CERTAIN FACTORS WHICH AFFECT THE STORAGE LIFE OF PREPARED PLAIN CAKE MIXES CONTAINING DRIED EGGS

by

LOUISE LIGGETT

B. S., University of Tennessee, 1947

A THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Foods and Nutrition

KANSAS STATE COLLEGE
OF AGRICULTURE AND APPLIED SCIENCE

1950

TABLE OF CONTENTS

INTRODUCTION

The prepared mix industry has grown rapidly during the last few years introducing new problems and opportunities for research. The stability and further growth of the industry depends to some extent upon the quality of the products which are offered consumers. In turn, the quality of the ingredients helps to determine the quality of the mix itself. Storage conditions under which mixes are held from the time of preparation and packaging to the time of consumption also affect the quality of these products.

There is a lack of information about various factors which affect the storage life of prepared mixes containing dried whole egg. The effect of storage temperatures upon plain cake mixes for definite periods of time is not known. The effect of the presence or absence of shortening upon the storage life of these mixes also is unknown. With such additional information, dried whole egg might well become an important ingredient in prepared mixes. Research along these lines should help determine a method of preparing, packaging, and storing prepared plain cake mixes which would result in high quality products.

The purpose of this study was twofold: First, to determine a method of preparing, packaging, and storing prepared plain cake mixes containing dried whole egg which results in high quality products; and second, to determine the maximum shelf life of plain cake mixes containing dried whole egg, prepared with and without shortening when held under two different storage conditions.

PROCEDURE

Ingredients

The ingredients for the control cake and the mixes were as nearly identical as possible. The control cake contained the following: sugar, shortening, dried whole egg, nonfat dry milk solids, cake flour, salt, baking powder, distilled water, and vanilla. Mix I contained the same ingredients as the control with the exception of water and vanilla. Mix II contained the same ingredients as the control except that water, vanilla, and shortening were omitted. The water and vanilla not included in Mix I and the water, vanilla, and shortening omitted from Mix II were added at the time of combining for baking. A golden layer cake formula used in earlier work and followed throughout the study was as follows:

Ingredients	Weights (g)	Approximate measure
Sugar	210.2	1 cup, 1 tablespoon
Shortening	70.1	1/3 cup
Dried whole egg	18.3	4 tablespoons
Nonfat dry milk solids	21.6	3 tablespoons
Cake flour	157.7	1 2/3 cups
Salt	4.2	2/3 teaspoon
Baking powder	8.6	2 1/8 teaspoons
Distilled water	195.0	3/4 cup, 1 tablespoon
Vanilla		1/2 teaspoon

Each ingredient for the control cakes was stored separately under the best known storage conditions as determined by previous experiments. The dried whole egg used had a moisture content of 5 per cent, a solubility rating of 1.25, a bacterial count of 50,000, and a color rating of fair. Finely granulated sugar, a high-ratio vegetable shortening available to institutions and to commercial bakeries, nonfat dry milk solids, high-grade cake flour, salt, a sulfate-phosphate baking powder, distilled water, and pure vanilla extract were used in all the cakes.

Equipment

The equipment used throughout the study was similar to that found in any well equipped laboratory and included the following: a torsion balance which was used for all weighing; Kraft-Cellophane bags which were moisture-vapor-grease-proof; a curling iron which was used for sealing the Kraft-Cellophane bags; large tin cans having close fitting covers which were used for storing mixes; large glass jars with screw lids used for storing dry ingredients for the control cakes; standard measuring spoons; two graduate cylinders; a centigrade chemical thermometer; a Taylor thermograph which recorded laboratory temperature; Eastman timers; a 10 speed, model K5-A, KitchenAid mixer having steel bowls of five-quart capacity and a flat paddle, whose approximate revolutions were 60 per minute on speed 1 and 132 on speed 4; a small aluminum cup having straight sides in which batter was weighed in order that the specific gravity could be computed; a glass funnel for determining consistency of the batter; and aluminum cake pans 7 3/4 inches square and 1 7/8 inches deep for baking the cakes. All cakes were baked in a gas oven equipped with a revolving hearth and an accurate thermostatic heat control. A Taylor oven thermometer was used to check the oven temperature.

Method of Procedure

The dry ingredients and shortening for all the cakes were carefully weighed. Sugar was prescreened prior to weighing. Dried whole egg was sifted to facilitate accurate weighing. Dry ingredients for each mix were combined by sifting together three times.

From these mixtures of dry ingredients, an equal number of random samples for each of two groups was drawn. Each mixture of one group, Mix I, was immediately heat sealed in a Kraft-Cellophane bag. Shortening was added to each mixture of the remaining group which was then called Mix II. The ingredients of Mix II were further blended with the flat paddle on the KitchenAid mixer for 15 seconds on speed 1 before being heat sealed in a Kraft-Cellophane bag.

One-half of the packaged mixes of each type was randomly selected to be stored at refrigerator temperature, approximately 40° F; the remaining one-half was to be stored at laboratory temperature, which varied from 64° F. to 94° F. Each group of mixes to be stored at each temperature was separated by random selection into six classifications, depending on the storage period. After the mixes were carefully labeled they were stored, under the conditions previously described, for one of the following storage periods: 0 weeks, 3 weeks, 7 weeks, 20 weeks, 26 weeks, or 32 weeks.

At the end of each storage period cakes were mixed, baked, and tested from each of the following:

1) Ingredients for the control

2) Mix I stored at laboratory temperature

3) Mix I stored at refrigerator temperature

4) Mix II stored at laboratory temperature

5) Mix II stored at refrigerator temperature

The plan for this study was drawn up in such a way that statistical methods could be used for the analysis of the data. Four replications of each cake were necessary to obtain a sufficient degree of accuracy in the results and to provide a means for the calculation of experimental error. The preparation and packaging of the mixes for four replications was completed in four consecutive days, one day being used for each replication. Cakes were then baked at the end of their respective storage periods. During each baking period, one cake from each of the five lots mentioned above was baked each day, making a total of 20 cakes. For the entire study a total of 120 cakes was made.

At the time of mixing for baking, the dry ingredients for the control cakes were combined by sifting together three times. The order of mixing the cakes was determined by random selection.

Each cake was mixed as follows: The ingredients for the control cake or the mix, as the case might be, were placed in the mixer bowl. The vanilla and 100 ml of distilled water were added. The contents of the bowl were mixed 30 seconds on speed 1, scraped down, and the mixing continued for 1 minute and 30 seconds on speed 4. The remaining 95 ml of water were added and blended in for 30 seconds on speed 1. The batter was scraped from the bottom and sides of the bowl a second time, and the mixing completed in 1 minute and 30 seconds on speed 4. Immediately, the bowl was removed from the mixer and the temperature of the batter determined and recorded. A 57 ml cup of batter was weighed, recorded, and saved to test for consistency.

Five hundred ninety grams of cake batter were then weighed into an aluminum cake pan which had been lined on the bottom with waxed paper. A spatula was used to cut through the batter 12 times in each direction in order to expel large air bubbles and to help make the baked cake symmetrical. The cakes were baked for 45 minutes at a temperature of 365° F. in a preheated gas oven.

The baked cakes were removed from the oven and allowed to cool in the pans on a wire rack for 15 minutes, then were loosened from the sides of the pans and turned out onto a wire rack. The waxed paper which adhered to the bottom of each cake was removed and the cakes turned to an upright position. After cooling they were placed on a cooky sheet and covered tightly with a larger cake pan until time for testing.

Tests and Determinations

Tests and determinations made for each cake were as follows: the temperature of the room during mixing and during testing; the specific gravity and temperature of the batter; the consistency of the batter; height of the finished cake and shortness, compressibility and quality of the cake as judged by a palatability committee.

The specific gravity determination was made as follows: an aluminum cup having a capacity of 57 ml was filled with the batter and the excess scraped off with a spatula. The weight of this quantity of batter was determined and recorded for each cake. The specific gravity of the sample was obtained by dividing the weight of the sample by the weight of an equal volume of water at the same temperature.

Consistency of the batter was determined by placing the sample used for the specific gravity determination into a glass funnel, on the stem of which were two marks 5.0 centimeters apart. The bore of the stem was approximately 8 millimeters in diameter. The length of time required for the batter to move from the upper mark to the lower one was recorded as a measure of the consistency of the batter.

Approximately 20 hours after baking, the cakes were cut into four uniform slices one inch thick by means of an apparatus similar to a mitre box. This apparatus was made of hardwood, closed at both sides and one end with a kerf on each side one inch from the closed end into which fitted a long knife. The first slice which had a crust on one side was not used for testing.

The height of each cake was determined by measuring, with a centimeter scale, the height of the uncut cake. Measurements were made at the outer edges, at the center, and at points one-half the distance from the center to each edge. The average of the five measurements was recorded as the standing height of the cake.

Shortness of the cake was determined by a gram shortometer, an apparatus consisting of a modified spring balance and a remodeled laboratory balance as described by Kramer (1935) and used by Roberts (1945) and Gordon (1947). The shortometer measured in grams the force necessary to break a slice of cake one inch in thickness. On the weighing pan of the spring balance were two parallel bars three inches apart which supported the slice of cake to be tested. A third bar, suspended from the right hand pan of the remodeled laboratory balance, was adjusted to apply pressure on the cake at a point midway between the two parallel bars. The dial of the balance was adjusted to zero. Distilled water was syphoned at a constant rate into a 250 cc glass beaker which had been placed on the right-hand pan. The force necessary to break the cake was indicated by two movable hands rotating on the face of the spring balance. Upon breaking, one hand remained stationary for reading the breaking force; and the other hand returned to zero. Three one-inch slices were tested on the shortometer, and the average of these readings was recorded as shortness of the cake.

