

THE DETERMINATION OF OPTIMUM TIME AND TEMPERATURE CONDITIONS
IN THE OIL TREATMENT OF SHELL EGGS

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INTRODUCTION

The great bulk of the annual egg crop is disposed of as market eggs for human consumption. Most of these eggs are sold to consumers in the shell but some are used for freezing or drying for bakers, candy and mayonnaise makers, and for other purposes. The preservation of the interior quality of eggs sold in the shell is of vital importance to egg producers, distributors, and consumers.

The egg is a highly perishable product and if not given proper care between the time it is laid and the time it is consumed may deteriorate markedly in several respects. The porous nature of the shell of the egg permits gases and water to escape from the shell and allows bacteria to enter the egg when eggs are exposed to unsatisfactory environmental conditions. One of the most effective methods of preserving quality in shell eggs is by dipping them in mineral oil in order to seal the pores.

The preservation of hens' eggs by the use of various materials was perhaps first tried by the Chinese much over a century ago. In spite of the long period which has elapsed, there is a serious lack of information on the proper preservation of shell eggs. Many people are familiar with the preservation of eggs in the home by means of water glass. This method is still used today on a commercial scale in some European countries.

The commercial oil treating of shell eggs is reported to have begun about 30 years ago in this country. Mechanical dipping equipment was first developed and used between 1910 and 1911. About this time, Victor Clairemont patented his oil-dipping machine. It was not used widely until about 1925. The development of oil dipping machinery operated by electricity has increased considerably since then.

Oil dipping or processing, as it is sometimes called, is now used extensively by firms placing eggs in storage. Experience and some research has shown that the cost of oil treating eggs is more than compensated for by increased yields of top grade eggs coming out of storage. Some experiments have also been conducted in oil treating eggs at the farm. In general, there has not been any uniformity with respect to the temperature nor the time used in oil treatment.

Many firms prefer to keep their oil at room temperature (70° to 80°F.). Others prefer to heat the oil to insure higher oil temperatures than egg temperatures. This is reported to reduce the possibility of the egg shells absorbing any great quantity of contaminated oil and consequently tends to reduce spoilage in storage. One outstanding authority on this subject has stated that oil temperatures should always be higher than the eggs being oiled. In order to insure this condition, a temperature of 110°F. is recommended. One equipment manufacturer

suggested an oil temperature of 120°F. when his equipment is used.

It became quite evident, in reviewing the literature and in discussing the oil treating of eggs with prominent specialists on the subject, that specific information on the optimum time and temperature for oiling eggs is wholly inadequate. Consequently, this experiment was undertaken to explore a wide range of oil treatments. Not only were some of the more common treatments duplicated but extreme heat and time treatments were also conducted. In view of the fairly recent interest in thermostabilization, one group of eggs was also thermostabilized for comparison and also for information on the deterioration of egg quality under storage conditions.

LITERATURE REVIEW

The preservation of interior quality in shell eggs has been a problem since eggs were first produced. Years ago when egg production was more seasonal than it is today, the most common method of home preservation used by producers was the water-glass or lime-water method. This method is still recommended where the eggs are to be used in the home. This method of preservation is still widely used in normal market channels in foreign countries such as Denmark, where refrigerated warehouse space is lacking.

Some of the earliest attempts to preserve quality by oiling eggs were undertaken in 1807. In this country, it is reported that Benjamin Franklin also experimented with oil as a preservative agent for shell eggs. A wide variety of materials for shell treating eggs have been tried, ranging from cactus juice, rubber, cellulose compounds, linseed oil, aluminum foil, plastics and oil coating. Almy, Macomber and Hepburn (1922) investigated a variety of methods for preserving eggs, including oiling. They found that mineral oils were superior to vegetable oils, and that the heavy mineral oils were more effective than the lighter oils when applied at 239°F.

Considerable interest in the oiling of eggs manifested itself in the early thirties. Swenson, Slocum, and James (1931) (1933) (1936) carried out numerous experiments,

using various treatments and oils. They observed no difference between paraffin and asphalt base oils, but found that oils with pour points higher than the storage temperature were more effective in maintaining good egg grade. These same authors, (1936) studied the use of cold oil at ordinary temperatures. It was their contention that the use of heated oil might possibly have a deleterious effect upon egg quality. It was also their thought that the use of oil at ordinary temperatures (60-80°F.) would not require heat, therefore there would be no possibility of undesirable heating effects upon quality. Swenson (1931) developed a vacuum-carbon dioxide method of oiling eggs which produced better results than other methods.

Experiments in the oiling of eggs were carried out by both the plain open-bath dip and the vacuum-carbon dioxide methods. Eggs graded according to the U. S. Standards were oiled by both methods at 60 and 80°F. and then placed in a refrigerated warehouse for seven months. The results showed that eggs oil treated at ordinary temperatures (60-80°F.) without heating maintained 100 percent more of the original quality than the untreated controls. Oiling by use of the vacuum-carbon dioxide method was 35 percent more efficient than the plain open-bath dip and 73 percent better than the control lot. It was concluded that the oil dipping of eggs at ordinary temperatures was superior to heated oils, however, no eggs were treated

in warm oil for comparison.

Evans and Carver (1943) carried on three experiments to determine at what age eggs should be oiled. Wilhelm (1940) observed a rapid percent loss of albumen index during the first 24 hours after an egg was laid. He believed that this rapid loss was closely associated with a loss of carbon dioxide from the albumen. Sharp (1937) found eggs to be best preserved at their natural carbon dioxide concentration. It appeared that eggs should be oiled as soon as practicable after they were laid.

Evans and Carver found in the first experiment that eggs which had been oiled as gathered showed a gain in albumen index over the classified index, which was determined the day after the eggs were laid. Eggs oiled the evening of the day gathered had a loss of albumen index. Unoiled eggs showed the greatest loss. The sooner the eggs were oiled the less moisture they lost, as indicated by changes in air cell size. Eggs oiled immediately had the most cloudy albumen while unoiled eggs had the least cloudy ones.

