.328	0.336

*Eggs warmed to 24°C and beaten at room temperature, 23-24°C.

Table E-5. BEATING TIMES, FOAM TEMPERATURES, AND SPECIFIC GRAVITIES OF FOAMS AND BATTERS

Series V. Cakes Made with Spray-dried (0.5% Moisture) Eggs

Replication	Total beating time	Foam temperature	Specific gravity of foam	Specific gravity of batter		
				Control	Flavored	Baking powder
	sec.	°C				
1	420	34.0	0.231	0.325	0.323	0.323
2	420	33.0	0.271	0.339	0.402	0.354
3	420	33.0	0.220	0.320	0.328	0.316
4	345	34.5	0.238	0.326	0.326	0.318
5	360	33.5	0.229	0.313	0.313	0.308
Mean	393	33.5	0.238	0.325	0.338	0.324

Table E-6. BEATING TIMES, FOAM TEMPERATURES, AND SPECIFIC GRAVITIES OF FOAMS AND BATTERS

Series VI. Cakes Made with Unaged and Aged Commercial Spray-dried (5.0% Moisture) Eggs*

Rep-li-ca-tion	Days in Storage at 37°C							
	0		7		14		28	
	Con-trol	Baking powder	Con-trol	Baking powder	Con-trol	Baking powder	Con-trol	Baking powder
	Total beating time (1 min., speed 1)							
1	360 sec.		---		360 sec.		No foam	
2	360		420 sec.		660		formed	
3	360		360		660		in 20-min.	
4	360		360		600		beating.	
5	360		390		660			
Mean	360		383		588		(1200)	
	Foam temperature							
1	45.0°C		--		43.0°C			
2	43.0		45.5°C		44.0			
3	44.0		44.5		45.0			
4	44.0		47.5		44.7			
5	47.0		45.5		52.0			
Mean	44.6		45.7		45.7			
	Specific gravity of foam							
1	0.220		---		0.251		(0.976)	
2	0.229		0.248		0.283			
3	0.231		0.238		0.305			
4	0.235		0.251		0.313			
5	0.241		0.229		0.320			
Mean	0.231		0.242		0.294		(0.976)	
	Specific gravity of batter							
1	0.356	0.339	---	---	0.390	0.385	0.992	0.941
2	0.375	0.390	0.347	0.335	0.406	0.412	---	---
3	0.359	0.363	0.349	0.344	0.441	0.437	---	---
4	0.359	0.359	0.359	0.361	0.451	0.449	---	---
5	0.356	0.356	0.344	0.333	0.495	0.447		
Mean	0.361	0.361	0.350	0.343	0.437	0.426	0.992	0.941

*Egg-sugar mix warmed to 68°C; beaten at 80°C.

Table E-7. BEATING TIMES, FOAM TEMPERATURES, AND SPECIFIC GRAVITIES OF FOAMS AND BATTERS

Series VII. Cakes Made with Unaged Spray-dried Eggs from Three Different Plants

Replication	Controls		Dried eggs***		
	Shell* eggs	Vacuum** dried (Lab.)	Plant 1	Plant 2	Plant 3
	Total beating time (approx. 1 min., speed 1)				
1	225 sec.	390 sec.	270 sec.	195 sec.	285 sec.
2	180	510	270	225	260
3	180	330	270	180	240
4	180	360	270	180	240
5	210	390	240	180	240
Mean	195	396	264	192	253
	Foam temperature				
1	23.3°C	35.2°C	37.0°C	35.0°C	34.5°C
2	23.0	38.5	34.0	37.0	36.3
3	24.0	34.0	35.7	36.2	35.7
4	24.0	34.0	36.5	36.0	36.2
5	21.0	36.3	34.0	36.0	34.2
Mean	23.1	35.6	35.4	36.0	35.4
	Specific gravity of foam				
1	0.256	0.267	0.257	0.231	0.263
2	0.259	0.259	0.264	0.243	0.246
3	0.267	0.246	0.269	0.243	0.251
4	0.267	0.248	0.257	0.236	0.243
5	0.263	0.264	0.271	0.246	0.261
Mean	0.262	0.257	0.264	0.240	0.253
	Specific gravity of batter				
1	0.320	0.361	0.357	0.318	0.353
2	0.315	0.364	0.368	0.325	0.342
3	0.330	0.339	0.364	0.322	0.347
4	0.344	0.339	0.349	0.308	0.337
5	0.335	0.361	0.364	0.323	0.353
Mean	0.329	0.353	0.360	0.319	0.346

*Egg magma warmed to 27°C; beaten at room temperature, 23-24°C.

**Egg reconstituted at room temperature; beaten at 45°C.

***Egg-sugar mix warmed to 68°C; beaten at 45°C.

Table E-8. BEATING TIMES, FOAM TEMPERATURES, AND SPECIFIC GRAVITIES OF FOAMS AND BATTERS

Series VIII. Cakes Made with Shell Eggs, Fresh and Aged; Frozen Pasteurized Eggs, Hold and Flash; and Dried Eggs, Vacuum-dried and Spray-dried (0.5% Moisture)

Repli-	Shell**		Pasteurized**		Dried***	
cation	Fresh	Aged	Hold	Flash	Vacuum	Spray
	Total beating time (approx. 1 min., speed 1)					
1	210 sec.	210 sec.	225 sec.	300 sec.	240 sec.	300 sec.
2	195	225	240	210	225	210
3	170	165	270	195	225	210
4	165	170	300	300	210	---
5	170	180	270	300	210	225
Mean	182	190	261	261	222	236
	Foam temperature					
1	22.7	22.8	22.7	22.7	33.5	33.0
2	22.5	23.2	22.0	22.5	33.5	33.0
3	22.8	22.7	22.5	22.5	34.0	33.7
4	22.5	22.5	22.2	22.5	33.0	33.8
5	23.0	22.8	22.7	23.5	33.5	33.8
Mean	22.7	22.8	22.4	22.7	33.5	33.3
	Specific gravity of foam					
1	0.249	0.236	0.263	0.254	0.243	0.222
2	0.254	0.235	0.263	0.266	0.233	0.254
3	0.256	0.254	0.264	0.264	0.261	0.263
4	0.263	0.261	0.271	0.267	0.261	0.263
5	0.263	0.267	0.266	0.269	0.261	0.259
Mean	0.255	0.251	0.265	0.264	0.252	0.252
	Specific gravity of batter					
1	0.313	0.296	0.337	0.322	0.339	0.302*
2	0.316	0.300	0.325	0.330	0.318	0.310*
3	0.306	0.320	0.342	0.332	0.340	---
4	0.325	0.318	0.356	0.351	0.349	0.313*
5	0.318	0.335	0.342	0.349	0.351	0.308*
Mean	0.316	0.314	0.340	0.337	0.339	0.308*

*Baking powder added.

**Egg magma warmed to 27°C; beaten at room temperature, 23-24°C.

***Egg-sugar mix warmed to 68°C; beaten at 45°C.

Table F-1. BAKING LOSSES

Series I. Cakes Made with Fresh and Aged Infertile Shell Eggs

Replication	Days in storage at 25°C					
	0	7	14	21	35	42
	gm.	gm.	gm.	gm.	gm.	gm.
1	16.5	17.0	17.5	16.0	17.5	16.5
2	16.5	14.0	16.0	16.0	15.5	15.0
3	15.5	15.5	17.5	16.0	15.0	15.0
4	14.5	15.5	15.5	15.5	17.0	15.5
5	14.5	16.0	16.5	16.0	15.0	15.0
6	15.5	16.0	16.0	16.0	16.0	15.5
7	16.5	15.5	16.0	16.0	16.0	17.0
Mean	15.6	15.6	16.4	15.8	16.0	15.6

Table F-2. BAKING LOSSES

Series II. Cakes Made with Fresh Infertile Shell Eggs Beaten at 24°C and 27°C and Mixed with 50, 60, and 75 Strokes

Replication	24°C			27°C		
	Strokes			Strokes		
	50	60	75	50	60	75
	gm.	gm.	gm.	gm.	gm.	gm.
1	14.0	14.5	13.5	15.0	16.0	15.0
2	15.5	14.0	15.5	14.5	14.5	15.0
3	15.0	14.5	14.0	17.0	16.0	16.5
4	16.0	17.0	16.0	14.5	15.0	14.5
5	16.5	16.5	15.5	16.5	16.0	16.5
Mean	15.4	15.3	14.9	15.5	15.5	15.5

Table F-3. BAKING LOSSES

Series III. Cakes Made with Unheated and Pasteurized Liquid Whole Eggs and Unheated and Pasteurized Commercially Frozen Eggs