After testing for shortness, one-half of each broken slice was used to test for compressibility. The apparatus used consisted of an Eastman timer and a remodeled laboratory balance similar to that described by Platt and Kratz (1933) and used by Roberts (1945) and Gordon (1947). A plunger 31 mm in diameter was screwed into the underside of the right hand pan of the balance. The cake sample to be tested was placed on an adjustable platform just below the plunger so that the plunger rested easily upon it. The plunger was held in contact with the slice of cake by means of a 10 g weight placed on the pan above. The left hand pan held a linked chain which balanced a 200 g weight on the right hand pan. A wooden drum with a handle extended over the left hand pan so that the chain could be wound easily from the pan to the drum, thereby allowing the 200 g weight to act upon the cake. The end of a pointer suspended from the crossarm of the balance passed in front of a scale at the lower part of the balance and indicated the millimeters compressed. For the compressibility test the chain was wound onto the drum in 30 seconds. The compressibility reading of each cake sample was then made from the scale one and one-half minutes after the chain was wound off. The average reading for the three samples was determined and recorded as the compressibility of the cake.

The remaining halves of the broken slices not used for the compressibility determinations were cut into two pieces, and one other piece was cut from the remainder of the cake. These pieces were numbered, covered to prevent drying out, and given to members of the palatability committee to score, according to Form I (Appendix). The test piece for each member of the palatability committee was a slice from the same relative position in the cake. The committee was composed of five members from the Department of Foods and Nutrition faculty, one research assistant, and one graduate research assistant. Form II (Appendix) was used for recording all data.

Methods of Controlling Conditions

Throughout the study all selections were made by random sampling.

Standard methods and baking techniques were used throughout the study. The ingredients, packaging materials, storage conditions, working conditions, and manipulation of materials were controlled as far as possible. The preparation and packaging of the mixes, as well as the baking and testing of the cakes, was carried out in the research laboratory, Room 16, Calvin Hall.

At the time of preparing and packaging the mixes and at the time of mixing, baking, and testing the cakes, laboratory conditions of humidity and temperature were recorded, since it was thought that certain characteristics of the cakes might be related to atmospheric conditions. At the time of mixing for baking, the ingredients of each cake were subjected to the same conditions of atmospheric humidity and temperature for one hour prior to mixing. The order of mixing the cakes was determined by random selection. These procedures were considered essential in order to equalize as far as possible any effect upon the cakes due to variations in temperature and atmospheric humidity within the day's baking period.

Analysis of Data

All data were submitted for statistical analysis. The analyses of variance were followed by the use of least significant differences whenever the F ratio was significant. With the small groups available in this study, the least significant difference method was thought to be satisfactory, although it is technically incorrect. Interaction between cake types and storage (C x S) was tested against sampling variation. If this were significant, the interaction mean square was used as error variance for cake types and storage.

REVIEW OF LITERATURE

A number of investigations have been carried out on the use of dried whole egg in bakery products. LeClerc and Bailey (1940) noted that for certain products dried, frozen, and shell eggs could be used interchangeably. They pointed out, however, that in certain industries dried eggs were the most suitable form for use. According to the same authors, 80 per cent of the dried egg used in 1931 was incorporated into pancake, cake, pastry, and doughnut flours and into prepared ice cream powders and mixes. Stewart (1948) declared that dried whole egg met competition with shell and frozen egg in all areas except in the prepared mix field. He stated that dried whole egg did not keep satisfactorily for long periods of time when incorporated into dry mixes. A recent article, Anonymous (1949), stated that cake mixes containing dried egg had a shorter storage life than did cake mixes packaged without egg.

Dry mixes on the market listed by Hudson (1949) were: biscuit; doughnut; pancake; gingerbread; corn or bran muffin; and white, yellow, devil's food, or spice cake mixes. These were marketed either in 50 or 100 pound bags for commercial trade or in 14 or 20 ounce packages for the housewife. It was observed by Hudson (1949) that the bulk products were consumed within three months after packaging, while the smaller packages were usually subjected to a shelf life of from 2 to 10 or 12 months. Temperatures during this time of storage were sometimes as high as 120° F. during the summer months. He pointed out that more than half of the tonnage of these products was made from formulas which required the addition of egg in one form or another.

LeClerc and Bailey (1940) reported that dried egg was an essential ingredient in most prepared mixes. Since Hudson (1949) considered dried egg the most critical and important ingredient of prepared mixes, he suggested that the dry mix manufacturer would not be interested in dried whole egg until the problem of keeping quality was solved.

Stewart (1948) recommended that research be carried out on the advantages of low storage temperatures and low moisture content in helping to solve the problem of increased shelf life of prepared mixes containing dried egg. Other methods he mentioned of treating egg during the process of drying in order to improve the quality, were: acidifying, sugar drying, and the reblending of whites and yolks which had been dried separately. A number of investigators recommended gas packing in carbon dioxide or nitrogen or a combination of the two as a means of increasing shelf life of dried whole egg. Conrad et al. (1948) reported that the development of off flavors was reduced somewhat by inert gas packing.

They stated that one of the reactions involved might be the oxidation of the lipid fraction. Boggs and Fevold (1946) found that reducing moisture content to a low level, acidification, and gas packing were means of increasing the shelf life of whole egg powder. Stuart, Hall, and Dicks (1942) pointed out that the most important single factor in preserving good quality during storage was the control of moisture content in production and during storage.

A dried whole egg product which would keep suitable for baking for nine months at ordinary temperatures could be secured only if gas packing, acidifying, sugar drying, and reducing moisture content to a low level were all taken into consideration, according to Stewart (1948).

Hudson (1949) considered the present standards for bacterial content of dried egg as vague and meaningless. He suggested that reasonable standards should include freedom from forms of pathogenic bacteria; less than 50 coliform counts per gram; less than 100 mold and yeast counts per gram; and a standard plate count not yet determined.

In discussing deteriorative changes in food products, Andrews (1949) pointed out that air and water were the two prominent factors which determined how long a food could be stored and what happened to it during storage. Child (1946) suggested that the simplest type of chemical change involved in the deterioration of fats was hydrolysis caused by moisture and lipolytic enzymes. The moisture present and the enzymes, which may be derived from the original plant tissues or from adventitious microorganisms, cause the breakdown of fats into fatty acids. Atmospheric oxygen combines readily with unsaturated fatty acids to form peroxides which are relatively unstable and soon break down to yield a number of unpleasant flavors and odors, according to Andrews (1949). He reported that rancidity development could be retarded by keeping fats from contact with air or by adding small amounts of antioxidants.

The container in which a food or food product is packaged has been considered important. Carlin (1948) noted that the shelf life of prepared mixes could be reduced by "surface rancidity" whenever fat soaked into the carton or the liner. He stated that oxidation was speeded up when fats soaked into paper packaging material because of the increase in surface area and in oxidation catalysts. Andrews (1949) also observed that if a fat from a prepared mix seeped through a package, the fat became rancid sooner than if the mix were properly packaged.

Another critical ingredient in dry mixes is the dried milk product included. Holm (1945) contended that spray dried and vacuum dried milks have great avidity for moisture and must be packaged so that they are guarded against absorption of moisture from the atmosphere. He pointed out that, although the factors concerned in the development of staleness of dried milks are not well known, it appeared that excessively high moisture content and high temperatures of storage favored the development of staleness. He stated that the moisture content of the product should not exceed 2.5 per cent and the temperature of storage should not exceed

75° F. Since dried milk products packed in air might vary greatly in their keeping quality, Holm (1945) found it difficult to state a given period of time during which the product would be usable. He did state, however, that dried milks made according to the best known procedures and stored at 75° F. would remain usable for approximately six months.

Hudson (1949) found that while the moisture content of the mixes might be approximately 6 per cent at the time of packaging, it might climb to 7 or 8 per cent in areas of high humidity. He also noted that the amount of protection against moisture take-up might be partially determined by the individual manufacturer's willingness to invest in packaging materials. In the past, the type of packaging material usually employed by dry mix manufacturers, to protect against an increase in moisture content, has been a wax laminated glassine liner. He reported that even with the better packaging materials, an absolute barrier to moisture-vapor transfer could not be expected.

Tinklin (1944) found that the method of incorporating dried whole eggs into a cake containing fat had a definite effect upon the finished product. She noted that methods in which dried whole eggs were incorporated by sifting them with the flour or sugar were easier to use and required less work than those in which it was necessary to reconstitute the eggs before using. With the four-minute method, the reconstituted egg was added halfway in the mixing process so that only two minutes of mixing was necessary to complete the procedure. This produced thin batters which had high specific gravity. The cakes had uneven texture but were quite tender. The volume was relatively small, and the quick method of mixing resulted in an inferior product. A short method of mixing in which the dried whole egg was incorporated as a dry ingredient was not a part of the study reported.

Lowe (1943) observed that the extent of mixing affected crust, shape of cake, volume, and texture. The crust of a cake which had little mixing browned well and was rough. The top of the cake was nearly level or slightly rounded. The cake volume might be more or less when the cake ingredients were just blended than when the batter was stirred a little longer. When the ingredients were not well blended, the cake produced had a horny, flinty texture, which was sometimes called bready. The cells were coarse and large with thick cell walls. A cake baked from batter which had less than optimum mixing dried out and staled more rapidly than one which had optimum mixing. Lowe (1943) cited Olsen's work in which it was found that the rate of staling of plain cake was greatest during the first 24 hours.

Halliday and Noble (1928) contended that a more velvety cake, which would retain its freshness for a longer period of time, would be obtained if the ingredients were blended so that a stable emulsion was formed. According to Nason (1939), eggs are the emulsifying agent which bring about an even distribution of fat in a cake batter. A water-in-oil type of emulsion, an oil-in-water type, or a combination of the two might be present in a cake batter, according to Lowe (1943). Hauser (1948) noted that lecithin is a very powerful agent in producing an oil-in-water type of emulsion. The work of Snell, Olsen, and Kremers (1935) indicated that egg yolk owes its emulsifying properties to an unstable complex, "lecitho-protein", containing both lecithin and protein.