The second experiment was designed to show the effect of three-months storage at 32°F. on oiled eggs. The eggs oiled as gathered did not show as great a loss of albumen index as eggs oiled later. Oiling the eggs at noon and in the evening appeared as satisfactory as doing it more often, when the eggs were stored for three months. It should be pointed out that in these experiments all eggs

were collected seven times a day. There was no significant difference in decrease in albumen index between eggs oiled on the third day or later and unoiled eggs, when both were stored for three months. There was little difference in albumen cloudiness of eggs oiled the first two days. Eggs oiled after this were less cloudy, and unoiled eggs least cloudy. They concluded that the interior quality of storage eggs was best preserved by oiling the eggs on the day that they were laid.

In the course of this experiment it was observed that the eggs oiled on the day they were gathered had a considerable quantity of a very "watery" albumen surrounding a small amount of very firm, cloudy albumen. They therefore set up another experiment to study the relative amounts of "watery" albumen from a quantitative standpoint. They found that there was a loss of albumen index, increase in percent outer liquid albumen and decrease in percent firm albumen from one period to the next for all treatments. Unoiled eggs had the greatest loss in albumen index at four weeks and those oiled immediately the least. There was little decrease in the percent of firm albumen of unoiled eggs, while it was considerable in the oiled eggs. There was no significant difference among the three treatments with respect to the percent of outer liquid albumen.

There was no significant difference in the percent loss of albumen index between the eggs oiled as gathered and those oiled the next morning, after the eggs had been

in cold storage for twelve weeks. There was no significant difference between unoiled eggs and eggs oiled the next morning in the increase in percent outer liquid albumen. Eggs oiled as gathered had a much greater increase in percent outer liquid albumen than unoiled eggs or eggs oiled the day after they were laid.

It was concluded that best results were obtained with eggs oiled the day after they were laid. Further evidence was provided by cooking studies on eggs from the second experiment. McIntosh, Tanner, Evans and Carver (1942) found that from a culinary standpoint, eggs oiled the day after they were laid were superior to eggs oiled at any other time or to unoiled eggs stored under the same conditions.

Evans (1942) conducted further experiments to determine whether the value of a heavy oil could be improved by diluting it with a solvent. Five solvents were used to dilute a paraffin base oil with a pour point of about 38°F. Each solvent was added to give a level of 100, 90, 80 and 50 percent by volume in the resulting mixture. The solvents were distillation fractions of petroleum and had boiling point ranges as follows: 150-270°F.; 190-270°F.; 218-330°F.; 300-385°F.; 314-398°F. The eggs were then stored for two weeks in a room where the temperature ranged from 60 to 80°F. It was found that there was a 57 percent loss of albumen index in the unoiled eggs. Eggs treated with any of the solvents without the oil lost

practically the same percent albumen index and had the same increase in air cell size as unoiled eggs. In most cases a mixture of 50 percent oil and 50 percent solvent was as effective as 100 percent oil.

The solvents with low boiling point ranges had the least harmful effects at the 80 or 90 percent levels of solvent. The more volatile the solvent, the more nearly the preservation effect approached that of the oil. There was no significant difference between the oil diluted with 50 percent of one of the more volatile solvents and the oil alone. The oils diluted with the more volatile solvents were more effective in preventing increase in air cell size than those diluted with the less volatile solvents.

The albumen index loss occurring in stored eggs was better prevented by oiling at room temperature with an oil having a Sayboldt viscosity of 105 at 100°F. than by oiling with one having a viscosity of 54 at 100°F. There was no significant difference in the preservation of oiled eggs between using the oil at room temperature (60-70°F.) and heating the oil to 135°F. to reduce the viscosity to 54 Sayboldt viscosity. However, lowering the viscosity of the oil by the addition of a volatile solvent significantly improved the oil in so far as preventing a loss of albumen index in treated eggs was concerned.

Thermo-stabilization of eggs. The process of thermo-stabilization of shell eggs to enhance keeping quality

was announced in January 1943. The original purpose of the first investigation was to develop a process or treatment to destroy the germ or blastoderm of fertile eggs in order that they keep as well as infertile as far as their subsequent reaction to environmental conditions was concerned. This treatment consisted of immersing the eggs in heated liquids and by circulating warm air around the eggs. A relatively low temperature (about 140°F.) was used so that the heat could penetrate the eggs before any part of the eggs was coagulated. This stabilizing effect by the use of heat has been designated thermo-stabilization.

The original investigation was conducted by the University of Missouri in cooperation with the Quartermaster Corps of the U. S. Army (1943). Eggs of known history produced by the Experiment Station flock were used in all tests except one. The eggs in each experimental group were selected at random from the same pens of the same age to eliminate differences between groups of hens and pullets and to eliminate any influence of age of egg. Ten or more eggs were used in most lots. The temperature of the egg to be immersed or treated is very important and in this experiment most of the eggs were held between 70 and 80°F. The eggs were immersed in water of constant temperature for definite periods. Mineral oil was also used in a similar manner. Some of the eggs were immersed in still or circulating water or oil and in some of the later tests the eggs were rotated in the liquid.

Five methods of measuring egg quality were used in making observations on broken-out eggs which had been treated. These methods were: (a) albumen score; (b) height of albumen; (c) Haugh units; (d) percentage of outer thin albumen; (e) strength of yolk membrane.

Albumen score. This method was used because it is considered one of the most rapid and most practical. It consists of comparing broken-out eggs resting on a flat glass surface with a series of nine photographic scores which were developed by Dr. Van Wagenen at Cornell University.

Height of albumen. The height of albumen was taken as a measure of the progressive change from thick to thin albumen. This measurement in millimeters was made with a spherometer at a point about one centimeter or one-half inch from the yolk.

Haugh Unit. The weight of the egg as well as the height of thick albumen was recorded and permitted the calculation of the Haugh Unit (1937).

Percentage of outer thin albumen. The percentage of outer thin albumen was determined by drawing the thin albumen into a pipette and then weighing. The amount of thick and inner thin albumen combined was determined similarly and the percentage of outer thin was calculated.