Replication	Laboratory eggs				Commercially frozen	
	Un-heated	140°F 8 min.	142°F 5 min.	144°F 3 min.	Un-heated	Pasteur-ized
	gm.	gm.	gm.	gm.	gm.	gm.
1	16.0	16.0	15.0	15.5	--	--
2	17.0	16.5	15.0	15.5	16.0	16.0
3	16.5	15.5	16.0	15.0	15.0	16.0
4	16.5	16.5	15.5	16.5	15.0	14.5
5	17.0	17.5	16.0	15.0	16.0	14.5
6	16.0	16.0	16.5	15.5	16.0	15.0
Mean	16.5	16.0	15.7	15.5	15.6	15.2

Table F-4. BAKING LOSSES

Series V. Cakes Made with Frozen Unheated and Pasteurized Liquid Whole Eggs

Replication	Un-heated	143°F 15 min.	143°F 30 min.	148°F 0.5 min.	155°F 0.1 min.
	gm.	gm.	gm.	gm.	gm.
1	18.0	18.0	16.0	17.5	17.5
2	17.5	18.5	18.5	17.5	17.5
3	18.0	18.0	18.5	18.0	19.5
4	17.0	17.5	19.5	17.5	17.0
5	17.0	17.5	17.5	17.0	16.5
Mean	17.5	17.9	18.0	17.5	17.6

Table F-5. BAKING LOSSES

Series V. Cakes Made with Spray-dried (0.5% Moisture) Eggs

Replication	Control	Flavored	Baking powder
	gm.	gm.	gm.
1	17.5	16.0	17.5
2	16.5	15.5	16.5
3	16.5	17.0	17.5
4	17.0	17.5	18.5
5	16.0	15.0	17.5
Mean	16.7	16.2	17.5

Table F-6. BAKING LOSSES

Series VI. Cakes Made with Unaged and Aged Commercial Spray-dried (5.0% Moisture) Eggs

Replication	Days in storage at 37°C							
	0		7		14		28	
	Control	Baking powder	Control	Baking powder	Control	Baking powder	Control	Baking powder
	gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.
1	15.0	15.5	--	--	16.0	19.0	9.5	14.0
2	17.5	16.5	17.0	17.5	16.5	16.5	--	--
3	16.0	16.0	19.0	16.5	18.5	19.0	--	--
4	16.5	17.0	17.5	17.5	15.5	14.5	--	--
5	15.5	16.5	18.0	17.0	17.0	17.0	--	--
Mean	16.1	16.3	17.1	17.1	16.7	17.2	9.5	14.0

Table F-7. BAKING LOSSES

Series VII. Cakes Made with Unaged Spray-dried Eggs from Different Plants

Rep-lica-tion	Controls		Dried eggs		
	Shell eggs	Vacuum-dried (Lab.)	Plant 1	Plant 2	Plant 3
	gm.	gm.	gm.	gm.	gm.
1	15.5	16.0	17.0	16.0	16.5
2	16.5	17.0	16.0	16.0	17.0
3	16.5	15.5	16.5	17.5	16.5
4	15.5	16.5	16.5	16.5	17.0
5	16.0	15.0	15.5	15.5	15.5
Mean	16.0	16.0	16.3	16.3	16.5

Table F-8. BAKING LOSSES

Series VIII. Cakes Made with Shell Eggs, Fresh and Aged; Frozen Pasteurized Eggs, Hold and Flash; and Dried Eggs, Vacuum-dried and *Spray-dried (0.5% Moisture)

	Shell		Pasteurized		Dried	
	Fresh	Aged	Hold	Flash	Vacuum	Spray
	gm.	gm.	gm.	gm.	gm.	gm.
1	15.5	15.5	17.5	15.5	15.5	17.0
2	16.0	16.5	18.5	17.0	15.5	18.5
3	17.0	16.0	17.0	16.5	15.5	17.0
4	15.5	16.0	15.0	17.5	15.0	17.0
5	16.5	17.0	18.0	16.5	17.5	18.0
Mean	16.1	16.2	17.2	16.6	15.8	17.5

*Baking powder added.

Table G-1. VOLUMES OF CAKES

Series I. Cakes Made with Fresh and Aged Infertile Shell Eggs

Replication	Days in storage at 25°C					
	0	7	14	21	35	42
	cc.	cc.	cc.	cc.	cc.	cc.
1	690	695	700	720	715	750
2	680	680	670	690	755	750
3	685	690	680	690	720	755
4	670	675	700	665	750	755
5	680	685	690	695	720	725
6	690	680	700	700	725	730
7	680	695	705	695	740	755
Mean	682	686	692	694	732	746

Table G-2. VOLUMES OF CAKES

Series II. Cakes Made with Fresh Infertile Shell Eggs Beaten at 24° and 27°C and Mixed with 50, 60, and 75 Strokes

Replication	24°C			27°C		
	Strokes			Strokes		
	50	60	75	50	60	75
	cc.	cc.	cc.	cc.	cc.	cc.
1	670	690	685	700	710	730
2	675	695	685	680	705	685
3	690	720	710	695	690	715
4	710	685	720	680	685	700
5	690	710	735	690	685	735
Mean	687	700	707	689	695	713

Table G-3. VOLUMES OF CAKES

Series III. Cakes Made with Unheated and Pasteurized Liquid Whole Eggs and Unheated and Pasteurized Commercially Frozen Eggs

Replication	Laboratory eggs				Commercially frozen	
	Unheated	140°F 8 min.	142°F 5 min.	144°F 3 min.	Unheated	Pasteurized
	cc.	cc.	cc.	cc.	cc.	cc.
1	735	685	725	710	---	---
2	710	710	720	720	620	670
3	710	700	730	720	615	645
4	720	710	715	725	610	675
5	715	715	725	715	615	620
6	665	700	720	705	610	645
Mean	709	703	723	716	614	651

Table G-4. VOLUMES OF CAKES

Series IV. Cakes Made with Frozen Unheated and Pasteurized Liquid Whole Eggs

Replication	Unheated	143°F 15 min.	143°F 30 min.	148°F 0.5 min.	155°F 0.1 min.
	cc.	cc.	cc.	cc.	cc.
1	705	710	700	680	715
2	725	720	715	705	720
3	720	695	735	705	725
4	715	730	720	710	730
5	705	690	705	710	690
Mean	714	709	715	702	716

Table G-5. VOLUMES OF CAKES

Series V. Cakes Made with Spray-dried (0.5% Moisture) Eggs

Replication	Control	Flavored	Baking powder
	cc.	cc.	cc.
1	550	545	615
2	585	520	615
3	610	580	655
4	615	610	675
5	600	585	620
Mean	592	564	636

Table G-6. VOLUMES OF CAKES

Series VI. Cakes Made with Unaged and Aged Commercial Spray-dried (5.0% Moisture) Eggs

Replication	Days in storage at 37°C							
	0		7		14		28	
	Control	Baking powder	Control	Baking powder	Control	Baking powder	Control	Baking powder
	cc.	cc.	cc.	cc.	cc.	cc.	cc.	cc.
1	595	645	---	---	530	545	185	265
2	585	600	585	575	500	510	---	---
3	595	620	550	600	480	520	---	---
4	595	610	555	590	465	505	---	---
5	585	645	565	600	420	545	---	---
Mean	591	624	564	591	479	525	185	265

Table G-7. VOLUMES OF CAKES

Series VII. Cakes Made with Unaged Spray-dried Eggs from Different Plants

Replication	Controls		Dried eggs		
	Shell eggs	Vacuum-dried (Lab.)	Plant 1	Plant 2	Plant 3
	cc.	cc.	cc.	cc.	cc.
1	725	640	610	700	635
2	695	635	595	675	630
3	680	665	615	650	615
4	695	655	600	645	625
5	710	670	630	735	640
Mean	701	653	610	681	629

Table G-8. VOLUMES OF CAKES

Series VIII. Cakes Made with Shell Eggs, Fresh and Aged; Frozen Pasteurized Eggs, Hold and Flash; and Dried Eggs, Vacuum-dried and *Spray-dried (0.5% Moisture)

Replication	Shell		Pasteurized		Dried	
	Fresh	Aged	Hold	Flash	Vacuum	Spray
	cc.	cc.	cc.	cc.	cc.	cc.
1	720	725	700	700	665	695
2	715	700	710	700	640	660
3	710	710	640	695	640	700
4	710	710	660	670	640	690
5	695	705	670	665	650	695
Mean	710	710	676	686	647	688

*Baking powder added.