In addition to acting as an emulsifying agent, eggs serve other functions in cake, according to LeClerc and Bailey (1940). Eggs exert a binding action because the egg proteins coagulate with heat and thereby aid the flour in forming the structure of the finished cake. They retain air which has been incorporated into the cake batter and in this way increase lightness and enhance the cell structure. Eggs also exert a moistening effect and prevent staling. Egg yolks, which contain a considerable quantity of fat, exert a shortening action in cake. Protein, fat, lecithin, minerals, and vitamins present in eggs add appreciably to the food value of cake. Eggs also influence the flavor, color, grain, texture, and general appearance of a cake.

Since dried egg has been considered the most critical and the most important ingredient in prepared mixes, the changes which result during storage to affect the quality of dried egg merit consideration.

Pyke and Johnson (1941) found that a highly significant correlation existed between the volume and tensile strength of cakes and the quality of eggs. They found that the coagulation temperature of eggs was elevated as a result of deterioration. When poor quality eggs were used in a cake, the volume was less and the tensile strength was reduced.

Ary and Jordan (1945) reported that the solubility index was one of the first physical and chemical tests developed for evaluating the quality of egg powders for cooking. Gorseline (1943) noted that unless the dried egg was soluble, it could not properly perform the function of coagulation to maintain the cell structure of cake. He reported that the solubility of dried egg decreased during storage and that the change was rapid in temperature ranges above 60° F. but was far less rapid at lower temperatures. Dawson et al. (1945) agreed that dried whole egg containing 3 to 5 per cent moisture should be stored at 60° F. or lower in order to maintain flavor and cooking quality for longer than six months. Stewart, Best, and Lowe (1943) contended that rate of change in solubility of dried egg was greatly accelerated at temperatures above 30° C. (86° F.).

White and Thistle (1943) considered temperature the most important single factor affecting the keeping quality of dried whole egg. They found that at temperatures from 7.1° C. (44.8° F.) to 13.3° C. (55.9° F.) the rate of deterioration increased with increase in moisture content. Changes in solubility during storage were found to be more pronounced when the moisture content was above 5 per cent according to Stuart, Hall, and Dicks (1942). Relative humidity above 85 or 90 per cent was found to effect an increase in mold and bacterial growth in dried whole egg powder having a moisture content of 5 per cent or above. Stuart, Gorseline, Smart, and Dawson (1945) reported that the solubility of dried whole egg powder of low sanitary quality decreased to a greater extent and at a much more rapid rate than did powder of high sanitary quality. The solubility of both types decreased during storage at all temperatures from 0° F. to 110° F. They concluded that temperatures of 45° F. or less were necessary to prevent marked decreases in solubility in powder of high sanitary quality. Stuart, Gorseline, and Dicks (1942) observed that the chemical changes which accompanied mold and bacterial growth caused a change in pH and decreased solubility. Gross bacterial contamination of mixed liquid egg might result in lowered pH in reconstituted powders, according to Lightbody and Fevold (1948). Thistle et al. (1943) pointed out that moisture content and bacterial content in dried whole egg powder varied independently but both were necessary measures of quality.

Stuart, Grewe, and Dicks (1942) found a positive correlation between the solubility index of spray dried whole egg powder and the volume and quality of pound cakes. These workers pointed out that one type of insolubility was the result of changes in the egg during processing, while another type was caused by changes in the egg during storage. Too high a temperature during drying would harden and coagulate the albumen, thus decreasing solubility and leavening power, according to LeClerc and Bailey (1940). Ary and Jordan (1945) cited the work of McNally and Dizikes in which measures of solubility were correlated with quality of cakes and pointed out that these workers had found that eggs of low solubility produced heavy cakes. Miller, Lowe, and Stewart (1947) observed changes in spray dried whole egg powder with storage. They found that the thickening power, the aerating power, and the palatability of the egg decreased rapidly with aging.

Fevold et al. (1946), in studying sources of off flavors developed during storage, concluded that the principal undesirable flavor arises from the phospholipids, apparently through oxidation. They stored dried yolk alone, dried white alone, and recombined dried yolk and white as whole egg powder. There was no loss of palatability when whites alone were stored. When the yolks were stored, either alone or with the whites, palatability dropped markedly and progressively. When the yolk and white were stored together as whole egg powder, the rate of deterioration was higher than when the yolk was stored alone.

Makower and Shaw (1948) found that the initial rate of oxygen absorption by several dehydrated egg powders could be measured partially as a function of temperature and moisture content. They found that the rate of oxygen absorption was markedly accelerated by light. They suggested that data on oxygen absorption be used in conjunction with other observations to estimate the extent of flavor change in egg powders exposed to oxygen. Fryd and Hanson (1945) studied the relationship of chemical analysis to flavor. They observed a relationship between chemical factors and flavor changes of dried egg powder and devised a formula to predict flavor scoring on the basis of chemical analyses. Flavor decrease is accompanied by an increase both in fluorescence and in free fatty acid content, according to these investigators.

Other objective tests have been used for determining quality of dried whole egg as: the pH measurements suggested by Stuart, Gorseline, and Dicks (1942) and the foaming volume determination recommended by Reid and Pearce (1945).

Variations in the flavor of egg powder have been considered minor factors in foods subjected to baking temperatures, but the retention of beating power was considered important by Lightbody and Fevold (1948). These investigators reported that off flavors produced during processing might be a burnt flavor caused by drying conditions which were too severe; a fishy flavor caused by copper contaminations; or a sour flavor caused by bacterial action on liquid egg before drying. Other undesirable flavors might be traced to improper storage in non-air-tight containers in proximity to articles with pronounced odors.

Peterson (1946) reported that fat serves the following functions in cake: it helps aerate the cake batter; it helps to carry the milk, eggs, and sugar in the batter; it contributes to eating quality; it produces shortness and tenderness in the baked product; and it imparts freshness. He explained the shortening and tenderizing action that fat exerts in cake. Shortening, in contrast to flour, sugar, eggs, and other cake ingredients, remains unchanged in composition during baking. During the mixing process the fat particles become dispersed throughout the batter. These particles impart a characteristic softness and tenderness to the finished product.

Peterson (1946) believed that shortening plays an important part in the formation of the structure of the batter because it helps to produce tiny cells or bubbles of microscopic size. These cells contain air or a mixture of air and carbon dioxide which becomes saturated with moisture vapor from liquids in the cake batter. During baking the cells expand under pressure caused by increase in temperature and thereby produce the expansion in the cake. The resulting cell structure in the cake is thought to be influenced by the character of the fat and by the manner in which the shortening is dispersed in the cake batter. Carlin (1944) agreed with these observations. Peterson (1946) suggested that because the shortening plays an important part in the formation of the structure of the batter, it influences the volume, the grain, and the texture of the finished cake.

Shortening affects the flavor and eating quality of cake as well as the "freshness". Peterson (1946) defined "freshness" as the maintenance of good eating quality until the cake could be consumed. He further pointed out that the flavor and eating quality of cake might be improved by the use of "high ratio" shortenings. According to the same author, processed shortenings available to institutions and commercial bakeries are capable of carrying high ratios of sugar and liquid in cake batters. The resulting cakes have improved flavor and eating quality.

Carlin (1944) noted that modern shortenings, made either from plasticized oils which have been blended with harder fats or from hydrogenated products, will cream satisfactorily over a wide range of temperatures. He observed that creaming quality in shortening is important in obtaining symmetrical cakes having good texture. Dunn and White (1937) pointed out that shortenings used in cakes should cream well, because the lightness of the cake depends primarily upon the creaming behavior of the fat.

Andrews (1949) reported that in many foods, moisture catalyzed by enzymes breaks down fats into their component fatty acids with a resulting adverse effect on taste appeal. The oxidation of fats by atmospheric oxygen has been considered by Child (1946) to be more evident and more rapid the higher the mean unsaturation of the constituent glycerides. Andrews (1949) observed that the oxidation process proceded slowly in hydrogenated vegetable oils. Child (1946) listed factors which accelerate oxidation as follows: heat, light, the presence of some metals, and chemical accelerators. He noted that oxidative processes were accelerated by a rise in temperature and were sufficiently retarded under the conditions of commercial cold storage for most edible fats to be kept in good condition for long periods, provided that other causes of deterioration, such as absorption of taints and microbiological spoilage, were absent. According to the same investigator, the most obvious factor which predisposes a fat to oxidative rancidity is its degree of unsaturation and particularly its content of acids of a higher degree of unsaturation than oleic. Carlin (1944) suggested that the knowledge of antioxidants or "stabilizers" combined with the hydrogenation process has enabled the shortening industry to advance rapidly toward the goal of rancidity resisting fats of all types. Child (1946) discussed "flavor reversion" which is a type of deterioration due to slight oxidation short of rancidity development. The resulting production of undesirable flavors appears to be associated with the presence of linolenic or other acids with more than two double bonds. He reported that slight hydrogenation to a degree supposedly sufficient to reduce all the linolenic acid does not prevent "flavor reversion".

Temperature of storage and moisture content are major controlling factors concerned with the deterioration of nonfat dry milk solids. Holm (1945) stated that if the moisture content of a dried milk product exceeded the optimum range of 2 to 3 per cent, defects of discoloration, caking, and the development of stale and/or fishy flavors might be expected. He recommended that when the dried milk product was stored in contact with air, the temperature of storage should be as low as possible. For each increase of 10 degrees centigrade in the storage temperature, he found the rate of deterioration practically doubled.

Off flavors in dried milk products have been listed by Holm (1945) as those off flavors inherent in the milk; cooked flavors developed during processing; and staleness, rancidity, and tallowiness which may develop during storage. The development of rancidity and tallowiness does not occur readily in nonfat dry milk solids because of the low fat content. Hetrick and Tracy (1945) studied the keeping quality of spray dried whole milk, gas packed and packed in air and stored at room temperature. The gas packed samples remained satisfactory for a longer period of time than did the samples packed in air. They concluded that the initial loss in palatability of the gas packed powder, on storage, might be associated with oxygen absorption by some nonfat constituent or by oxygen reaction with some nonfat constituent. "Cooked" or "burned" flavors according to Holm (1945) were caused by subjecting the milk to excessively high temperatures or long periods of heating before drying.