Strength of yolk membrane. The amount of pressure required to rupture the vitelline membrane surrounding the yolk was considered a satisfactory measure of yolk

stabilization. A special device was used to determine the pressure required to rupture the vitelline membrane after the albumen had been removed.

A series of experiments were conducted using water, mineral oil, and hot air as the heating media in thermo-stabilizing eggs. The results were compared by means of the measurements indicated previously.

It was found that eggs treated for ten minutes at 130°F. in still water was not sufficient to completely arrest embryonic development. When the temperature was raised to 135°F., and the eggs were immersed for 10, 20, and 40 minutes, they were completely stabilized with respect to embryonic development.

In another experiment in which warm air circulated by a household fan was used to treat eggs, it was found that where the temperature was held at 135°F. and at 150° to 153°F., more than 20 minutes were necessary to stop embryonic development. Later work indicated that air held at 140°F. and circulated at high velocity around the eggs would stop embryonic development in from 8 to 12 minutes.

It was observed early in this investigation that the normal breakdown of thick albumen did not occur in treated lots. Therefore an experiment was planned for measuring the relative decline in the albumen score of treated and untreated eggs. Untreated infertile controls held for 6 days at 100°F. had an average albumen score of 3.1 whereas eggs from the same pens immersed in still water

at 130°F. for 20 to 60 minutes had average albumen scores of 2.3 and 2.5, respectively. The results indicated that the thick albumen was stabilized by the treatment, so that treated eggs held at 100°F. for 6 days retained the quality of the albumen much better than the untreated eggs.

Eggs varying from three hours to ten days were candled as U. S. Extras and then treated. The results showed that albumen quality (albumen score) was best in fresh-laid eggs but the difference between eggs one day old and the five days old is rather small and not of much practical importance. High quality eggs, though they may be several days old, can be treated by this process so that the quality of the albumen is retained remarkably well.

Barott and McNally (1943) studied the relationship of temperature to time of coagulation. This was considered necessary since albumen stabilization, embryo destruction, and bacterial sterilization each have a definite temperature-time limit. The upper limit for these factors is set by the degree of albumen coagulation. Their paper presents three temperature-time curves, one for opacity of egg albumen, one for standard opacity, and one for embryonic destruction.

One time-temperature curve ranges between 124.5°F. and 144°F. It was found that temperatures lower than 124.5°F. produced no opacity in the albumen even after two

hours of immersion in circulating hot water. The time interval for immersion at temperatures above 144°F . became extremely critical and an increase in opacity could be observed in the albumen next to the shell by as slight an increase in the time of immersion as 30 seconds. The time of immersion required for the appearance of perceptible opacity varied from four minutes at 144°F . to 44 minutes at 124.5°F .

The curve developed for standard opacity is supplemented with photographs of eggs showing five stages of opacity. This photographic standard was used in measuring various stages of opacity in later treatments.

It was found that the development of the embryo was arrested by immersion at temperatures between 122°F . and 132°F . for periods of time which produced no opacity. The lethal curve for the embryo and the curve for perceptible opacity have a common time of immersion at 132°F . Embryonic destruction was not considered of great significance relative to this method of treatment, since development was stopped for times of immersion even less than that necessary to produce stage number 1 opacity.

Gibbons, Michael, and Irish (1947) conducted investigations to determine which of the available oils for treating shell eggs were most suitable and the influence of different temperatures. The eggs used in this experiment were one day old when treated, which is considered to be the ideal time for maintaining quality by oiling,

Evans and Carver (1942). The results indicated that oils with a Sayboldt viscosity of 70 to 100 at 100°F. are more suitable for maintaining egg quality than lighter oils. In general, pour point was not as important as viscosity; at 30°F. however, a high pour point seemed to be of some advantage. The use of oil at temperatures higher than room temperature offered no advantage in preserving quality or in the amount of oil retained on the shell. The results secured showed that there was little difference between light and heavy oils applied over a much wider range of temperature. The use of oils at elevated temperatures seem to be a trade practice originating in a desire to save oil. Although it seems reasonable that pour points above the storage temperature should give better results, this work does not altogether support this claim. Some of the best oils had very low pour points according to the laboratory test, and even according to the manufacturers' specifications the pour points were lower than the storage temperature.

The quality of eggs oiled when one day old with eight commercial oils and six mixtures and stored at 70° and 30°F. was assessed by candling, yolk index, and thick white height. Mineral oils with Sayboldt viscosities of 70 to 100 at 100°F. maintained egg quality and prevented weight loss better than oils of lower viscosity. Viscosity of oil seemed more important than pour point, although at 30°F. there was some indication that a high pour point was

advantageous. Oiled eggs maintained their grades two or three times longer than unoiled eggs and lost 1/10 to 1/4 as much in weight. Heavy oil diluted with mineral spirits did not give as good results as lighter oils of comparable viscosity. The addition of vaseline and magnesium stearate improved the action of the light oils. There was little difference in the quality of eggs dipped in oils maintained at 76°, 100° and 130°F.

Gibbons (1947) proposed a new method of determining the yolk index while the yolk is imbedded in the albumen. Sharp and Powell (1930) presented a method whereby the yolk was separated from all adhering albumen and chalazae. The yolk was then placed on a level glass plate, the diameter and height measured, and the yolk index calculated by dividing the latter by the former. This method is time consuming and vitelline membranes are frequently ruptured when old eggs are involved.

The method presented by Gibbons consisted of breaking the egg on a clean level glass plate and measuring the yolk diameter immediately with calipers along the axis bisecting the short and the long diameters. The yolk height was then measured with a spherometer. These two measurements were completed within 30 to 40 seconds after breaking the egg. It was found that there was excellent correlation between this latter method and the more laborious method previously mentioned.