Table H-1. TENSILE STRENGTH MEASUREMENTS

Series I. Cakes Made with Fresh and Aged Infertile Shell Eggs

Replication	Days in storage at 25°C					
	0	7	14	21	35	42
1	41	37	31	27	26	27
2	52	35	32	31	26	28
3	40	38	43	29	23	37
4	29	40	30	28	26	37
5	36	35	37	31	32	27
6	35	33	32	35	30	26
7	42	39	37	30	28	27
Mean	39	37	35	30	27	30

Table H-2. TENSILE STRENGTH MEASUREMENTS

Series II. Cakes Made with Fresh Infertile Shell Eggs Beaten at 24° and 27°C and Mixed with 50, 60, and 75 Strokes

Replication	24°C			27°C		
	Strokes			Strokes		
	50	60	75	50	60	75
1	47	40	32	37	38	38
2	44	40	50	43	41	42
3	44	42	42	40	44	45
4	37	40	35	38	40	40
5	33	43	33	36	46	36
Mean	41	41	38	39	42	40

Table H-3. TENSILE STRENGTH MEASUREMENTS

Series III. Cakes Made with Unheated and Pasteurized Liquid Whole Eggs and Unheated and Pasteurized Commercially Frozen Eggs

Replication	Laboratory eggs				Commercially frozen	
	Unheated	140°F 8 min.	142°F 5 min.	144°F 3 min.	Unheated	Pasteurized
1	37	44	32	34	--	--
2	37	34	31	31	40	31
3	35	39	35	34	34	32
4	37	39	36	34	36	30
5	42	44	31	33	36	33
6	48	37	34	29	44	33
Mean	39	39	33	33	38	32

Table H-4. TENSILE STRENGTH MEASUREMENTS

Series IV. Cakes Made with Frozen Unheated and Pasteurized Liquid Whole Eggs

Replication	Unheated	143°F 15 min.	143°F 30 min.	148°F 0.5 min.	155°F 0.1 min.
1	33	34	29	33	35
2	32	32	33	32	40
3	31	28	29	29	37
4	33	28	36	33	37
5	43	37	35	43	40
Mean	34	32	32	34	38

Table H-5. TENSILE STRENGTH MEASUREMENTS

Series V. Cakes Made with Spray-dried (0.5% Moisture) Eggs

Replication	Control	Flavored	Baking powder
1	41	36	30
2	45	46	39
3	37	48	41
4	45	46	33
5	44	47	41
Mean	42	45	37

Table H-6. TENSILE STRENGTH MEASUREMENTS

Series VI. Cakes Made with Unaged and Aged Commercial Spray-dried (5.0% Moisture) Eggs

Replication	Days in storage at 37°C					
	0		7		14	
	Control	Baking powder	Control	Baking powder	Control	Baking powder
1	32	25	--	--	40	42
2	46	46	35	35	42	40
3	36	23	49	31	38	37
4	43	37	44	36	47	37
5	41	33	40	36	53	46
Mean	40	33	34	28	44	40

Table H-7. TENSILE STRENGTH MEASUREMENTS

Series VII. Cakes Made with Unaged Spray-dried Eggs from Different Plants

Repli-cation	Controls		Dried eggs		
	Shell eggs	Vacuum-dried (Lab.)	Plant 1	Plant 2	Plant 3
1	44	47	52	38	50
2	46	45	43	37	34
3	44	34	45	49	43
4	44	40	48	39	48
5	43	36	47	36	45
Mean	44	40	47	40	44

Table H-8. TENSILE STRENGTH MEASUREMENTS

Series VIII. Cakes Made with Shell Eggs, Fresh and Aged; Frozen Pasteurized Eggs, Hold and Flash; and Dried Eggs, Vacuum-dried and *Spray-dried (0.5% Moisture)

Repli-cation	Shell		Pasteurized		Dried	
	Fresh	Aged	Hold	Flash	Vacuum	Spray
1	43	25	40	34	47	39
2	30	24	36	44	33	38
3	38	30	32	38	38	35
4	43	28	25	39	48	33
5	43	39	32	43	46	41
Mean	39	29	33	40	42	37

Table J-1. AVERAGE SCORES OF CAKES BY DAYS

Series I. Cakes Made with Fresh and Aged Infertile Shell Eggs

Characteristic	Replication	Days in storage at 25°C 0	7	14	21	35	42
Crumb color (5)	1	5.0	5.0	5.0	5.0	5.0	5.0
	2	5.0	5.0	5.0	5.0	5.0	5.0
	3	5.0	5.0	5.0	5.0	5.0	5.0
	4	5.0	5.0	5.0	5.0	5.0	5.0
	5	5.0	5.0	5.0	5.0	5.0	5.0
	6	5.0	5.0	5.0	5.0	5.0	5.0
	7	5.0	5.0	5.0	5.0	5.0	5.0
	Mean	5.0	5.0	5.0	5.0	5.0	5.0
Texture and grain (35)	1	27.0	28.6	29.2	26.8	27.8	29.4
	2	28.4	29.0	28.0	28.4	28.8	30.0
	3	29.2	29.2	30.2	28.2	29.6	30.6
	4	29.0	29.2	29.8	28.6	30.4	31.0
	5	28.0	29.2	27.8	28.8	30.2	30.8
	6	29.0	28.2	28.8	28.4	30.2	28.8
	7	27.0	27.8	29.4	28.2	30.0	31.0
	Mean	28.2	28.7	29.0	28.2	29.6	30.2
Tenderness (30)	1	25.0	25.4	26.4	26.4	26.8	27.0
	2	26.4	27.6	26.6	27.4	27.4	27.8
	3	26.6	27.0	26.0	26.2	27.6	26.6
	4	26.8	26.2	26.8	26.4	27.2	26.2
	5	25.0	26.4	25.4	26.8	27.4	26.8
	6	26.4	26.4	26.4	26.8	27.2	26.6
	7	26.0	25.4	24.8	27.0	27.2	27.0
	Mean	26.0	26.3	26.1	26.7	27.2	26.9
Moistness (10)	1	8.6	8.6	8.6	8.4	8.6	8.2
	2	8.4	8.4	8.4	8.4	8.6	8.6
	3	8.2	8.4	8.4	8.2	8.6	8.0
	4	8.6	8.8	8.6	8.8	8.6	8.0
	5	8.4	8.6	8.6	8.4	8.6	8.8
	6	8.4	8.4	8.4	8.2	8.2	8.6
	7	8.4	8.6	8.8	8.6	8.6	8.2
	Mean	8.4	8.5	8.5	8.4	8.5	8.4

(Continued)

Table J-1 (Continued)

Characteristic	Replication	Days in storage at 25°C					
		0	7	14	21	35	42
Flavor (20)	1	17.8	17.8	16.8	17.4	17.0	15.8
	2	17.6	16.8	16.8	17.2	17.2	14.4
	3	17.2	16.6	16.2	16.6	17.4	14.4
	4	17.6	16.4	16.8	17.4	14.2	14.8
	5	16.2	17.0	16.2	13.8	16.2	14.0
	6	16.6	16.4	16.4	14.8	13.6	14.4
	7	16.4	16.6	16.6	17.6	14.6	13.4
	Mean	17.0	16.8	16.5	16.4	15.7	14.4
Total scores (100)	1	83.4	85.4	86.0	84.0	85.2	85.2
	2	85.8	86.8	84.8	86.4	87.0	85.6
	3	86.2	86.2	85.8	84.2	88.2	84.6
	4	87.2	85.6	87.4	86.0	85.4	85.0
	5	82.6	86.2	83.0	81.6	87.4	85.4
	6	85.4	83.8	84.8	83.6	84.2	83.4
	7	83.0	83.4	84.6	86.2	85.4	84.6
	Mean	84.8	85.3	85.2	84.6	86.1	84.8

Table J-2. AVERAGE SCORES OF CAKES BY DAYS

Series II. Cakes Made with Fresh Infertile Shell Eggs Beaten at 24° and 27°C and Mixed with 50, 60, and 75 Strokes

Characteristic	Replication	24°C Strokes			27°C Strokes		
		50	60	75	50	60	75
Crumb color (5)	1	5.0	5.0	5.0	5.0	5.0	5.0
	2	5.0	5.0	5.0	5.0	5.0	5.0
	3	5.0	5.0	5.0	5.0	5.0	5.0
	4	5.0	5.0	5.0	5.0	5.0	5.0
	5	5.0	5.0	5.0	5.0	5.0	5.0
	Mean	5.0	5.0	5.0	5.0	5.0	5.0
Texture and grain (35)	1	29.6	30.0	31.0	27.4	30.8	29.0
	2	29.8	31.2	31.2	30.0	30.6	30.6
	3	27.8	28.6	28.4	27.2	27.8	28.4
	4	26.6	26.2	26.6	25.4	26.4	28.0
	5	26.0	28.4	29.4	27.4	28.2	29.4
	Mean	28.0	28.8	29.4	27.2	28.7	29.1
Tenderness (30)	1	25.6	24.6	26.8	26.2	26.2	26.6
	2	26.2	26.0	25.8	27.0	26.6	27.4
	3	25.4	27.0	27.0	26.0	25.2	25.8
	4	26.4	25.8	26.6	26.2	26.4	26.6
	5	25.2	26.4	25.6	26.0	25.4	26.4
	Mean	25.8	26.0	26.4	26.3	26.0	26.6
Moistness (10)	1	8.4	8.2	8.6	8.4	8.2	8.4
	2	8.4	8.6	8.6	8.6	8.4	8.4
	3	8.0	8.4	8.4	8.4	8.2	8.4
	4	8.6	8.4	8.6	8.6	8.6	8.4
	5	8.0	8.4	8.4	8.4	8.2	8.4
	Mean	8.3	8.4	8.5	8.5	8.3	8.4
Flavor (20)	1	17.8	17.2	18.2	16.8	17.8	18.0
	2	17.4	18.2	17.6	17.6	18.0	17.6
	3	16.6	18.0	17.8	17.6	17.4	18.0
	4	17.4	17.4	17.8	17.4	17.4	17.4
	5	17.0	17.2	18.0	17.6	17.0	18.2
	Mean	17.2	17.6	17.9	17.4	17.5	17.8
Total scores (100)	1	86.4	85.0	89.6	83.8	88.0	87.0
	2	86.8	89.0	88.2	88.2	88.6	89.0
	3	82.8	87.0	86.6	84.2	83.6	85.6
	4	84.0	82.8	84.6	82.6	83.8	85.4
	5	81.6	85.2	86.6	83.2	83.6	87.6
	Mean	84.3	85.8	87.1	84.4	85.5	86.9