RESULTS AND DISCUSSION

Batters

The majority of cake batters were thin and runny but smooth with shiny appearance. They were characterized by high specific gravity and low consistency readings and could be poured easily into the pans. Batters made from mixes stored without shortening at laboratory or refrigerator temperature for seven or more weeks were an exception. These were viscous, having an appearance like whipped cream. Tests of these batters showed low specific gravity and high consistency readings. Batters made from mixes containing shortening stored for seven weeks or longer had lower consistency readings than batters from mixes stored without shortening or batters from ingredients for the control (Table 1).

In general, after 32 weeks' storage of mixes and ingredients for the control, batters of all types were thick and dull. The specific gravity measurements for this baking period were lower for cakes of each type than at any other period throughout the investigation. Consistency measurements of the batters in most cases were higher than those taken at other baking periods. All of the cakes with the exception of those prepared from Mix II stored at laboratory temperature had thick, light, delicate batters. The

Table 1. Characteristics of batters affected by storage. Averages of four replications.

Cake type	Storage period (weeks)	Room temperature during mixing (°C.)	Batter temperature (°C.)	Specific gravity	Consistency min.	sec.
	0	26.7	27.0	.9263	1	25
	3	27.8	26.2	.9404	1	48
Control	7	27.8	27.0	.9316	2	27
	20	25.6	26.0	.9228	2	44
	26	24.4	24.0	.9035	1	33
	32	22.8	21.7	.8351	10	15
	0	26.7	27.4	.9298	1	47
Mix I	3	27.8	26.2	.9439	1	28
Stored at	7	27.8	27.0	.9263	1	53
laboratory	20	25.6	26.0	.8895	5	4
temperature	26	24.4	24.0	.8789	3	15
	32	23.3	22.6	.8531	9	48
	0	26.7	27.1	.9281	1	24
Mix I	3	27.8	25.7	.9158	1	35
Stored at	7	27.2	27.0	.9105	3	39
refrigerator	20	25.5	25.0	.8684	5	32
temperature	26	24.0	24.0	.8737	4	13
	32	23.3	22.5	.8263	15	16
	0	26.7	26.9	.9175	2	36
Mix II	3	27.8	27.1	.9719	0	19
Stored at	7	27.2	28.0	.9719	0	20
laboratory	20	25.5	26.0	.9544	0	42
temperature	26	23.9	25.0	.9386	0	44
	32	23.3	22.5	.9142	1	17
	0	26.7	26.6	.9211	1	58
Mix II	3	27.8	24.5	.9228	1	33
Stored at	7	27.8	28.0	.9526	0	31
refrigerator	20	25.6	25.0	.9052	0	55
temperature	26	24.4	24.0	.9158	0	32
	32	23.3	22.6	.8719	4	7

batters from Mix II which had been stored at laboratory temperature were thin at this baking period. Room and batter temperatures were lower here than they had been during the warmer months (Table 1). In her study which was carried out in the same research laboratory, Tinklin (1944) found that there appeared to be no relationship between temperature and consistency and specific gravity of batters. Data from the study, herein reported, indicate that, although temperatures of ingredients and atmospheric conditions might be related to characteristics of batters, other factors were also important. It was thought that the changes in specific gravity and consistency which occurred with increased storage might have been due in part to changes in the emulsifying power of the egg caused by deterioration. The fat distribution in the cake batters was thought to be partially a function of egg quality.

Lowe (1943) observed that thin, runny, smooth batters produced inferior cakes, while viscous batters produced more desirable ones. The viscous batters in the present study did not produce the most desirable cakes from the standpoint of eating quality since the flavor was undesirable.

Specific Gravity.

Table 2. Analysis of variance for the specific gravity determinations.

Source of variation	Degree of freedom	Specific gravity determination Mean square	Probability
Cakes	4	.0114	.001
Storage	5	.0194	.001
C x S	20	.0012	ns
Samples	90	.00089	
Total	119		

The mean specific gravity for batter prepared from Mix II containing shortening and stored at laboratory temperature was significantly different from the means of other batters (Table 3). This mix produced significantly heavier batters.

Table 3. Test means for 120 cakes.

Cake type	Specific gravity mean
Mix II with shortening, laboratory storage	.9457
Mix II with shortening, refrigerator storage	.9149
Control	.9104
Mix I without shortening, laboratory storage	.9009
Mix I without shortening, refrigerator storage	.8868

With few exceptions, the mixes stored without shortening produced thicker batters with lower specific gravity readings than did the mixes stored with shortening. A possible explanation might be given in this way: during the blending of the fat with the dry ingredients of the mixes, egg particles might have become coated with thin layers of fat. These layers of fat could have reacted with moisture and/or atmospheric gases first, thereby protecting the egg particles. When the particles were not coated with fat, deterioration proceeded at a faster rate than it did when they were protected to some degree.

The specific gravity measurements obtained at the 32-week baking period were significantly lower than those obtained earlier in the study (Table 4).

Table 4. Test means for 120 cakes.

Storage (weeks)	Specific gravity mean
0	.9247
3	.9398
7	.9391
20	.9076
26	.9026
32	.8566

Lowe (1943) reviewed the work of Sunderlin and Collins who found that thin batters were associated with oil-in-water emulsions, while thick batters had water-in-oil emulsions. Although microscopic examinations of the batters was not a part of this present study, the thin, heavy batters produced at the beginning were thought to be associated with oil-in-water emulsions, while the thick, light batters prepared later were thought to be associated with water-in-oil emulsions. Hauser (1948) observed that lecithin, present in egg yolk, is a very powerful agent in producing oil-in-water emulsions, while cholesterol, also present, promoted the water-in-oil type. He noted that, during storage, egg yolk lecithin undergoes a chemical change of a hydrolytic nature accompanied by a loss of emulsifying power. Cholesterol, present in much smaller amounts but relatively stable, is able to promote the water-in-oil type of emulsion associated with thick batters.

Consistency. In general the batters having high specific gravity had low consistency readings, while those with low specific gravity had high consistency readings. Tinklin and Vail (1946) found a highly significant correlation between specific gravity and consistency, but suggested that specific gravity was a better indication of cake quality than was consistency.

Differences in consistency measurements attributed to types of cakes and those attributed to interaction between types of cakes and periods of storage lacked statistical significance.

Consistency measurement differences due to storage were highly significant (P = .001). Increased storage time effected an increase in consistency measurements. The mean consistency measurement obtained at the 32-week baking period was significantly higher than means obtained at other baking periods (Table 5).

Table 5. Test means for 120 cakes.

Storage (weeks)	Consistency mean
0	110.3
3	80.8
7	106.35
20	124.4
26	216.75
32	1169.4

It was thought that the deteriorative changes in the egg yolk observed by Hauser (1948) occurred in the dried whole egg used in this study. The change in emulsifying power discussed earlier might have been responsible for the change from thin, heavy batters of low consistency readings to thick, light batters of high consistency readings.

Baked Cakes

Shortness. Shortness measurements varied over a wide range, from 87 g to 139 g for the total 120 cakes. The average shortness measurement for the 20 cakes baked at the zero week storage period was 114 g. This value was arbitrarily chosen as representative of the shortness value of cakes made from the ingredients used in this study and mixed by the short mixing method. There was a tendency toward a decrease in shortness measurements of cakes made from ingredients for the control and from mixes stored at refrigerator temperature from zero weeks to 20 weeks. There was a tendency toward an increase in shortness measurements of cakes prepared from mixes stored in the laboratory from the beginning of the study to the baking period after 20 weeks of storage. Shortness values of all cakes increased after 26 weeks' storage over the values obtained after 20 weeks of storage. This increase in shortness value was followed by a decrease evident at the last baking period. Statistically, no trend was found in the data, and it is difficult to explain the fluctuations.

The differences among shortness values attributed to difference in cake types were significant beyond the 1 per cent level. Shortness measurements were significantly increased by storage in the laboratory if shortening were present during storage (Table 6).

Table 6. Test means for 120 cakes.

Cake type	Shortness mean
Mix II with shortening, laboratory storage	122.1
Control	112.5
Mix I without shortening, laboratory storage	112.1
Mix II with shortening, refrigerator storage	111.5
Mix I without shortening, refrigerator storage	106.2

It is not known why an increase in shortness measurements was effected by storage at laboratory temperature in only the one type of mix. A high shortness measurement is an indication of a cake which is less tender, one which requires more force to break.

Shortness measurement differences due to storage were significant at the 1 per cent level. The shortness measurement mean obtained at the 26-week baking period was significantly higher than other measurements taken during the study. Unknown factors might have been responsible for these differences.

Differences due to interaction between cakes and periods of storage were possibly due to sampling variation.

Compressibility. Compressibility measurements ranged from 0.6 mm to 4.2 mm for the total 120 cakes. The mean compressibility value of all cakes obtained at the first baking period was 1.94. For the purpose of comparison in this study, this value was chosen as typical. Measurements higher than this figure were an indication that cakes had a more compressible crumb, while the lower measurements indicated that the cake crumb was less compressible. In general, average compressibility readings were lower than the 1.94 mean at the 3, 20, and 26-week baking periods; while average readings were higher than this value at the baking period following 7 and 32 weeks' storage (Table 7). The statistical analysis detected no trend in these fluctuations, and no explanation can be given for the differences except that laboratory conditions of temperature and humidity might have affected batter structure in such a way that differences in compressibility were obtained. There appeared to be no relationship between shortness readings, compressibility measurements, and texture scores.

Differences in compressibility measurements due to storage were significant (P = .01). At the seven-week baking period, the mean compressibility reading for all cakes was higher than any other mean obtained during other baking periods. The difference

Table 7. Characteristics of cakes affected by storage. Averages of four replications.