Stewart and Bose (1948) conducted experiments using solvent-oil mixture in shell treating eggs. All eggs were less than one hour old and weighed between 55 and 60 grams. Shell treatment was accomplished by dipping the eggs momentarily in oil or in the solvent-oil mixtures at room temperature. Sonneborn's Carnation oil was used for all studies. The following solvents were used: commercial pentane (Skelly A), commercial hexane (Skelly B), special heptane (Skelly), deodorized kerosene (Sonneborn Deo-Base), carbon tetrachloride, and acetone.

It was indicated that for optimal retention of thick albumen quality and for preventing moisture loss, the eggs should be oiled as soon as possible after laying. It was recommended that for the optimal retention of thick albumen quality without having excessive amounts of thin white, eggs should be processed approximately 18 hours after being laid.

The results of these studies were considered quite striking in that they showed that extremely high dilutions of oil in pentane were effective in maintaining thick albumen quality, preventing weight loss, and in retaining the naturally occurring carbon dioxide content of the eggs. Mixtures containing as little as eight to ten percent oil were practically as efficient as undiluted oil. These results appear to be somewhat at variance with those of Evans (1942), although Stewart and Bose used different solvents. The eggs dipped in 90:10 pentane-in-oil

mixtures were only slightly oily in appearance immediately after treatment and were practically free of oiliness after standing a few hours. Eggs dipped in 80:20 or lower ratio mixtures were oily immediately after treatment and retained their oiliness for several days after the 14-day storage period.

Pentane was found to be far superior to all of the other petroleum solvents tested. It was felt that as the length of the hydrocarbon chain is increased, the efficiency of the solvent-oil mixtures decreased. This was believed to account for the difference between the work of Evans (1942) and this study. The following hypothesis is presented to help explain the results obtained with pentane. It appears that only small amounts of oil are required to seal the pores of the shell; however, in order for this amount of oil to be effective, it must penetrate the protein "filling" in the pores (Stewart 1935). Pentane appears to have the property of carrying the oil into the pores. This hypothesis also helps explain the lack of "shine" on eggs oiled in the 90:10 pentane-oil mixtures.

Bose and Stewart (1948) carried out several experiments in heat treating eggs. Eggs weighing 54-60 grams within five hours after being laid were obtained for treatment. The eggs were placed in a wire basket and immersed in a well-stirred, thermostatically-controlled water bath maintained at a temperature of 130^oF. This temperature was chosen because both the albumen and the yolk could be

heated to bath temperature without danger of coagulation. After heat treatment, the eggs were cooled to room temperature before being given any further treatment.

Oiling was accomplished by dipping the eggs for one minute in Carnation (Sonneborn) egg-processing oil kept at room temperature. Prior to heat treatment and (or) oiling, the eggs were held in a thermostatically controlled incubator kept at 68°F. Storage consisted of placing the eggs in desiccators over a sulphuric acid solution (suitable strength to give 50 percent relative humidity); the eggs were kept in an incubator at 77°F. for 14 days.

The following observations were made of the eggs after storage: (a) pH of albumen; (b) weight loss during treatment and during storage; (c) albumen index; (d) yolk index (with albumen intact); and (e) percent outer thin white.

With eggs five hours old, the heat treatment had no effect on the initial quality as measured by the albumen and yolk indices. Heat treatment produced a definite improvement in the albumen quality of four-day old eggs. The degree of improvement was roughly linear with heating time. No effect was noted on the yolk index of these eggs. Seven-day old eggs were also heat treated for 20 or 40 minutes at 130°F. and showed an increase in albumen index of 45 percent. These results indicated that the albumen index of eggs which have undergone some deterioration were improved by heat treatment.

Eggs oiled within five hours after being laid showed a good retention of albumen quality even when the eggs were unheated or when heat-treated for very short periods. However, when the heat treatment exceeded 40 minutes, no difference in the albumen index of oiled and unoiled eggs was observed. With four-day old eggs, there was no significant difference between the oiled and unoiled eggs, heated or unheated.

The effects of heating and oiling yolk index were somewhat different. Oiling and heat treating either fresh or aged eggs permitted a good retention of yolk quality during storage. This result was interpreted to mean that the oiled eggs contained sufficient carbon dioxide (even after four days) so that the yolk index was maintained fairly close to the original value. The oiling was complementary to heating in the early stages: after 40 minutes of heating no complementation occurred, since maximum stabilization had been achieved.

The five-hour old eggs increased in outer thin albumen during heat treatment. During storage only those lots which had received less than a 40-minute heat treatment showed any appreciable increase in the percent of thin white. With the four-day old eggs, there was no increase in percent thin albumen during heat treatment. Those lots heat-treated for 20 minutes or more maintained their initial values during storage. Those lots which received no heat treatment had very high percentages of thin albumen after

storage. There was not much difference between the oiled and unoled eggs except those not heat treated.

There was an appreciably greater loss in weight as a result of heat treating five-hour old eggs as compared with heat treating four-day old eggs. The data indicated that the evaporation rate of fresh eggs is considerably greater than that of older eggs. Increasing the time of heat treatment decreased the percent loss in weight during storage. The results suggested that heating the egg effects the mechanism by which water is lost from the egg shell. Coagulation of the proteins in the shell and/or membranes suggested itself as a possible reason for this effect.

There is considerable variation in the present methods of oil processing eggs. There is even a difference of opinion among employees of the same firm. Published reports by three employees of one of the largest processors varied somewhat in their recommendations. The temperatures ranged from 70°F. to 100°F. and the dipping time from 5 seconds to 90 seconds. Greatest emphasis was placed on the sanitation of the equipment rather than upon the method of oil treatment.

Recent work by Winter and Cotterill (1949) indicated that there was little or no difference in egg quality by treating eggs in oil at temperatures varying from 55° to 190°F. Unfortunately the loss in quality was measured by candling, which is not a reliable method of quality

determination. In view of the wide differences in opinions and methods of oil processing, it was felt desirable to conduct an experiment to determine, if possible, whether time and temperature differences are of any great consequence.