Table J-3. AVERAGE SCORES OF CAKES BY DAYS

Series III. Cakes Made with Unheated and Pasteurized Liquid Whole Eggs and Unheated and Pasteurized Commercially Frozen Eggs

		Laboratory eggs				Com. frozen	
		Un-heated	140°F 8 min.	142°F 5 min.	144°F 3 min.	Un-heated	Pasteur-ized
Crumb color (5)	1	5.0	5.0	5.0	5.0	----	----
	2	5.0	5.0	5.0	5.0	5.0	5.0
	3	5.0	5.0	5.0	5.0	5.0	5.0
	4	5.0	5.0	5.0	5.0	5.0	5.0
	5	5.0	5.0	5.0	5.0	5.0	5.0
	6	5.0	5.0	5.0	5.0	5.0	5.0
	Mean	5.0	5.0	5.0	5.0	5.0	5.0
Texture and grain (35)	1	29.6	29.8	30.2	28.8	----	----
	2	30.2	31.0	20.5	30.5	28.2	28.5
	3	28.5	30.0	29.2	29.0	28.7	28.0
	4	28.7	29.2	28.7	29.0	25.7	26.2
	5	30.8	30.2	31.0	30.4	28.2	27.6
	6	30.2	29.0	30.0	30.2	27.7	28.5
	Mean	29.6	29.8	29.9	29.6	27.7	27.7
Tenderness (30)	1	26.8	26.4	27.4	26.6	----	----
	2	27.7	28.0	28.2	28.2	26.5	27.7
	3	27.5	27.5	27.2	26.2	25.2	26.5
	4	27.5	27.7	28.0	27.7	26.5	27.2
	5	26.4	27.0	27.2	27.0	25.8	25.8
	6	25.5	27.0	26.0	27.2	25.0	27.0
	Mean	26.9	27.2	27.3	27.1	25.8	26.8
Moistness (10)	1	8.6	8.4	8.4	8.2	----	----
	2	8.7	9.0	9.0	8.7	8.5	8.5
	3	8.0	8.7	8.7	8.7	8.2	8.2
	4	8.5	9.0	8.7	8.7	8.0	8.5
	5	8.4	8.8	8.8	8.6	8.2	8.6
	6	8.5	8.7	8.5	8.7	8.5	8.7
	Mean	8.4	8.7	8.6	8.6	8.3	8.5
Flavor (20)	1	17.8	17.6	17.8	17.4	----	----
	2	17.8	18.0	18.2	18.2	16.0	16.5
	3	17.8	17.8	18.0	17.8	15.8	15.8
	4	17.8	17.8	18.0	17.0	15.2	15.7
	5	17.2	17.4	17.2	17.0	15.8	15.4
	6	16.2	16.5	16.2	15.5	13.0	14.8
	Mean	17.4	17.5	17.6	17.1	15.2	15.6
Total scores (100)	1	87.8	87.2	88.8	86.0	----	----
	2	89.5	91.0	91.0	90.8	84.2	86.2
	3	86.8	89.0	88.2	86.8	83.0	83.5
	4	87.5	88.7	88.5	87.5	80.2	83.2
	5	87.8	88.4	89.4	88.0	82.0	81.4
	6	85.5	86.2	85.8	86.8	79.2	84.0
	Mean	87.5	88.3	88.6	87.6	81.7	83.6

Table J-4. AVERAGE SCORES OF CAKES BY DAYS

Series IV. Cakes Made with Frozen Unheated and Pasteurized Liquid Whole Eggs

Characteristic	Replication	Unheated	143°F 15 min.	143°F 30 min.	148°F 0.5 min.	155°F 0.1 min.
Crumb color (5)	1	5.0	5.0	5.0	5.0	5.0
	2	5.0	5.0	5.0	5.0	5.0
	3	5.0	5.0	5.0	5.0	5.0
	4	5.0	5.0	5.0	5.0	5.0
	5	5.0	5.0	5.0	5.0	5.0
	Mean	5.0	5.0	5.0	5.0	5.0
Texture and grain (35)	1	27.4	30.2	30.6	24.8	30.4
	2	28.8	31.0	30.6	27.6	30.8
	3	29.2	32.6	29.8	30.0	31.0
	4	28.4	30.2	31.6	28.2	30.0
	5	29.4	28.4	31.2	30.4	29.4
	Mean	28.6	30.5	30.7	28.2	30.3
Tenderness (30)	1	25.8	25.0	25.8	25.4	26.2
	2	25.8	25.6	25.8	24.4	26.0
	3	26.0	28.0	26.0	25.2	26.4
	4	26.6	24.8	25.2	25.2	24.2
	5	25.8	24.8	25.6	25.2	25.6
	Mean	26.0	25.6	25.7	25.1	25.7
Moistness (10)	1	8.8	8.6	8.6	8.6	8.4
	2	8.8	8.8	8.6	8.6	8.8
	3	8.8	8.6	8.6	8.6	8.6
	4	8.8	8.6	8.8	8.8	8.8
	5	8.8	8.6	8.4	8.6	8.6
	Mean	8.8	8.6	8.6	8.6	8.6
Flavor (20)	1	16.6	16.0	15.6	16.6	16.8
	2	16.2	16.8	14.6	17.0	17.6
	3	17.4	16.8	16.0	17.8	17.8
	4	17.4	17.4	17.2	18.0	18.0
	5	17.6	17.8	17.2	17.0	16.4
	Mean	17.0	16.9	16.1	17.3	17.3
Total scores (100)	1	83.6	85.6	85.4	80.4	86.8
	2	84.6	87.2	84.6	82.6	88.2
	3	86.4	91.0	85.4	86.6	88.8
	4	86.2	86.0	87.6	85.2	86.0
	5	86.4	84.6	87.4	86.2	85.0
	Mean	85.5	86.7	86.1	84.2	86.9

Table J-5. AVERAGE SCORES OF CAKES BY DAYS

Series V. Cakes Made with Spray-dried (0.5% Moisture) Eggs

Characteristic	Replication	Control	Flavored	Baking powder
Crumb color (5)	1	5.0	5.0	5.0
	2	5.0	4.6	5.0
	3	4.8	4.6	4.8
	4	5.0	4.8	4.6
	5	4.8	4.4	4.6
	Mean	4.9	4.7	4.8
Texture and grain (35)	1	21.2	21.2	25.6
	2	23.2	21.4	26.4
	3	24.0	21.0	25.4
	4	23.4	23.4	28.2
	5	24.2	21.6	22.4
	Mean	23.2	21.7	25.6
Tenderness (30)	1	21.0	21.8	24.2
	2	22.4	21.0	23.4
	3	22.8	20.6	23.0
	4	24.8	24.6	26.0
	5	23.6	23.8	23.0
	Mean	22.9	22.3	23.9
Moistness (10)	1	7.4	7.6	8.0
	2	8.4	8.4	8.0
	3	8.6	8.4	8.2
	4	8.4	8.6	8.6
	5	8.8	8.8	7.2
	Mean	8.3	8.3	8.0
Flavor (20)	1	14.2	15.8	15.6
	2	15.0	17.4	14.2
	3	15.2	16.2	15.2
	4	12.2	16.0	15.4
	5	15.4	15.6	14.6
	Mean	14.4	16.2	15.0
Total scores (100)	1	68.6	71.2	78.4
	2	74.0	72.6	77.2
	3	75.4	70.8	76.6
	4	73.4	77.6	82.8
	5	76.8	74.2	72.0
	Mean	73.6	73.3	77.4

Table J-6. AVERAGE SCORES OF CAKES BY DAYS

Series VI. Cakes Made with Unaged and Aged Commercial Spray-dried (5.0% Moisture) Eggs