Cake type	Storage period (weeks)	Room temperature when testing (°C.)	Standing height (cm)	Shortness (g)	Compressibility (mm)	Palatability scores* General appearance	Texture	Eating quality	Total
Control	0	28.3	4.7	117	1.7	24.5	21.4	14.8	60.7
	3	27.8	4.5	115	1.5	25.7	23.3	16.1	65.1
	7	28.9	4.6	110	2.5	25.1	21.8	15.2	62.1
	20	25.6	4.7	109	1.6	25.2	21.9	15.1	62.1
	26	25.0	4.7	118	1.3	23.1	19.3	12.4	54.8
	32	23.9	4.8	103	2.0	22.8	18.9	12.5	54.2
Mix I Stored at laboratory temperature	0	28.3	4.7	110	2.0	25.5	22.6	16.2	64.3
	3	27.8	4.5	112	1.6	26.1	22.6	15.8	64.5
	7	28.9	4.7	114	2.4	25.2	21.8	15.2	62.2
	20	25.6	4.7	106	2.1	22.9	28.8	8.6	50.3
	26	25.0	4.8	125	1.6	22.0	17.2	7.3	46.5
	32	24.4	4.5	109	2.5	18.0	17.1	5.8	40.9
Mix I Stored at refrigerator temperature	0	28.3	4.5	110	1.9	24.5	22.0	15.3	61.8
	3	27.8	4.6	106	2.0	25.6	22.4	15.6	63.6
	7	28.9	4.7	108	2.6	24.9	22.1	15.0	62.0
	20	25.6	4.7	105	2.3	24.6	20.9	14.9	60.4
	26	25.0	4.8	106	2.1	23.6	20.3	12.6	56.5
	32	23.9	4.7	99	2.4	21.5	19.6	13.0	55.0
Mix II Stored at laboratory temperature	0	27.8	4.6	117	2.0	24.7	22.4	15.8	62.9
	3	27.8	4.6	125	1.4	26.4	21.4	15.1	62.8
	7	28.3	4.7	120	2.2	25.0	21.2	14.4	60.6
	20	25.6	4.6	118	1.8	23.7	18.0	9.9	51.7
	26	25.0	4.7	134	1.2	21.7	16.1	7.9	45.6
	32	23.3	4.8	114	2.2	20.0	17.0	8.1	45.0
Mix II Stored at refrigerator temperature	0	27.8	4.6	113	1.9	24.9	24.4	15.6	63.8
	3	27.8	4.5	105	1.9	25.3	22.7	15.6	63.6
	7	28.9	4.6	108	2.2	25.5	22.2	15.1	62.8
	20	25.6	4.7	106	1.8	25.7	21.0	14.4	61.1
	26	25.0	4.7	126	1.5	24.0	19.3	12.3	55.6
	32	23.3	4.7	114	2.0	23.1	19.0	13.1	55.5

* Possible scores were as follows: general appearance, 30; texture, 30; eating quality, 20; and total, 80.

between the readings taken at the first baking period and those taken after 7 weeks' storage was significant at the 5 per cent level.

Neither the differences due to cake types nor those due to interaction between cake types and storage were significant.

Total Palatability. These scores included the following: general appearance, texture, and eating quality. Figure 1 shows the effect of storage upon total palatability. Total palatability averages for the 120 cakes ranged from 65.1 to 40.9 (Table 7). The highest possible score was 80 points with the score card used. The cakes in this study were scored approximately 20 hours after baking. Lowe (1943) reviewed the work of Olsen who found that the rate of staling was greatest during the first 24 hours and that cakes creamed a short time staled more rapidly than those creamed for a longer period.

Scores for the different cake types obtained at the first three baking periods were similar. The lowest average score received during these periods was 60.6, while the highest was 65.1. The control cake and the cakes made from mixes stored at refrigerator temperature received scores which ranged from 54.2 to 62.1 during the last three baking periods. Laboratory stored mixes produced cakes having total palatability scores ranging from 40.9 to 51.7 during these periods, thus indicating that these cakes were less desirable than the control or those made from refrigerator stored mixes (Table 7).

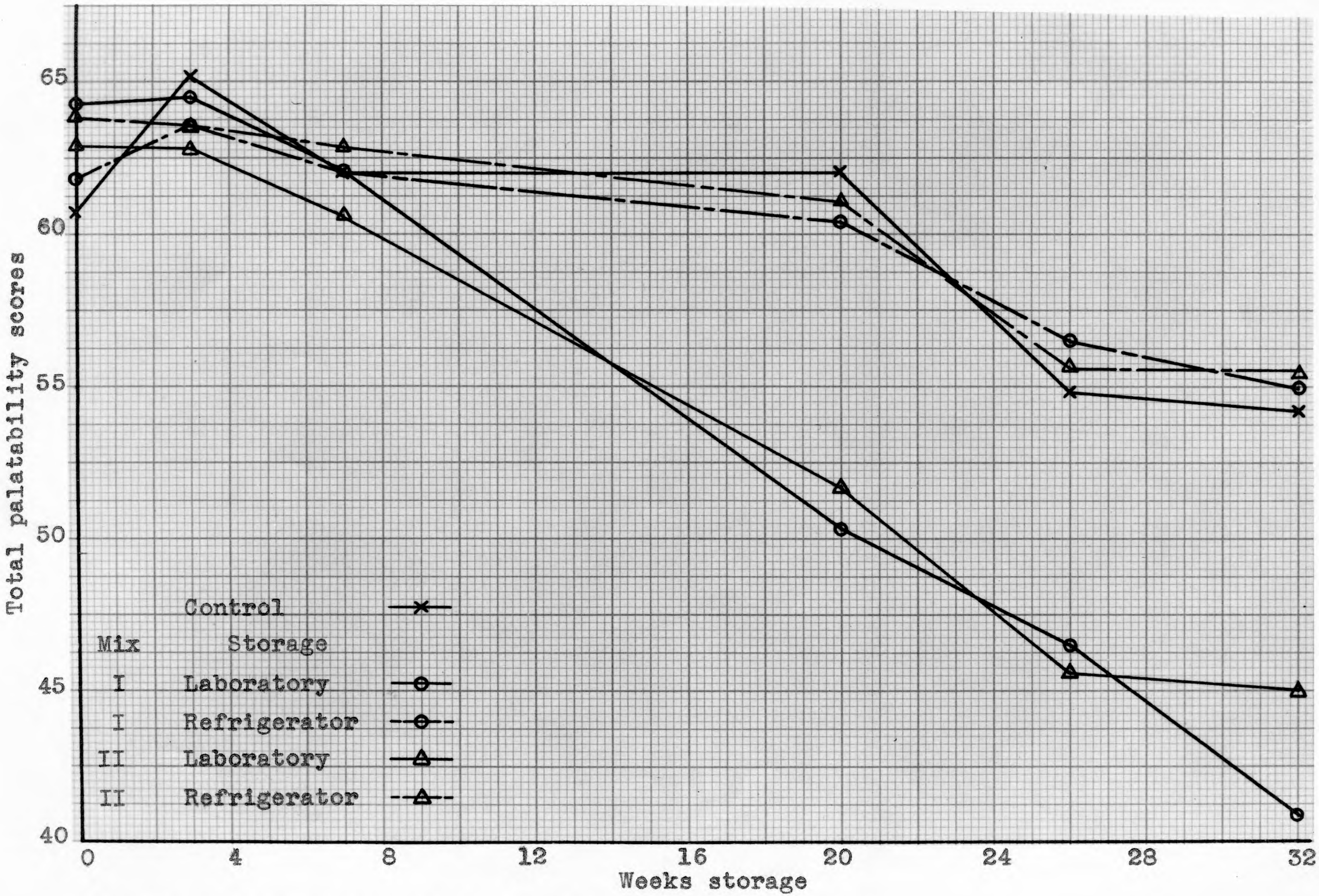

Fig. 1. Effect of storage on total palatability.

Variations in total palatability scores due to differences among cake types were significant (P = .05). Cakes made from mixes stored at laboratory temperature received significantly lower scores than did the control cake or cakes made from mixes stored at refrigerator temperature (Table 8).

Table 8. Test means for 120 cakes.

Cake type	Total palatability mean
Mix II with shortening, laboratory storage	54.8
Mix I without shortening, laboratory storage	54.9
Control	59.8
Mix I without shortening, refrigerator storage	59.9
Mix II with shortening, refrigerator storage	60.4

Storage periods produced highly significant differences in total palatability scores (P = .001). Total palatability decreased with increased storage with the major change occurring between the seventh and twentieth weeks of storage. The total palatability mean score obtained after 20 weeks' storage was significantly different from those obtained at any of the first three baking periods or from those of the last two baking periods (Table 9).

Table 9. Test means for 120 cakes.

Storage (weeks)	Total palatability mean
0	62.7
3	63.9
7	61.9
20	57.1
26	51.8
32	50.1

The variation in total palatability scores which was attributed to interaction between cakes and storage was significant (P = .001).

General Appearance. Crust characteristics, shape of cake, and color of crumb were included in the portion of the score card devoted to general appearance. Crust characteristics received low scores when the crust appeared blistered, somewhat greasy or had an uneven or pale color. All the cakes made during this investigation had blistered top surfaces. Lowe (1943) pointed out that cakes which had very little mixing had crusts which browned well and were rough. A dark square on the top surface was observed in cakes of each type one or more times during the study. The presence of the light and dark areas might be attributed to the short method of mixing. Mix II stored at laboratory temperature for 26 weeks or more produced cakes with crusts which were somewhat greasy in appearance. The crusts of cakes made from Mix I after

20 or more weeks' storage at laboratory temperature were pale in color.

Small yellow flecks of egg were noted in batters of all types after 32 weeks' storage of mixes and of ingredients for the control. These egg particles which were not evenly dispersed throughout the batter produced a somewhat mottled appearance in the top surface of the cakes and also caused the cakes to stick to the pans. Cakes made from stored mixes were difficult to remove from the pan, Anonymous (1949).