EXPERIMENTAL PROCEDURE

The eggs used in the course of this experiment were produced by the University of Maryland poultry department flock. Because of the large number of eggs required for this experiment, it was necessary to process eggs produced from the last week in March until the middle of May. It was also necessary to use eggs which varied considerably in size because of the limited number of eggs available. The eggs varied from 50 grams to 75 grams and most of the lots averaged around 61 grams. After being collected, the eggs were kept in the cellar egg room at the poultry plant. They remained in the egg cellar on the evening of the day laid and were transported to the poultry laboratory about 4 p.m. the following day. The eggs remained in the laboratory until the time of treatment at about 6:30 p.m. The room temperature during this period generally varied from 75 to 80°F.

Individual lots consisted of 180 eggs. These were removed from the egg case and placed in cup flats on a laboratory bench. Each egg was numbered consecutively from 1 to 180 in pencil on the large end of the egg. Individual eggs were then weighed in grams and candled. Car-Pro egg trays (3 dozen type) were then used to hold the eggs while they were dipped in the oil.

The oil processing tank was improvised from a war-surplus sterilizer, and contained 35 gallons of Sonneborn's

Carnation Mineral Oil. The heating elements consisted of two Aminco Lolag flexible immersion heaters suspended about one inch from the bottom of the tank. One coil was rated at 1000 watts and the other at 750 and they were connected to a bimetal thermoregulator which kept the temperature uniform. The oil was circulated and vigorously agitated by means of a Cenco variable speed stirrer. The stirring speed was increased until the surface of the oil appeared as though the liquid was boiling. In some instances the force of the oil dislodged a few eggs from the egg tray and they fell to the bottom of the tank.

The eggs contained in Car-Pro egg trays were dipped manually and rotated in the oil for the allotted number of seconds. They were then removed and placed upon clean cup flats for draining. After all of the 180 eggs in one lot were dipped in the oil and draining was complete, the eggs were placed in used fillers. These fillers and also the cases had been used only once and were in very good condition. The eggs were placed in the cases in numerical order, that is, the filler with the smallest numbers was at the bottom of the case and vice versa. The case was then taken to the refrigerator, which is the second in a bank of refrigerators so that it is necessary to enter the first refrigerator in order to gain access to the second one. This permitted a more uniform control of the storage temperature. The refrigerator was adjusted for 30°F.; however, variations of two to three degrees were fairly common.

Within the refrigerator, a series of slatted shelves were constructed so that air circulated around each egg case. These shelves minimized the handling of cases in getting the samples each month. The refrigerator was used exclusively for holding eggs to approximate storage conditions. The necessity of removing samples for several days each month was not conducive to ideal storage conditions.

A monthly sample from each lot consisted of 20 eggs. This sample contained eggs from each of the 5 layers in the half case containing the lot. The eggs from each layer were also taken from various locations in the filler. This was accomplished by taking all eggs in each flat whose numbers ended with the same figure as the first egg chosen. For example, at the first breaking, all of the eggs whose numbers ended with the figure 1 were taken. This method of sampling resulted in a sample which contained eggs from different sections of all layers.

The eggs in a sample were placed in consecutive order in a filler and flat and taken to the laboratory. They were weighed in grams as soon as possible. It was noticed that the eggs became "sweaty" during the weighing, consequently the weights did not reflect the actual loss in weight. The weighings were continued for purposes of comparison only. The eggs were then candled and graded into 12 separate quality grades. These grades were based on the U. S. Standards for eggs but each grade was sub-divided into three sub grades for finer distinction. For example,

Grade AA was subdivided into grades AA1, AA2, and AA3. This permitted much closer grading. However, since the eggs were cold, the candled grades of these cold eggs were not compared with the original candled grades. The candled grades were used solely for comparing lots of eggs of the same age.

After the candling was completed, the eggs were individually broken onto a level flat plate glass about 12" by 12". The shell was cracked by tapping gently on the sharp edge of the glass. The egg was then opened in a hinge-like fashion by inserting the thumb nails in the cracked shell and carefully separating the two halves. A great deal of care is necessary in opening the eggs but even with the best of care some of the eggs were damaged in opening. This is particularly true for eggs which have a tough shell membrane. Immediately upon breaking, the two halves of the shell were smelled for off odors.

MEASURES OF EGG QUALITY

The measurements of egg quality in the opened egg are quite numerous. In this experiment, however, the measures of quality most commonly used in research of a comparable nature were used. Particular attention was given to the experiments conducted by the U. S. Army, the Missouri Agricultural Experiment Station and the National Agricultural Research Center at Beltsville, Maryland. These agencies have conducted investigations in egg quality

and thermostabilization over a period of several years. After reviewing the various experiments in oil processing, the following egg quality measures were selected: (1) height of albumen; (2) Van Wageningen albumen score; (3) Haugh unit; and (4) yolk index.

Height of albumen. The height of the thick albumen in a broken-out egg is a measure of the breakdown of the thick albumen envelope. As the thick albumen becomes weak and thin it flattens out and occupies a larger area. The height of the albumen is determined by the use of a spherometer calibrated in millimeters. Because of the variation in height in the albumen surface area it is necessary to standardize the point of measurement. This point is about one centimeter or one-half inch from the yolk.

Van Wageningen albumen score. This score is frequently referred to as the Van Score and is so-called in this paper. This score consists of nine photographs of broken-out eggs varying from the best to the poorest. The photos present both an overhead and a side view of each egg. A numerical score is given each photo, the best egg is scored 1.0 and the poorest 5.0. The broken-out egg is compared with the photographs and given the numerical score of the photo which it most nearly resembles. This is the most rapid and one of the more practical measurements used in egg quality investigations.

Haugh Unit. This measure of quality requires that the height of the thick albumen and the weight of the egg be

known. These two measurements can then be converted into a Haugh Unit quality figure by means of a nomogram. This is the only quality measure which considers the weight of the egg, consequently eggs of various sizes are comparable. The procedure, however, is time consuming and is not used too frequently.