Characteristic	Replication	Days in storage at 37°C 0 Control	0 Bak. Pdr.	7 Control	7 Bak. pdr.	14 Control	14 Bak. pdr.	28 Control	28 Bak. pdr.
Crumb color (5)	1	5.0	5.0	--	5.0	3.4	4.4	1.0	1.0
	2	5.0	4.8	4.6	4.6	3.8	3.8	--	--
	3	5.0	5.0	4.2	4.6	3.0	3.4	--	--
	4	5.0	4.8	4.8	4.8	3.4	4.0	--	--
	5	5.0	4.8	4.6	4.8	3.6	4.2	--	--
	Mean	5.0	4.9	4.6	4.7	3.4	3.9	1.0	1.0
Texture and grain (35)	1	25.8	27.4	--	--	17.4	21.6	0.4	6.8
	2	26.2	21.2	24.6	20.8	20.4	21.4	--	--
	3	27.0	24.2	23.8	24.0	16.6	17.8	--	--
	4	26.2	24.4	25.0	27.4	19.2	21.8	--	--
	5	28.0	27.0	24.8	25.4	14.6	18.8	--	--
	Mean	26.6	24.8	24.6	24.4	17.6	20.3	0.4	6.8
Tenderness (30)	1	25.2	24.2	--	--	21.2	22.0	4.0	7.4
	2	24.4	23.2	24.8	23.4	22.6	22.0	--	--
	3	25.4	23.8	24.2	24.4	20.6	22.6	--	--
	4	22.4	24.0	23.0	24.2	19.6	22.0	--	--
	5	24.0	24.0	23.2	24.2	18.4	19.6	--	--
	Mean	24.3	23.8	23.8	24.1	20.5	21.6	4.0	7.4
Moistness (10)	1	8.6	8.2	--	--	7.6	8.0	2.8	2.6
	2	8.2	7.4	7.6	7.4	8.0	7.6	--	--
	3	8.4	7.2	8.2	8.2	7.2	7.6	--	--
	4	8.0	8.0	7.8	8.4	7.2	7.4	--	--
	5	8.6	8.4	8.4	8.6	7.2	7.8	--	--
	Mean	8.5	7.8	8.0	8.2	7.4	7.7	2.8	2.6
Flavor (20)	1	14.0	14.6	--	--	9.8	11.2	2.8	3.0
	2	13.2	14.0	15.0	13.6	10.8	11.0	--	--
	3	14.4	13.4	12.8	14.2	10.4	11.4	--	--
	4	15.2	14.0	14.6	12.8	11.2	10.4	--	--
	5	14.0	13.2	12.0	13.4	7.0	10.4	--	--
	Mean	14.2	13.9	13.6	13.5	9.8	10.9	2.8	3.0
Total scores (100)	1	78.6	79.4	--	--	59.4	66.8	11.0	20.8
	2	77.0	70.6	76.6	69.8	65.6	65.8	--	--
	3	80.2	73.6	73.2	75.4	57.8	62.8	--	--
	4	76.8	75.2	75.2	77.6	60.6	65.8	--	--
	5	79.6	77.4	73.0	76.4	50.8	60.8	--	--
	Mean	78.4	75.2	74.5	74.8	58.8	64.4	11.0	20.8

Table J-7. AVERAGE SCORES OF CAKES BY DAYS

Series VII. Cakes Made with Unaged Spray-dried Eggs from Different Plants

Characteristic	Replication	Controls		Dried eggs		
		Shell eggs	Vacuum-dried (Lab.)	Plant 1	Plant 2	Plant 3
Crumb color (5)	1	5.0	5.0	5.0	5.0	5.0
	2	5.0	5.0	5.0	5.0	5.0
	3	4.8	5.0	5.0	5.0	5.0
	4	5.0	4.8	5.0	5.0	5.0
	5	4.4	5.0	5.0	5.0	5.0
	Mean	4.8	5.0	5.0	5.0	5.0
Texture and grain (35)	1	29.0	27.8	26.2	29.0	27.2
	2	28.4	29.6	25.8	27.0	25.6
	3	29.5	29.3	27.0	24.5	25.5
	4	29.8	28.0	25.8	26.8	29.5
	5	29.0	27.8	27.2	30.6	29.2
	Mean	29.1	28.5	26.4	27.6	27.0
Tenderness (30)	1	27.0	24.2	25.0	26.0	25.0
	2	25.2	26.4	23.8	25.6	24.2
	3	26.5	25.6	24.0	25.8	25.3
	4	24.8	26.0	24.5	24.8	25.5
	5	26.0	24.0	25.2	26.8	23.8
	Mean	25.9	25.4	24.5	25.8	24.8
Moistness (10)	1	8.6	8.4	8.4	8.6	8.4
	2	8.4	8.4	8.2	8.4	8.4
	3	8.5	8.3	8.0	8.0	8.3
	4	8.3	8.3	8.0	8.3	8.0
	5	8.6	8.4	8.6	8.4	8.6
	Mean	8.5	8.4	8.2	8.3	8.3
Flavor (20)	1	16.6	16.4	12.8	17.2	14.8
	2	16.6	15.6	15.2	17.0	16.0
	3	16.3	15.5	14.8	15.5	14.3
	4	16.5	15.5	15.5	17.0	14.0
	5	16.8	15.4	13.4	15.8	15.8
	Mean	16.7	15.7	14.3	16.5	15.0
Total scores (100)	1	86.2	81.8	77.4	85.8	80.4
	2	83.6	85.0	78.0	83.0	79.2
	3	85.5	84.5	78.8	78.8	78.3
	4	84.3	82.5	78.8	81.8	82.0
	5	84.8	80.6	79.4	86.6	82.4
	Mean	84.9	82.9	78.5	83.2	80.5

Table J-8. AVERAGE SCORES OF CAKES BY DAYS

Series VIII. Cakes Made with Shell Eggs, Fresh and Aged; Frozen Pasteurized Eggs, Hold and Flash; and Dried Eggs, Vacuum-dried and Spray-dried (0.5% Moisture)

Characteristic	Replication	Shell		Pasteurized		Dried	
		Fresh	Aged	Hold	Flash	Vacuum	Spray
Crumb color (5)	1	5.0	5.0	5.0	5.0	4.8	5.0
	2	5.0	5.0	5.0	5.0	5.0	4.8
	3	5.0	5.0	5.0	5.0	5.0	4.8
	4	5.0	4.6	5.0	5.0	4.8	4.6
	5	5.0	5.0	5.0	5.0	5.0	4.6
	Mean	5.0	4.9	5.0	5.0	4.9	4.7
Texture and grain (35)	1	28.5	26.0	30.5	30.5	24.8	28.0
	2	30.6	29.8	31.0	29.8	28.2	25.8
	3	29.2	27.0	29.4	28.0	27.8	29.8
	4	28.0	27.0	29.0	29.2	25.0	29.2
	5	28.2	29.2	28.8	26.8	27.2	31.8
	Mean	28.9	27.8	29.7	28.9	26.6	28.9
Tenderness (30)	1	26.8	26.0	26.0	26.5	23.5	26.0
	2	25.4	26.6	26.6	26.6	26.8	25.8
	3	26.8	27.0	25.8	26.8	25.2	26.6
	4	25.8	26.2	26.2	25.6	25.4	25.4
	5	26.0	26.6	25.8	24.4	25.8	26.2
	Mean	26.1	26.5	26.1	26.0	25.3	26.0
Moistness (10)	1	8.3	8.5	8.3	8.5	8.3	8.3
	2	8.6	8.2	8.6	8.4	8.6	8.2
	3	8.2	8.6	8.6	8.6	7.6	8.6
	4	8.2	8.2	8.4	8.6	7.4	8.4
	5	8.4	8.2	7.4	8.0	7.6	8.0
	Mean	8.3	8.3	8.3	8.4	7.9	8.3
Flavor (20)	1	17.8	16.5	15.8	18.0	17.5	14.0
	2	18.2	16.4	16.6	17.6	17.4	13.4
	3	17.0	15.8	16.0	17.0	17.0	14.8
	4	17.2	16.6	16.0	17.6	16.4	14.6
	5	17.6	13.6	16.0	17.4	17.6	13.2
	Mean	17.6	15.8	16.1	17.5	17.2	14.0
Total scores (100)	1	86.3	82.0	85.5	88.5	78.8	81.3
	2	87.8	86.0	87.8	87.4	86.0	78.0
	3	86.2	83.4	84.8	85.4	82.6	84.6
	4	84.2	82.6	84.6	86.0	79.0	82.2
	5	85.2	82.6	83.0	81.6	83.2	83.8
	Mean	85.9	83.3	85.1	85.8	82.0	82.0