Scores for the shape of the cake reflected depressions or other asymmetrical characteristics. Average standing heights for the 120 cakes ranged from 4.5 cm to 4.8 cm (Table 7). In general the cakes had slightly rounded tops. Lowe (1943) found that the top of a cake was nearly level or slightly rounded when the cake batter had very little mixing. Sometimes the mixes produced cakes which were not symmetrical, but it is difficult to point out any related factor or factors. Mix I stored at laboratory temperature produced cakes at the 32-week baking period which had quite undesirable depressions in the center. Dawson et al. (1945) observed a noticeably bad flavor occurring in cakes containing dried whole egg as the volume became poor. In the present study, undesirable flavors were detected at the 20-week baking period, while depressions in the center of the cakes were noted only at the 32-week baking period.

When the undesirable tan color observed by Dawson et al. (1945) appeared in the crumb, cakes received low scores on color of crumb. The crumb of cakes baked from mixes stored at laboratory temperature for 20 weeks or more had a brownish-gray or tan color. This undesirable color was evident during the remainder of the study. Dawson, Shank, Lynn, and Wood (1945) reported that dried whole eggs stored at temperatures above 75° F. caused cakes to be tan in color. Laboratory temperatures for this study were as high as 75° F. or higher during 29 weeks.

The variance of general appearance scores due to differences in types of cakes was non-significant. Variance of scores attributed to storage was highly significant (P = .001). The scores obtained after 26 weeks' storage were significantly different from those obtained at any of the first four baking periods or from those of the last baking period (Table 10).

Table 10. Test means for 120 cakes.

Storage (weeks)	General appearance mean
0	24.8
3	25.8
7	25.1
20	24.4
26	22.9
32	21.3

General appearance scores decreased with increased storage with the major change occurring after 20 weeks. Figure 2 shows the effect of storage on general appearance scores.

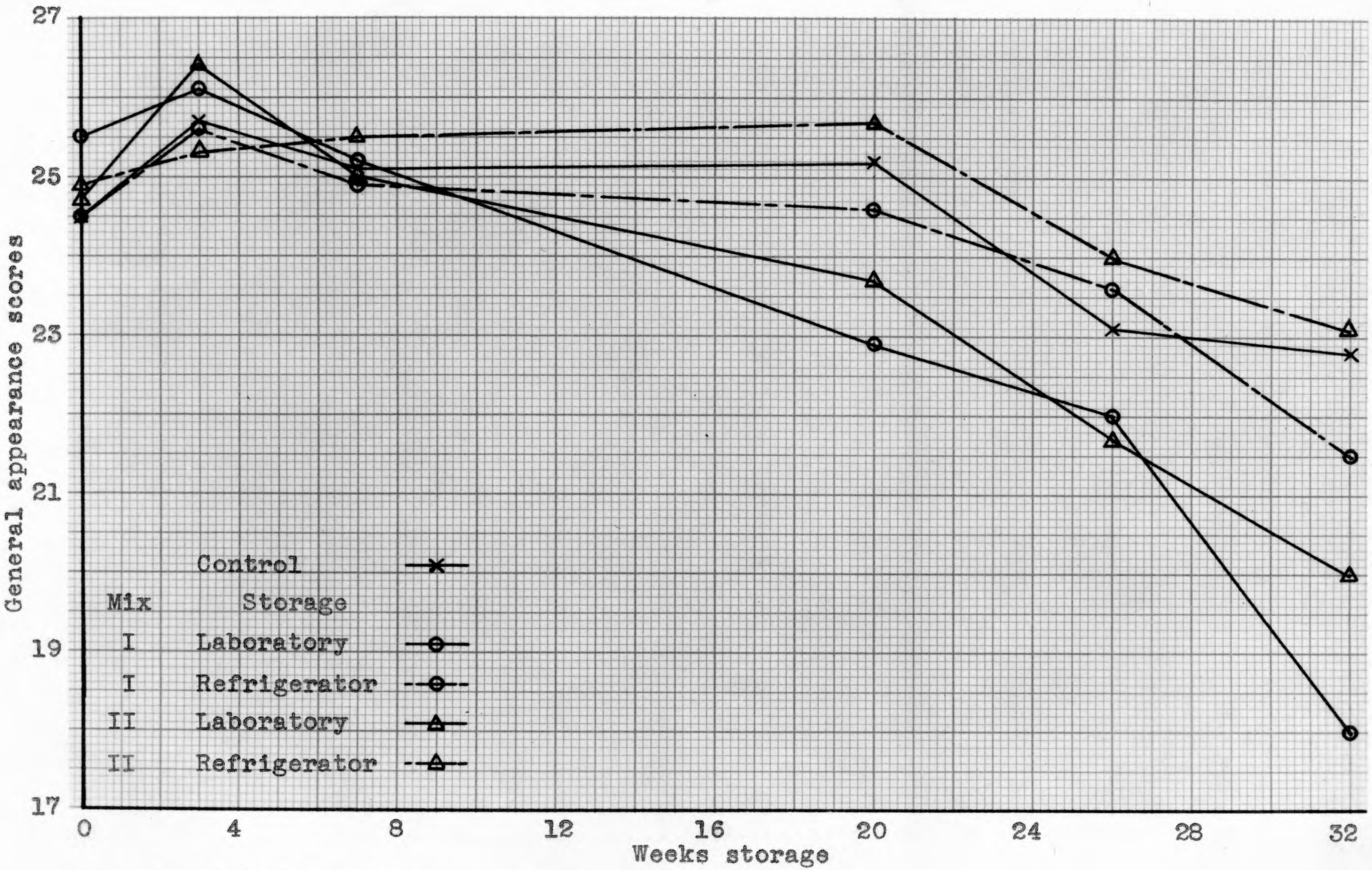

Fig. 2. Effect of storage on general appearance scores.

Interaction between cake types and storage produced highly significant differences (P = .001).

<u>Texture</u>. Members of the palatability committee scored crumb, tenderness, and velvetiness under the heading of texture. Such undesirable characteristics as compact crumb, uneven grain, layers of collapsed cells or dry crumb were detected in this portion of the score card.

All cakes baked had a coarse bready texture. Large holes were frequently noted in the interiors. The cells were large and the cell walls thick. Such texture characteristics could be expected in cakes prepared by a short mixing method. Davies (1937) and Nason (1939) agreed that coarse, uneven, harsh texture could be attributed to insufficient mixing. Lowe (1943) observed that the crumb of a cake made with a short mixing time was crumbly, not smooth and velvety. The cell walls were thick and the cells coarse and large. Halliday and Noble (1946) reported that uneven grain, holey structure, and a soggy layer along the bottom and just beneath the crust could be expected when the ingredients of a cake were not thoroughly combined.

Significant differences were found in texture scores for different cake types (P = .01). Cakes made from mixes stored at laboratory temperature received significantly lower scores for texture than did the control cake or cakes made from mixes stored at refrigerator temperature (Table 11). Storage of both types of mixes at laboratory temperature effected a decrease in texture scores.

Table 11. Test means for 120 cakes.

Cake type	Texture mean
Mix II with shortening, laboratory storage	19.3
Mix I without shortening, laboratory storage	20.0
Control	21.1
Mix I without shortening, refrigerator storage	21.2
Mix II with shortening, refrigerator storage	21.3

Storage produced highly significant differences in texture scores (P = .001). The scores were decreased by increased storage with the major change occurring sometime between the seventh and twentieth weeks. The mean score obtained at the 20-week baking period was significantly different from those obtained during any of the first three baking periods or from either of those obtained during the last two baking periods (Table 12).

Table 12. Test means for 120 cakes.

Storage (weeks)	Texture mean
0	22.4
3	22.4
7	21.8
20	20.1
26	18.4
32	18.3

After 26 weeks' storage all the mixes produced cakes with layers caused by collapsed cells. This layering was thought to be a result of deterioration of egg protein rather than the mixing process, since it was not observed throughout the entire experiment. At the 32-week baking period, the grain was compact and the texture such that the cakes "gummed up" or "balled up" in the mouth. Cakes were also crumbly at this time. Dawson, Shank, Lynn, and Wood (1945) observed that dried whole egg which had been stored for 23 weeks at 86° F. produced cakes with compact, crumbly, dry texture.

The variance of scores attributed to interaction between cake types and storage was significant at the 5 per cent level.

Eating Quality. The aroma of the batters prepared from the mixes stored at refrigerator temperature was described as good throughout the study. The aroma of the control batters was good throughout the first five storage periods, after which it was described as fair. Aroma changes were apparent after seven weeks' storage in mixes stored at laboratory temperature and in batters prepared from these mixes. The undesirable aroma was described as sharp and acid and was attributed to deterioration of egg. A possible explanation for the more rapid deterioration of the egg for the control cake as compared with egg incorporated into mixes stored at refrigerator temperature lies in the method of storage. Egg powder for the control cakes was stored in a large glass jar with a screw top lid. This powder was exposed to air each time the jar was opened. As the powder was used out of the jar, it was replaced by air. Egg powder in the mixes was protected against free exposure to air.

An off flavor which was described as sharp, acid, and/or bitter was noted in all the cakes at one time or another during the investigation. After seven weeks, this undesirable flavor was observed in cakes made from Mix I and Mix II stored at laboratory temperature. Cakes made from mixes stored at refrigerator temperature and from ingredients for the control had an undesirable flavor after 20 weeks. As the storage period increased, the undesirable flavor and aroma found in all the cakes became more objectionable. Variance in eating quality scores due to types of cakes was significant at the 5 per cent level. Mixes stored at laboratory temperature produced cakes with significantly lower scores as compared with the scores of the control cakes or those of cakes made from mixes stored at refrigerator temperature, (Table 13). Storage at laboratory temperature decreased eating quality in both types of mixes.

Table 13. Test means for 120 cakes.

Cake type	Eating quality mean
Mix I without shortening, laboratory storage	11.48
Mix II with shortening, laboratory storage	11.85
Control	14.30
Mix I without shortening, refrigerator storage	14.38
Mix II with shortening, refrigerator storage	14.31

Storage produced highly significant differences in eating quality scores (P = .001). The scores were decreased with increased storage with the major change occurring sometime between the seventh and twentieth weeks. The mean score obtained at each of the last three baking periods was significantly lower than those obtained during the earlier part of the study (Table 14). Variance in eating quality scores attributed to interaction between cake types and storage was highly significant (P = .001).