Yolk Index. The yolk index also requires two measurements for its determination, the height and the width of the yolk. The height is then divided by the width to obtain the yolk index, which is a measure of yolk deterioration. There are two methods of obtaining the yolk measurements. The original method, developed at Cornell University, requires that the yolk be removed from inside its albumen envelope. In the second method, yolk measurement is taken with the broken-out egg resting on a flat surface imbedded in the albumen. The latter method is most commonly used because of its speed and is the method used in this experiment.

OIL PROCESSING TREATMENTS AND RESULTS

A total of 31 different time and temperature treatments were conducted in which 5760 eggs were used. Also, one control lot of eggs, which were untreated and kept under the same storage conditions, were used for purposes of comparison. The temperature treatments ranged from 80° to 200°F., while the dipping time varied from 5 to 80 seconds. A summary of the various treatments is presented in table I.

In order to compare the numerous lots of eggs, the length of treatment is used to select the lots for comparison. The lots which were processed for 5 seconds namely: lots 1, 6, 11, 16, 21, 26 and 29 are placed in one group. The other lots were grouped in the same manner. The quality measures for each group were then compared in graph form as in Figure 1.

This figure presents the average monthly egg quality measures for lots 1, 6, 11, 16, 21, 26 and 29 for a period of seven months. The first samples were broken and measured the day after processing. The other samples were broken at monthly intervals in order to measure the progressive deterioration during the storage period. From figure 1, it is quite evident that the greatest amount of egg quality deterioration occurred during the fourth month of the storage period. This is true regardless of the treatment of the different lots of eggs. This rapid

TABLE I. Time and temperature treatments of 31 lots of eggs, each containing 180 eggs, processed in mineral oil and one control lot of 180 eggs.

Lot Number	Treatment	
	Temperature	Time of Immersion
1	80°F.	5 seconds
2	80°F.	10 seconds
3	80°F.	20 seconds
4	80°F.	40 seconds
5	80°F.	80 seconds
6	100°F.	5 seconds
7	100°F.	10 seconds
8	100°F.	20 seconds
9	95°F.	40 seconds
10	90°F.	80 seconds
11	120°F.	5 seconds
12	120°F.	10 seconds
13	120°F.	20 seconds
14	110°F.	40 seconds
15	100°F.	80 seconds
16	140°F.	5 seconds
17	140°F.	10 seconds
18	140°F.	20 seconds
19	125°F.	40 seconds
20	110°F.	80 seconds
21	160°F.	5 seconds
22	160°F.	10 seconds
23	160°F.	20 seconds
24	140°F.	40 seconds
25	120°F.	80 seconds
26	180°F.	5 seconds
27	180°F.	10 seconds
28	130°F.	80 seconds
29	200°F.	5 seconds
30	140°F.	80 seconds
Thermostabilized	140°F.	15 minutes
Untreated	No treatment	

breakdown also occurred in all of the other lots of eggs in this experiment.

There is some question as to the probable cause of this deterioration and no mention of this occurrence has been made in the literature. Since the control lot also showed maximum monthly decrease in albumen height during the fourth month, it was felt that the oil treatments were not the causative factor. It is interesting to note that the thermostabilized lot of eggs, figure 6, also had a maximum decrease in albumen height during the third and fourth month of the storage period. Since this lot of eggs had excellent albumen height readings, one is led to believe that all of the treatments had little or no effect upon the flattening of the albumen.

It is quite possible, however, that the lowering of the albumen height may be associated with the condition of the yolk. Some of the lots of eggs showed a lower yolk index during the third and fourth month than at any other time during the experiment.

Sharp (1937) stated that the progressive flattening and weakening of the yolk is associated with the passage of water from the white to the yolk, owing to osmotic forces. He developed the yolk index to measure this form of deterioration in eggs. He also pointed out that the pH of an egg rises rapidly during the first few days because of the loss of carbon dioxide. The pH of the white influences the passage of water into the yolk and also the

liquefaction of the thick white or albumen. The lowering of the yolk index under most conditions is directly related to the passage of water into the yolk. The relation between pH and the amount of outer thin white is more complex showing a minimum in the zone 8.0 to 8.5. This minimum is due to the inter-relation of two factors--the effect of low pH values which tend to shrink the thick white gel around the yolk, apparently causing some extrusion of the inner thin white, and the effect of high pH which tends to disintegrate the thick albumen.

The latter condition was observed and termed "shrunken albumen" in the course of this experiment. Some eggs after about three months in storage appeared quite different from other eggs when broken out. In general the thick albumen tended to be more "milky", was smaller in area, and clung tightly to the yolk. It was also observed that some of these eggs had a large amount of outer thin white. It is unfortunate that pH determinations were not taken, for they might possibly have shed some light on the albumen deterioration occurring during the third and fourth months.

Evans (1943) encountered a somewhat similar condition in his experiments. He varied the time of oiling eggs after they were laid. Eggs oiled as gathered had a much greater increase in percent outer liquid albumen than unoiled eggs or eggs oiled the day after they were laid. In his case, the "watery" condition developed after only three months in storage at 32^oF. He concluded that eggs