Table K-1. AVERAGE SCORES OF CAKES BY JUDGES

Series I. Cakes Made with Fresh and Aged Infertile Shell Eggs

Characteristic	Judge	Days in storage at 25°C					
		0	7	14	21	35	42
Crumb color (5)	1	5.0	5.0	5.0	5.0	5.0	5.0
	2	5.0	5.0	5.0	5.0	5.0	5.0
	3	5.0	5.0	5.0	5.0	5.0	5.0
	4	5.0	5.0	5.0	5.0	5.0	5.0
	5	5.0	5.0	5.0	5.0	5.0	5.0
	Mean	5.0	5.0	5.0	5.0	5.0	5.0
Texture and grain (35)	1	29.2	29.2	30.7	31.3	32.1	31.4
	2	26.7	28.0	27.7	27.6	29.9	30.6
	3	28.0	27.7	27.7	27.0	29.6	29.7
	4	29.6	30.6	20.1	27.7	29.7	30.8
	5	27.7	28.1	28.8	27.7	26.7	28.6
	Mean	28.2	28.7	29.0	28.2	29.6	30.2
Tenderness (30)	1	26.0	26.1	25.8	27.4	27.1	27.3
	2	25.6	26.1	26.0	26.1	27.0	27.3
	3	23.4	23.9	22.7	24.0	25.1	23.4
	4	27.7	27.7	27.7	28.0	28.4	27.8
	5	27.7	28.1	28.1	28.0	28.6	28.4
	Mean	26.0	26.3	26.1	26.7	27.2	26.9
Moistness (10)	1	8.6	8.6	8.7	8.6	8.6	8.6
	2	8.8	9.0	9.0	9.0	8.8	8.3
	3	9.0	9.0	8.7	8.8	9.0	8.7
	4	8.0	8.0	8.0	8.0	8.0	7.8
	5	7.7	8.1	8.3	7.8	8.3	8.3
	Mean	8.4	8.5	8.5	8.4	8.5	8.4
Flavor (20)	1	17.7	17.3	16.3	15.0	14.3	11.6
	2	17.6	16.7	17.0	16.6	16.8	16.1
	3	17.4	18.1	18.0	18.0	16.8	17.1
	4	16.7	14.4	14.0	15.3	14.3	10.7
	5	15.8	17.4	17.4	16.8	16.4	16.7
	Mean	17.0	16.8	16.5	16.4	15.7	14.4
Total scores (100)	1	86.6	86.3	86.6	87.3	87.1	83.8
	2	83.8	84.8	84.7	84.4	87.4	87.3
	3	82.8	83.6	82.1	82.1	85.6	84.0
	4	87.0	85.1	84.6	84.0	85.4	82.3
	5	83.7	86.8	87.7	85.0	85.0	87.0
	Mean	84.8	85.3	85.1	84.6	86.1	84.8

Table K-2. AVERAGE SCORES OF CAKES BY JUDGES

Series II. Cakes Made with Fresh Infertile Shell Eggs Beaten at 24° and 27°C and Mixed with 50, 60, and 75 Strokes

Characteristic	Judge	24°C			27°C		
		Strokes			Strokes		
		50	60	75	50	60	75
Crumb color (5)	1	5.0	5.0	5.0	5.0	5.0	5.0
	2	5.0	5.0	5.0	5.0	5.0	5.0
	3	5.0	5.0	5.0	5.0	5.0	5.0
	4	5.0	5.0	5.0	5.0	5.0	5.0
	5	5.0	5.0	5.0	5.0	5.0	5.0
	Mean	5.0	5.0	5.0	5.0	5.0	5.0
Texture and grain (35)	1	26.2	25.2	26.4	24.0	25.6	25.6
	2	27.6	30.0	29.4	28.6	29.6	30.0
	3	29.0	29.4	30.0	28.8	29.2	30.4
	4	27.8	29.4	30.0	27.8	29.6	30.4
	5	29.6	30.2	31.2	27.0	29.4	29.2
	Mean	28.0	28.8	29.4	27.2	28.7	29.1
Tenderness (30)	1	24.0	23.8	24.2	24.6	25.0	24.2
	2	26.0	26.8	26.8	27.0	26.4	27.8
	3	25.6	25.4	25.6	25.4	24.4	25.6
	4	26.2	26.6	27.6	27.4	26.8	28.0
	5	27.0	27.2	27.6	27.4	27.2	27.2
	Mean	25.8	26.0	26.4	26.3	26.0	26.6
Moistness (10)	1	8.0	8.0	8.0	8.0	8.0	8.0
	2	9.0	9.0	9.0	9.0	9.0	9.0
	3	8.8	8.8	9.0	9.0	8.4	8.8
	4	8.0	8.0	8.0	8.0	8.0	8.0
	5	7.6	8.4	8.4	8.4	8.2	8.2
	Mean	8.3	8.4	8.5	8.5	8.3	8.4
Flavor (20)	1	18.0	18.0	18.0	18.0	18.0	18.0
	2	18.0	18.0	18.0	17.4	18.0	18.0
	3	17.0	18.0	18.6	18.0	17.4	18.4
	4	15.8	15.6	16.8	16.0	16.6	17.4
	5	17.4	18.4	18.0	17.6	17.6	17.2
	Mean	17.2	17.6	17.9	17.4	17.5	17.8
Total scores (100)	1	81.2	80.0	81.6	79.6	81.8	80.8
	2	85.6	88.8	88.2	87.0	88.0	89.8
	3	85.4	86.4	88.2	86.2	84.4	88.2
	4	82.8	84.6	87.4	83.8	86.0	89.0
	5	86.6	89.2	90.2	85.4	87.4	86.8
	Mean	84.3	85.8	87.1	84.4	85.5	86.9

Table K-3. AVERAGE SCORES OF CAKES BY JUDGES

Series III. Cakes Made with Unheated and Pasteurized Liquid Whole Egg and Unheated and Pasteurized Commercially Frozen Eggs

Characteristic	Judge	Laboratory eggs Unheated	Laboratory eggs 140°F 8 min.	Laboratory eggs 142°F 5 min.	Laboratory eggs 144°F 3 min.	Com. frozen Unheated	Com. frozen Pasteurized
Crumb color (5)	1	5.0	5.0	5.0	5.0	5.0	5.0
	2	5.0	5.0	5.0	5.0	5.0	5.0
	3	5.0	5.0	5.0	5.0	5.0	5.0
	4	5.0	5.0	5.0	5.0	5.0	5.0
	5	5.0	5.0	5.0	5.0	5.0	5.0
	Mean	5.0	5.0	5.0	5.0	5.0	5.0
Texture and grain (35)	1	31.0	31.8	31.3	31.3	28.0	28.8
	2	31.6	31.6	31.6	31.6	28.8	30.0
	3	28.3	28.1	28.0	28.1	26.8	26.2
	4	28.6	28.6	30.0	28.3	27.0	26.5
	5	28.2	28.2	28.8	27.6	27.5	26.7
	Mean	29.6	29.7	29.9	29.4	27.6	27.6
Tenderness (30)	1	27.0	27.3	26.6	27.2	25.4	26.4
	2	27.3	27.8	28.0	27.3	25.8	27.2
	3	26.0	26.6	27.5	26.5	25.2	26.0
	4	25.6	26.3	26.3	27.3	26.0	27.5
	5	28.0	27.6	28.0	27.6	27.0	27.5
	Mean	26.8	27.1	27.3	27.2	25.9	26.9
Moistness (10)	1	9.0	9.0	9.0	9.0	9.0	9.0
	2	9.0	9.0	9.0	9.0	8.8	9.0
	3	8.5	8.8	8.8	8.6	8.0	8.4
	4	7.6	8.0	7.6	7.6	8.0	8.0
	5	7.6	8.6	8.4	8.2	7.2	7.8
	Mean	8.3	8.7	8.5	8.5	8.2	8.4
Flavor (20)	1	17.6	17.6	17.6	17.6	12.2	12.6
	2	18.0	18.0	18.0	18.0	16.8	18.0
	3	17.3	17.8	17.8	16.8	15.4	16.2
	4	14.6	15.0	14.6	14.3	12.5	13.5
	5	18.2	18.0	18.4	17.6	16.8	15.5
	Mean	17.1	17.3	17.3	16.9	14.7	15.1
Total scores (100)	1	89.6	90.6	89.7	90.2	79.6	81.8
	2	91.0	91.5	91.7	91.0	85.2	89.2
	3	85.1	86.5	87.2	85.2	80.4	81.8
	4	81.6	83.0	83.7	82.7	78.5	80.5
	5	87.0	87.4	88.6	86.2	83.5	82.5
	Mean	86.8	87.8	88.2	87.1	81.5	83.2