Table 14. Test means for 120 cakes.

Storage (weeks)	Eating quality mean
0	15.50
3	15.64
7	14.96
20	12.54
26	10.47
32	10.48

Lowe (1943) believed that from the standpoint of eating quality, flavor was of great importance. She reported that in a dough and batter series, good flavor and good texture are closely related. She further stated that on a score card she would rate flavor higher than texture, appearance, or tenderness. The similarily between the trends in decrease of total palatability and eating quality is striking (Figs. 1 and 3).

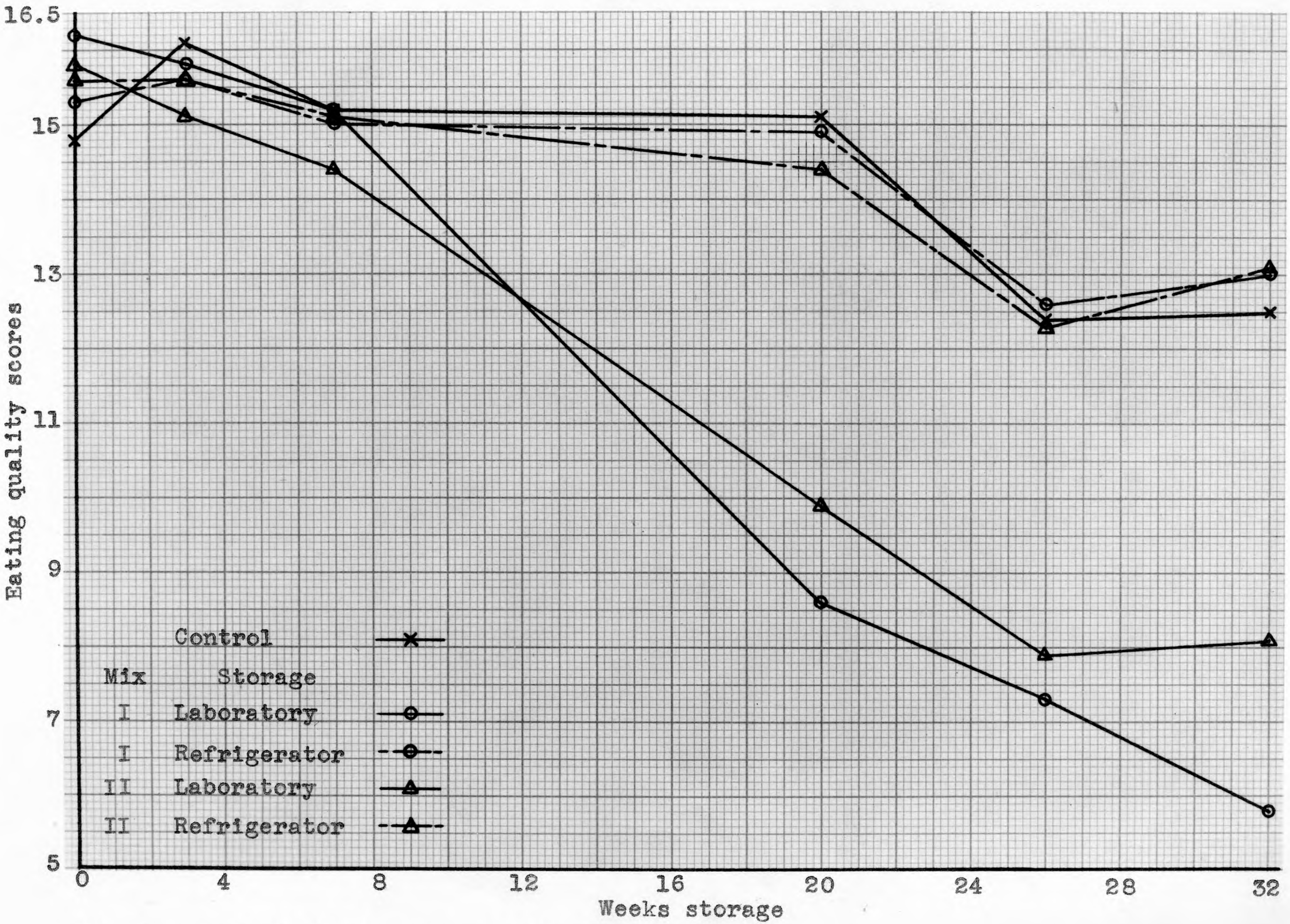

Fig. 3. Effect of storage on eating quality scores.

<u>Preference</u>. Members of the palatability committee ranked the cakes from first to fifth choice indicating that mixes stored at laboratory temperature produced cakes which were less desirable than those prepared from mixes stored at refrigerator temperature or from ingredients for the control. There was little difference in desirability between cakes made from Mix I stored at laboratory temperature and those made from Mix II stored at laboratory temperature. There was also little difference in the desirability among the remaining three cake types: cakes made from ingredients for the control, cakes made from Mix I stored at refrigerator temperature, and cakes made from Mix II stored at refrigerator temperature. However, the decided preference for cakes made from ingredients for the control and/or those made from mixes which had been stored at refrigerator temperature was obvious. The investigator would recommend that plain cake mixes containing dried whole egg be stored at refrigerator temperature.

The results of this investigation indicated that prepared plain cake mixes containing dried whole egg cannot be expected to keep well for a long period of storage. Other unpublished work carried out in the same laboratory indicated that acidified, 10 per cent sugared egg which had been dried at low temperature might be expected to have better keeping qualities than the plain dried whole egg used in this study.

For the sake of brevity and clarity, the statistical analyses were omitted from the text of the Results and Discussion in most cases. However, they appear in the Appendix.

SUMMARY

The purpose of this study was to determine (a) a method of preparing, packaging, and storing prepared plain cake mixes containing dried whole egg which results in high quality products and (b) the maximum shelf life of plain cake mixes containing dried whole egg, prepared with and without shortening when held under two different storage conditions.

Two plain cake mixes based on a golden layer cake formula were prepared. Mix I contained only dry ingredients while Mix II contained both dry ingredients and shortening.

Mixes of each group were heat sealed in moisture-vapor-grease-proof packaging material. One-half of each group was stored at laboratory temperature and the other half at refrigerator temperature. Mixes were stored for 0, 3, 7, 20, 26, and 32 weeks.

The shortening, water, and vanilla omitted from Mix I and the water and vanilla omitted from Mix II were added at the time of mixing for baking. The control at each baking period was freshly mixed from ingredients which had been stored separately under the best known storage conditions as determined by previous experiments.

At the end of each storage period, four cakes of each type were mixed by a four-minute method on a KitchenAid mixer, baked, and tested. A total of 120 cakes was made.

The following determinations were made: temperature of the laboratory during mixing, of the batter, and of the room during

testing; specific gravity and consistency of the batter; standing height, shortness, and compressibility of the cake; and desirability of the cake as determined by a palatability panel of six judges.

Statistical analysis of the data was made. It indicated the following three effects to be significant.

Storage of as much as 20 weeks effected a decrease in specific gravity of the batters and in total palatability, general appearance, texture, and eating quality of the cakes. Consistency measurements of the cake batters were increased with storage of more than 26 weeks.

There was no overall effect of the presence or absence of shortening independent of storage temperature. When mixes were stored at laboratory temperature, the presence of shortening increased the specific gravity of the batters and the shortness values of the cakes.

When the effect of temperature of storage was investigated, it was found that storage in the laboratory of both types of mixes decreased total palatability, texture, and eating quality of the cakes. Laboratory storage of mixes increased specific gravity of the batters and shortness values of cakes only when shortening was present in the mix during storage.

All cakes decreased in quality with increased storage of mixes and/or ingredients for the control, but cakes made from mixes stored in the laboratory decreased most rapidly. Under the conditions of this study, cakes made from laboratory stored mixes were desirable for a maximum storage period of seven weeks, while those made from refrigerator stored mixes were desirable for a maximum of 20 weeks. It would appear that the maximum shelf life of laboratory stored mixes would be partially dependent upon conditions of atmospheric humidity and temperature which prevailed during storage. The shelf life of the mixes was not appreciably affected by the presence or absence of shortening when the storage temperature was not a variable. As storage periods increased, mixes held at refrigerator temperature continued to produce desirable cakes, while those held at laboratory temperature produced somewhat undesirable ones. The temperature of storage appeared to affect the shelf life more than any other factor. The investigator would recommend that if cake mixes containing dried whole egg are to be held in storage more than seven weeks, they should be stored at refrigerator temperature.

ACKNOWLEDGMENT

Grateful acknowledgment is expressed to Miss Gwendolyn L. Tinklin, Assistant Professor, Department of Foods and Nutrition for her sincere interest and guidance throughout this study. Appreciation is also expressed to Dr. H. C. Fryer for the statistical analysis of the data and to members of the palatability committee who scored the cakes.

LITERATURE CITED

Andrews, John S.
Science touches your table. Progress Through Research 3:1-3. 1949.

Anonymous.
Eat your cake and have it, too. Progress Through Research 4:9-11. 1949.

Ary, Jean E., and Ruth Jordan.
Plain butter cakes and baked custards made from spray dried whole egg powder. Food Res. 10:476-484. 1945.

Boggs, Mildred M., and H. L. Fevold.
Factors in palatability of stored powders. Indus. and Engg. Chem. 38:1075-1079. 1946.

Carlin, G. T.
Packaging materials which resist rancidity. Food Indus. 20:1750-1751, 1874. 1948.

Carlin, George.
Progress in shortenings forced by shortages. Baker's Digest 18:37-38, 43. 1944.

Child, R.
Rancidity of fats and its prevention. Baker's Digest 20:52, 65. 1946.

Conrad, R. M., G. E. Vail, A. L. Olsen, G. L. Tinklin, J. W. Greene, and Charles Wagoner.
Improved dried whole egg products. Kans. Agr. Expt. Sta. Bul. 64. 62 p. 1948.