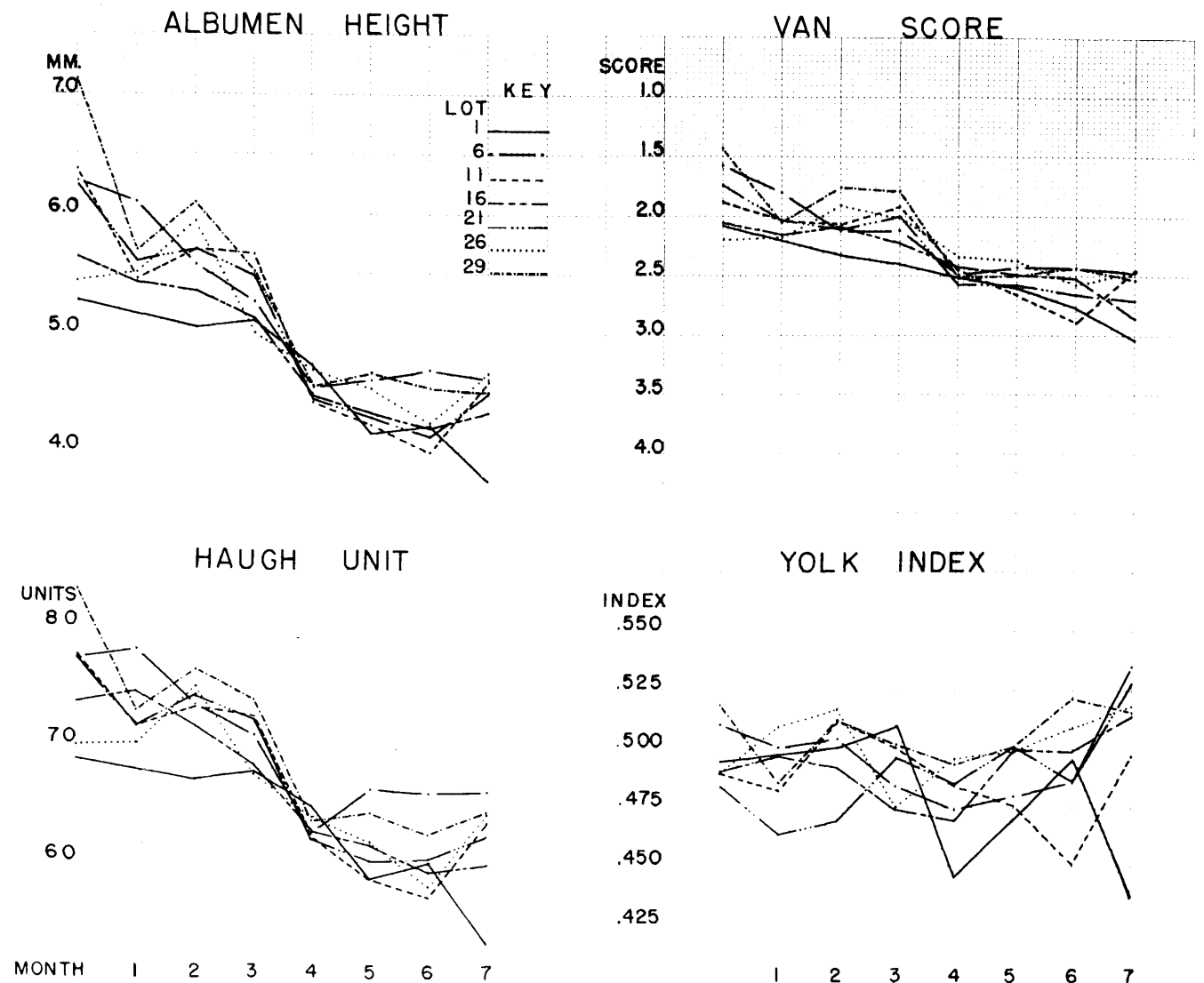


Fig. 1 EGG QUALITY INDICES FOR LOTS 1, 6, 11, 16, 21, 26, & 29

should preferably be oiled the day after they are laid.

Holst and Almquist (1931) pointed out that the water content of the fresh yolk is about 48 percent, while that of the fresh albumen normally is between 85 and 90 percent. This difference in concentration creates a tendency for water to pass into the yolk. The lowering of the yolk index was reported as probably directly associated with the passage of water into the yolk. Their experiments showed that the jelly-like structure of thick albumen begins to break down as the tendency of water to diffuse into the yolk becomes operative. The loss of quality in the yolk was accompanied by a corresponding loss of quality in the albumen. Their eggs were held at temperatures of 64°F. and 86°F.

Some investigators in Great Britain reported that the yolk index changed comparatively little as the result of storage at 0°C. for 6 or 41 weeks. In the carbon dioxide treatment, there was a slight increase in the index due to the variability of the thick albumen. Temperature rather than atmospheric conditions seemed to be the governing factor in modifying the yolk index. Fourteen days at 68°F. had a greater effect than six months at 32°F.

Denton and Titus (1944) conducted experiments with shell eggs held at a temperature of 29-31°F. for 12 weeks. When the egg shells were not treated, they found a linear relationship between the gain in water by the yolks and the pH of the whites. They found no consistent relation

between the pH of the yolks and the gain in weight by the yolks.

All of the above observations shed some light on the deterioration of yolks and the accompanying liquefaction of the thick albumen. No reference is made, however, as to the rate of deterioration over an extended storage period. The British investigations indicated that yolk index measurements should show relatively little change after eggs have been under storage conditions for several months.

The results in this experiment are not entirely in accord, for there were some changes in yolk index. In some instances the yolk index was higher for the last sample than for the first. This occurred in lots 6, 21, and 26 in the group under consideration in figure 1.

One of the outstanding differences among the lots in this group is the high average albumen height of lot 29 for the first two months. The average albumen height of the original sample of eggs is much higher than all of the other lots except the thermostabilized group. Lot 29 was oil treated at 200°F. for 5 seconds. There seems to be a partial stabilization of the albumen somewhat comparable to the thermostabilized group. It may be possible, therefore, to achieve results approaching thermostabilization by increasing the temperature and reducing the time of treatment. Although these results are based on a relatively small sample of eggs, there is a strong indication that

some sort of stabilization was accomplished. A duplicate experiment together with a series of time and temperature studies at the higher temperatures is desirable to substantiate the findings in this present trial.

Lot 29 is the only outstanding lot which differs materially from the other five lots in this group. Although the oil treatments vary from 80° to 180°F., there is no strong indication of superior quality which would favor a particular treatment. There is a considerable range in albumen height during the original stages although these differences become minimized after four months in storage. In any event, lot 1 seems to be the least desirable and lot 29 the most desirable in this group.

Lots 2, 7, 12, 17, 22 and 27 comprise the second group, figure 2, which has a common time element of 10 seconds and a temperature range from 80°F. to 180°F. The most obvious difference in comparing these lots is the great difference between the original albumen height averages of lots 2 and 12 and that of the others in this group. In the case of lot 2, the original sample contained 5 eggs which had albumen heights under 4 millimeters. This was sufficient to reduce the entire average considerably below what was to be expected. In lot 12 the conditions were similar, although the albumen height was somewhat higher for all eggs, even the poorest ones.