Table K-4. AVERAGE SCORES OF CAKES BY JUDGES

Series IV. Cakes Made with Frozen Unheated and Pasteurized Liquid Whole Egg

Characteristic	Judge	Unheated	143°F 15 min.	143°F 30 min.	148°F 0.5 min.	155°F 0.1 min.
Crumb color (5)	1	5.0	5.0	5.0	5.0	5.0
	2	5.0	5.0	5.0	5.0	5.0
	3	5.0	5.0	5.0	5.0	5.0
	4	5.0	5.0	5.0	5.0	5.0
	5	5.0	5.0	5.0	5.0	5.0
	Mean	5.0	5.0	5.0	5.0	5.0
Texture and grain (35)	1	30.8	32.0	31.0	27.8	31.4
	2	29.2	30.2	31.2	28.4	28.6
	3	27.4	30.0	30.0	27.8	29.2
	4	26.2	29.4	30.6	26.6	30.4
	5	29.6	30.8	30.8	30.4	32.0
	Mean	28.6	30.5	30.7	28.2	30.3
Tenderness (30)	1	25.2	25.4	24.2	24.8	25.4
	2	23.4	22.0	23.8	21.8	23.4
	3	24.4	24.0	24.0	22.4	22.4
	4	28.2	27.8	28.0	27.6	28.6
	5	28.8	29.0	28.4	28.8	28.6
	Mean	26.0	25.6	25.7	25.1	25.7
Moistness (10)	1	9.0	9.0	9.0	9.0	9.0
	2	9.0	9.0	9.0	9.0	9.0
	3	9.0	8.8	9.0	8.8	8.8
	4	8.0	8.0	8.0	8.0	8.0
	5	9.0	8.4	8.0	8.4	8.4
	Mean	8.8	8.6	8.6	8.6	8.6
Flavor (20)	1	17.4	16.0	16.2	17.8	18.0
	2	16.8	18.0	18.0	17.6	18.0
	3	17.0	17.4	14.0	16.4	15.4
	4	15.0	14.6	15.0	15.4	16.6
	5	19.0	18.8	17.4	19.2	18.6
	Mean	17.0	16.9	16.1	17.3	17.3
Total scores (100)	1	87.4	87.6	85.4	84.4	88.8
	2	83.4	84.2	87.0	81.8	84.0
	3	82.8	85.2	81.8	80.4	80.8
	4	82.8	84.8	86.6	82.6	88.6
	5	91.4	92.0	89.6	91.8	92.6
	Mean	85.5	86.7	86.1	84.2	86.9

Table K-5. AVERAGE SCORES OF CAKES BY JUDGES

Series V. Cakes Made with Spray-dried (0.5% Moisture) Egg

Characteristic	Judge	Control	Flavored	Baking powder
Crumb color (5)	1	5.0	4.6	5.0
	2	5.0	5.0	5.0
	3	5.0	5.0	5.0
	4	4.6	4.0	4.6
	5	5.0	4.8	4.6
	Mean	4.9	4.7	4.8
Texture and grain (35)	1	22.8	22.0	28.6
	2	16.6	15.4	21.8
	3	26.4	25.6	27.4
	4	21.0	18.4	23.8
	5	29.2	27.4	26.4
	Mean	23.2	21.7	25.6
Tenderness (30)	1	22.4	21.8	24.8
	2	17.8	17.6	20.0
	3	22.4	22.8	22.6
	4	26.0	24.6	25.6
	5	26.0	25.0	26.6
	Mean	22.9	22.3	23.9
Moistness (10)	1	8.8	8.6	8.8
	2	9.0	9.0	8.8
	3	8.6	8.8	8.6
	4	7.6	7.6	6.4
	5	7.6	7.8	7.6
	Mean	8.3	8.3	8.0
Flavor (20)	1	14.4	16.8	15.8
	2	14.6	16.8	15.0
	3	17.0	18.2	17.6
	4	11.4	13.8	12.0
	5	14.6	15.2	14.8
	Mean	14.4	16.2	15.0
Total scores (100)	1	72.8	73.8	83.0
	2	63.0	64.0	70.0
	3	79.4	80.4	81.0
	4	70.6	68.2	72.8
	5	82.4	80.0	80.2
	Mean	73.6	73.3	77.4

Table K-6. AVERAGE SCORES OF CAKES BY JUDGES

Series VI. Cakes Made with Unaged and Aged Commercial Spray-dried (5.0% Moisture) Eggs

Characteristic	Judge	Days in storage at 37°C							
		0		7		14		28	
		Control	Bak. pdr.	Control	Bak. pdr.	Control	Bak. pdr.	Con. trol	Bak. pdr.
Crumb color (5)	1	5.0	5.0	5.0	5.0	5.0	5.0	0.0	0.0
	2	5.0	5.0	4.3	4.5	2.0	3.0	0.0	0.0
	3	5.0	5.0	4.8	5.0	3.0	3.6	1.0	0.0
	4	5.0	4.6	3.8	4.0	2.8	3.0	1.0	1.0
	5	5.0	4.8	5.0	5.0	4.4	4.8	3.0	4.0
	Mean	5.0	4.9	4.6	4.7	3.4	3.9	1.0	1.0
Texture and grain (35)	1	27.2	29.4	25.0	26.2	14.0	17.2	0.0	1.0
	2	25.0	26.6	20.0	23.3	10.0	15.0	0.0	0.0
	3	27.2	26.8	26.8	26.5	18.6	23.2	0.0	10.0
	4	25.0	16.0	22.0	20.0	17.8	19.6	1.0	3.0
	5	28.8	25.4	29.0	26.7	27.8	26.4	1.0	20.0
	Mean	26.6	24.8	24.6	24.5	17.6	20.3	0.4	6.8
Tenderness (30)	1	22.8	23.6	22.0	22.8	15.2	17.4	0.0	0.0
	2	21.0	21.4	18.8	22.0	12.0	15.6	0.0	0.0
	3	23.8	21.4	23.8	24.0	23.2	22.2	10.0	22.0
	4	26.6	26.2	27.8	25.3	27.0	27.2	10.0	10.0
	5	27.2	26.6	26.8	26.3	25.0	25.8	0.0	5.0
	Mean	24.3	23.8	23.8	24.1	20.5	21.6	4.0	7.4
Moistness (10)	1	8.6	8.6	7.5	8.0	6.2	6.4	0.0	0.0
	2	9.0	8.4	9.0	9.0	9.0	9.0	0.0	0.0
	3	9.0	9.0	8.5	9.0	7.6	8.4	5.0	5.0
	4	8.0	6.8	8.0	8.0	7.6	7.8	4.0	4.0
	5	7.2	6.4	7.0	6.8	6.8	7.0	5.0	4.0
	Mean	8.4	7.8	8.0	8.2	7.4	7.7	2.8	2.6
Flavor (20)	1	14.2	15.0	15.5	13.3	10.8	12.6	0.0	0.0
	2	12.8	11.4	9.3	11.8	5.2	8.2	0.0	0.0
	3	17.0	17.6	16.5	16.8	12.2	13.8	5.0	10.0
	4	10.8	10.0	11.0	9.5	6.6	5.4	5.0	2.0
	5	16.0	15.4	15.8	16.3	14.4	14.4	4.0	3.0
	Mean	14.2	13.9	13.6	13.5	9.8	10.9	2.8	3.0
Total scores	1	77.8	81.6	75.0	75.3	51.2	58.6	0.0	1.0
	2	72.8	72.8	61.3	70.5	38.2	50.8	0.0	0.0
	3	82.0	79.8	80.3	81.3	64.6	71.2	21.0	47.0
	4	75.4	63.6	72.5	66.8	61.8	63.0	21.0	20.0
	5	84.2	78.4	83.5	80.3	78.4	78.4	13.0	36.0
	Mean	78.4	75.2	74.5	74.8	58.8	64.4	11.0	20.8

Table K-7. AVERAGE SCORES OF CAKES BY JUDGES

Series VII. Cakes Made with Unaged Spray-dried Eggs from Different Plants

Characteristic	Judge	Controls		Dried eggs		
		Shell eggs	Vacuum-dried (Lab.)	Plant 1	Plant 2	Plant 3
Crumb color (5)	1	5.0	5.0	5.0	5.0	5.0
	2	4.7	5.0	5.0	5.0	5.0
	3	4.6	5.0	5.0	5.0	5.0
	4	4.8	5.0	5.0	5.0	5.0
	5	4.8	5.0	5.0	5.0	5.0
	Mean	4.8	5.0	5.0	5.0	5.0
Texture and grain (35)	1	29.4	25.8	23.8	25.6	25.8
	2	30.0	28.0	25.3	28.7	26.3
	3	29.6	29.8	27.2	26.8	25.6
	4	27.2	29.6	26.0	27.2	26.4
	5	29.6	29.0	29.2	28.8	30.4
	Mean	29.1	28.4	26.3	27.4	27.0
Tenderness (30)	1	24.2	22.4	21.0	23.2	21.6
	2	26.0	25.0	22.7	24.0	23.0
	3	24.6	25.2	25.0	25.8	24.6
	4	27.2	27.2	26.6	27.8	26.8
	5	27.6	26.8	26.8	27.6	26.8
	Mean	25.9	25.3	24.4	25.7	24.6
Moistness (10)	1	9.0	8.4	8.0	8.2	8.2
	2	9.0	9.0	9.0	9.0	9.0
	3	8.8	9.0	8.8	9.0	9.0
	4	8.0	8.0	8.0	8.0	8.0
	5	7.8	7.6	7.8	7.8	8.0
	Mean	8.5	8.4	8.3	8.4	8.4
Flavor (20)	1	16.0	14.4	12.4	14.2	12.8
	2	18.0	18.0	18.0	18.0	18.0
	3	17.6	17.2	14.4	17.8	15.8
	4	14.8	14.4	11.4	15.4	12.8
	5	17.0	15.4	16.6	17.8	17.0
	Mean	16.7	15.9	14.6	16.6	15.3
Total scores (100)	1	83.6	76.0	70.2	76.2	73.4
	2	87.7	85.0	80.0	84.7	81.3
	3	85.2	86.0	80.2	86.4	82.2
	4	82.0	84.2	77.0	83.4	79.0
	5	87.0	83.6	85.8	87.0	87.0
	Mean	85.1	82.9	78.6	83.2	80.6