Davies, J. R.
Effect of formula and procedure variables upon cake quality. Cereal Chem. 14:819-833. 1937.

Dawson, Elsie, Dorothy E. Shank, Jane M. Lynn and Elizabeth A. Wood.
Effect of storage on flavor and cooking quality of spray dried whole egg. U. S. Egg and Poultry Magazine 51:154-161. 1945.

Dunn, J. A., and J. R. White.
Factor control in cake baking. Cereal Chem. 14:783-801. 1937.

Fevold, H. L., B. G. Edwards, A. L. Dimick, and M. M. Boggs.
Sources of off flavors developed during storage. Indus. and Engg. Chem. 38:1079. 1946.

Fryd, C. F., and S. W. F. Hanson.
Dried egg - the relationship of analysis to flavor. Jour. Soc. Chem. Ind. 64:55-56. 1945.

Gordon, Barbara Eales.
The effect of two mixtures containing lecithin on shortening qualities, palatability, and keeping qualities of certain baked products. Unpublished thesis. Kans. State Col. of Agri. and Appl. Sci. 44 p. 1947.

Gorseline, Harry E.
Dehydration of eggs. Proceedings of Institute of Food Technologists 4:70-77. 1943.

Halliday, Evelyn J., and Isabelle Noble.
Hows and whys of cooking. Chicago. Univ. Chicago Press. 175 p. 1928.

Halliday, Evelyn J., and Isabelle Noble.
Hows and whys of cooking. Chicago. Univ. Chicago Press. 328 p. 1946.

Hauser, E. A.
The importance of colloid chemistry in food technology. Food Tech. 2:144-157. 1948.

Hetrick, J. H., and P. H. Tracy.
Some observations on the keeping quality of spray dried whole milk stored at room temperature. Jour. Dairy Sci. 28:687-700. 1945.

Holm, George E.
Dried milks. Baker's Digest 19:145-146, 152. 1945.

Hudson, R. A.
What commercial users expect of dried eggs. U. S. Egg and Poultry Magazine 55:14-15, 26-27. 1949.

Kramer, Ruth.
Creaming properties of various fats as related to the specific gravity of the batter and to the quality of plain cake. Unpublished thesis. Kans. State Col. of Agri. and Appl. Sci. 46 p. 1935.

LeClerc, J. A., and C. H. Bailey.
Fresh, frozen, and dried eggs and egg products. (Their use in baking and for other purposes). Cereal Chem. 17:279-311. 1940.

Lightbody, H. D., and H. L. Fevold.
Biochemical factors influencing the shelf life of dried whole eggs and means for their control. In Mrak, E. M. and George F. Stewart, Advances in Food Research Vol. I. p. 149-194. New York, N. Y. Academic Press, Inc. 1948.

Lowe, Belle.
Experimental Cookery. 3rd ed. New York. John Wiley and Sons, Inc. 611 p. 1943.

Makower, B., and T. M. Shaw.
Oxygen absorption by dehydrated whole egg powder. Indus. and Engg. Chem. 40:1433-1437. 1948.

Miller, C. F., Belle Lowe, and G. F. Stewart.
Lifting power of dried whole egg when used in sponge cake. Food Res. 12:332-342. 1947.

Nason, Edith.
Introduction to Experimental Cookery. 1st ed. New York. McGraw-Hill Book Company. 317 p. 1939.

Peterson, M. B.
Shortening and cake quality. Baker's Digest 20:7-9. 1946.

Platt, Washington, and Phillip D. Kratz.
Measuring and recording some characteristics of test sponge cakes. Cereal Chem. 10:73-90. 1933.

Pyke, W. E., and G. Johnson.
Relationships between certain physical measurements upon fresh and stored eggs and their behavior in the preparation and baking of cake. Poultry Sci. 20:125-138. 1941.

Reid, Margaret, and J. A. Pearce.
Dried whole egg powder XVII. Objective tests and baking quality. Canad. Jour. Res. 23F:239-242. 1945.

Roberts, Aldene Nussbaumer.
The use of dried eggs of substandard quality in foods. Unpublished thesis. Kans. State Col. of Agri. and Appl. Sci. 63 p. 1945.

Snell, H. M., A. G. Olsen, and R. E. Kremers.
Lecithoprotein. The emulsifying ingredient in egg yolk. Indus. and Engg. Chem. 27:1222-1223. 1935.

Stewart, George, Leo R. Best, and Belle Lowe.
A study of some factors affecting the storage changes in spray dried egg products. Proceedings of Institute of Food Technologists 4:77-78. 1943.

Stewart, George.
There's a future for good dried eggs. U. S. Egg and Poultry Magazine 55:17-19, 28. 1948.

Stuart, L. S., Harry E. Gorseline, Helen F. Smart, and Virginia T. Dawson. Quality of egg powder affects rate of change in solubility. Food Indus. 17:154-156, 242. 1945.

Stuart, L. S., H. H. Hall, and Edna E. Dicks.
Storage changes in spray dried whole egg powder. U. S. Egg and Poultry Magazine 48:629-633, 658. 1942.

Stuart, L. S., Harry E. Gorseline, and Edna E. Dicks.
pH Measurements with spray dried whole egg powder. U. S. Egg and Poultry Magazine 48:634-635, 662. 1942.

Stuart, L. S., Emily Grewe, and Edna E. Dicks.
Solubility of spray-dried whole egg powder. U. S. Egg and Poultry Magazine 48:498-503. 1942.

Thistle, M. W., J. A. Pearce, and N. E. Gibbons.
Dried whole egg powder: Methods of assessing quality. Canad. Jour. Res. 21D:1-7. 1943.

Tinklin, Gwendolyn L.
A comparison of methods of incorporating dried whole eggs into cakes containing fat. Unpublished thesis. Kans. State Col. of Agri. and Appl. Sci. 63 p. 1944.

Tinklin, Gwendolyn L., and G. E. Vail.
Effect of method of combining the ingredients upon the quality of the finished cake. Cereal Chem. 23:155-165. 1946.

White, W. H., and M. W. Thistle.
Dried whole egg powder IV. Effect of moisture content on keeping quality. Canad. Jour. Res. 21D:211-222. 1943.

APPENDIX

Form I
Score Card for Cakes

Key: very desirable 9-10
desirable 7-8
acceptable 5-6
slightly undesirable 3-4
undesirable 1-2

Date____________________

Judge____________________

		Comments	Sample No.					
General appearance	1. CRUST - even golden brown, not too thick nor too thin - not blistered, sugary, or greasy.							
	2. SHAPE - symmetrical - top smooth and only slightly rounded - no cracks, bumps, or depressions.							
	3. COLOR OF CRUMB - even and rich looking - no objectionable color.							
Texture	1. CRUMB - springy, elastic, and slightly moist - even grain with small uniform cells having thin fine cell walls - not too compact							
	2. TENDERNESS - tender but not too light and feathery - not too tough or gummy.							
	3. VELVETINESS - smooth and soft like velvet to finger and palate.							
Eating quality	1. FLAVOR AND AROMA - delicate flavor and aroma - no objectionable, strong, bitter, or off flavors or aromas.							
	2. ALL the qualities which make a cake desirable or undesirable for eating, especially flavor, aroma, velvetiness, or pleasing texture.							

Which cakes do you prefer?

1st Choice ______ 4th Choice ______
2nd Choice ______ 5th Choice ______
3rd Choice ______

Form II

Chart for Recording Data for Individual Cakes

		Temperature					Baked cake		
Date	Cake type	Room when mixing (°C.)	Room when testing (°C.)	Batter	Batter weight for specific gravity	Consistency of batter (min-sec.)	Standing height (cm)	Shortness (g)	Compressibility (cm)

Analysis of variance for the specific gravity determinations.

Source of variation	Degree of freedom	Specific gravity determination Mean square	Probability
Cakes	4	.0114	.001
Storage	5	.0194	.001
C x S	20	.0012	ns
Samples	90	.00089	
Total	119		

Analysis of variance for the consistency determinations.

Source of variation	Degree of freedom	Consistency Mean square	Probability
Cakes	4	589251.42	ns
Storage	5	3660586.67	.001
C x S	20	287107.98	ns
Samples	90	424823.67	
Total	119		

Analysis of variance of shortness data.

Source of variation	Degree of freedom	Shortness measurement Mean square	Probability
Cakes	4	773.47	.01
Storage	5	483.21	.01
C x S	20	73.27	ns
Samples	90	118.06	
Total	119		

Analysis of variance of compressibility measurements.

Source of variation	Degree of freedom	Compressibility measurements Mean square	Probability
Cakes	4	.885	ns
Storage	5	1.604	.01
C x S	20	.114	ns
Samples	90	.380	
Total	119		

Analysis of variance for the total palatability scores.

Source of variation	Degree of freedom	Total palatability scores Mean square	Probability
Cakes	4	199.965	.05
Storage	5	694.542	.001
C x S	20	46.324	.001
Samples	90	5.749	
Total	119		

Analysis of variance for general appearance scores.

Source of variation	Degree of freedom	General appearance scores Mean square	Probability
Cakes	4	8.925	ns
Storage	5	56.402	.001
C x S	20	4.294	.001
Samples	90	.738	
Total	119		

Analysis of variance of texture scores.

Source of variation	Degree of freedom	Texture scores Mean square	Probability
Cakes	4	17.772	.01
Storage	5	71.974	.001
C x S	20	2.011	.05
Samples	90		
Total	119		

Analysis of variance of eating quality scores.

Source of variation	Degree of freedom	Eating quality scores Mean square	Probability
Cakes	4	51.54	.05
Storage	5	118.49	.001
C x S	20	11.87	.001
Samples	90	.89	
Total	119		

Test means for 120 cakes.

Storage (weeks)	Shortness mean
0	114.0
3	112.2
7	112.7
20	109.7
26	121.6
32	107.2

Test means for 120 cakes.

Storage (weeks)	Compressibility mean
0	1.94
3	1.80
7	2.39
20	1.90
26	1.60
32	2.20