Table K-8. AVERAGE SCORES OF CAKES BY JUDGES

Series VIII. Cakes Made with Shell Eggs, Fresh and Aged; Frozen Pasteurized Eggs, Hold and Flash; and Dried Eggs, Vacuum-dried and Spray-dried (0.5% Moisture)

Characteristic	Judge	Shell		Pasteurized		Dried	
		Fresh	Aged	Hold	Flash	Vacuum	Spray
Crumb color (5)	1	5.0	5.0	5.0	5.0	5.0	5.0
	2	5.0	5.0	5.0	5.0	5.0	5.0
	3	5.0	4.8	5.0	5.0	5.0	4.3
	4	5.0	4.8	5.0	5.0	4.6	4.4
	5	5.0	5.0	5.0	5.0	5.0	5.0
	Mean	5.0	4.9	5.0	5.0	4.9	4.7
Texture and grain (35)	1	27.2	29.6	29.0	26.8	28.0	30.0
	2	28.2	25.0	28.6	27.2	21.6	28.6
	3	29.5	29.0	29.8	29.5	28.3	28.5
	4	29.2	26.0	30.2	29.8	25.0	28.2
	5	30.6	30.0	21.0	30.8	30.8	29.4
	Mean	28.9	27.9	29.7	28.8	26.7	28.9
Tenderness (30)	1	25.2	27.4	25.2	24.6	25.6	25.6
	2	24.6	23.6	24.4	25.2	21.0	25.6
	3	24.8	24.5	24.0	24.8	25.8	24.0
	4	27.4	28.0	27.8	27.2	26.8	26.8
	5	28.4	28.6	28.6	27.8	28.0	27.6
	Mean	26.1	26.4	26.0	25.9	25.4	25.9
Moistness (10)	1	9.0	9.0	9.0	9.0	9.0	9.0
	2	9.0	9.0	8.6	8.6	6.8	9.0
	3	8.5	8.8	8.8	9.0	8.8	8.3
	4	7.6	7.6	7.6	7.8	7.0	8.0
	5	7.6	7.4	7.4	8.0	8.0	7.2
	Mean	8.3	8.4	8.3	8.5	7.9	8.3
Flavor (20)	1	18.4	16.2	17.6	17.8	18.2	12.0
	2	18.0	17.4	16.4	17.6	17.0	17.0
	3	18.0	17.8	17.5	18.5	17.8	16.3
	4	15.6	15.4	15.2	16.4	15.2	9.2
	5	17.8	12.4	14.0	17.4	17.0	16.0
	Mean	17.6	15.8	16.1	17.5	17.0	14.1
Total scores (100)	1	84.8	87.2	85.8	83.2	85.8	81.6
	2	84.8	80.0	83.0	83.6	71.4	85.2
	3	85.8	84.8	85.0	86.5	85.5	81.3
	4	84.8	81.8	85.8	86.2	78.6	76.6
	5	89.4	83.4	86.0	89.0	89.6	85.2
	Mean	85.9	83.4	85.1	85.7	82.2	82.0

Table L-1. ANALYSIS OF VARIANCE OF JUDGES' TOTAL SCORES OF CAKES

Series I. Cakes Made with Fresh and Aged Infertile Shell Eggs

Source of Variation	Degrees of Freedom	Mean Square
Replications	6	20.78
Treatments	5	10.46
Treatments x Replications	30	8.01
Judges	4	54.61
Judges x Replications	24	18.25*
Judges x Treatments	20	15.68
Treatments x Replications x Judges	120	9.65
Total	209	

*Significant

Table L-2. ANALYSIS OF VARIANCE OF JUDGES' TOTAL SCORES OF CAKES

Series II. Cakes Made with Fresh Infertile Shell Eggs Beaten at 24°C and 27°C and the Flour Combined with the Foam in 50, 60, and 75 Strokes

Source of Variation	Degrees of Freedom	Mean Square
Replications	4	94.99
Treatments	5	35.70
Treatments x Replications	20	8.62
Judges	4	245.48
Judges x Replications	16	32.07
Judges x Treatments	20	8.29
Treatments x Replications x Judges	80	6.86
Total	149	

Table L-3. ANALYSIS OF VARIANCE OF JUDGES' TOTAL SCORES OF CAKES

Series III. Cakes Made with Unheated and Pasteurized Liquid Whole Egg and Unheated and Pasteurized Commercially Frozen Egg

Source of Variation	Degrees of Freedom	Mean Square
Replications	4	30.47
Treatments	5	179.97**
Treatments x Replications	20	3.74
Judges	3	179.94
Judges X Replications	11	15.45**
Judges x Treatments	15	11.27**
Judges x Treatments x Replications	54	4.35
Total	113	

**Highly significant

Table L-4. ANALYSIS OF VARIANCE OF JUDGES' TOTAL SCORES OF CAKES

Series IV. Cakes Made with Frozen Unheated and Frozen Pasteurized Liquid Whole Egg

Source of Variation	Degrees of Freedom	Mean Square
Replications	4	38.05
Treatments	4	31.01
Treatments x Replications	16	14.89
Judges	4	310.13
Judges x Replications	16	16.08
Judges x Treatments	16	15.64
Judges x Treatments x Replications	64	11.70
Total	124	

Table L-5. ANALYSIS OF VARIANCE OF JUDGES' TOTAL SCORES OF CAKES

Series V. Cakes Made with Spray-dried (0.5% Moisture) Whole Egg

Source of Variation	Degrees of Freedom	Mean Square
Replications	4	54.85
Treatments	2	130.17
Treatments x Replications	8	53.27
Judges	4	642.42
Judges x Replications	16	33.30*
Judges x Treatments	8	34.54*
Judges x Treatments x Replications	32	13.64
Total	74	

*Significant

Table L-6. ANALYSIS OF VARIANCE OF JUDGES' TOTAL SCORES OF CAKES

Series VI. Cakes Made with Unaged and Aged Commercial Spray-dried (5% Moisture) Whole Egg

Source of Variation	Degrees of Freedom		Mean Square	
Replications		3		25.04
Treatments		5		1177.57**
Time in Storage	2		216.30	
Baking Powder Added	1		4.80	
Time x Baking Powder	2		2725.23	
Treatments x Replications		15		65.26
Judges		4		1613.83
Judges x Replications		12		68.78**
Judges x Treatments		20		183.17**
Judges x Replications x Treatments		60		16.69
Total		119		

**Highly significant

Table L-7. ANALYSIS OF VARIANCE OF JUDGES'TOTAL SCORES OF CAKES

Series VII. Cakes Made with Unaged Spray-dried Whole Egg from Different Plants

Source of Variation	Degrees of Freedom	Mean Square
Replications	4	3.70
Treatments	4	122.28**
Treatments x Replications	16	20.44
Judges	3	483.16
Judges x Replications	12	8.27
Judges x Treatments	12	31.35**
Judges x Replications x Treatments	48	9.48
Total	99	

**Highly significant

Table L-8. ANALYSIS OF VARIANCE OF JUDGES' TOTAL SCORES OF CAKES

Series VIII. Cakes Made with Shell Eggs, Fresh and Aged; Frozen Pasteurized Egg, Hold and Flash; and Dried Whole Egg, Vacuum-dried and Spray-dried

Source of Variation	Degrees of Freedom	Mean Square
Replications	4	29.73
Treatments	5	76.51*
Treatments x Replications	20	23.26
Judges	4	154.86
Judges x Replications	16	16.32
Judges x Treatments	20	51.67**
Judges x Replications x Treatments	74	12.54
Total	143	

*Significant. **Highly significant

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SCORE CARD FOR SPONGE CAKE

Characteristics					
CRUMB COLOR: uniform, characteristic of sponge cake	5				
TEXTURE AND GRAIN: fine evenly distributed cells with thin cell walls; feathery resilent crumb	35				
TENDERNESS	30				
MOISTNESS	10				
FLAVOR: free from excessive egg or acid	20				

Comments:

Judge________________________