The group of eggs in figure 2 in general shows a more rapid decline than was observed in previous group in

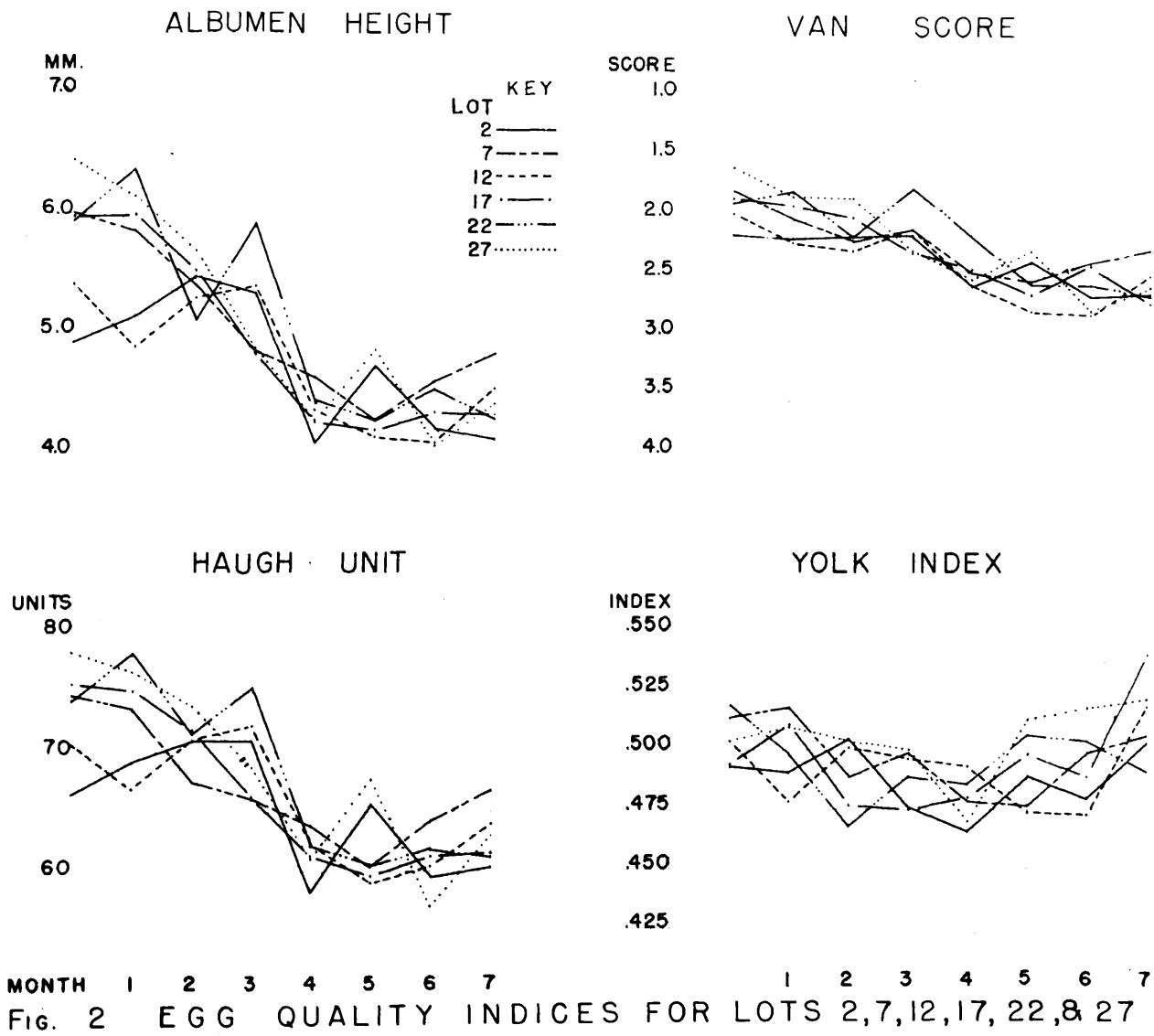


figure 1. After three months in storage, lots 7, 17 and 27 in figure 2 had albumen heights lower than 5.0 millimeters. In the previous group all of the lots had albumen heights over 5.0 millimeters at the same age. The most rapid decrease in albumen height occurred during the fourth month and also reached a point lower than the previous group. The difference in albumen height is not too great however.

Lot 27 is perhaps the outstanding lot in the group because of its high albumen height during the first few months. This lot also had a consistently high yolk index throughout most of the holding period. Since this lot was treated at 180°F. for 10 seconds, it seems probable that some slight amount of stabilization was manifested. It appears, however, that the stabilizing effect is not complete, for in both lots 29 and 27 the albumen height was about at the same level as in the lots of eggs with differing treatments after three months in storage. Apparently the stabilization was not as complete as in the thermostabilized lot, figure 6. The stabilizing effect in this lot seems apparent even after seven months in storage. The average albumen height of the thermostabilized lot at this age was 6.0 millimeters. This is equal to or better than the average albumen height for the first sample of many of the lots in the experiment. This of course raises the question as to whether complete stabilization of albumen could occur at high temperatures with short

periods of treatment.

Barrott and McNally (1943) conducted investigations on the heat treating of shell eggs at temperatures ranging from 124.5°F. to 144°F. They developed photographic standards (of actual eggs) to measure the opacity caused by heat treating the eggs. Numbers 1 and 2 of their standards were considered excellent examples of albumen stabilization. A time-temperature curve was also developed to show the range in treatments which are possible to arrive at standard opacity. Their treatments were conducted in a water bath. It was pointed out that albumen coagulation is the limiting factor in the use of heat treatments. The high temperatures and short periods of treatment used in this experiment did not coagulate albumen but did produce varying amounts of opacity. The results obtained for lots 27 and 29 indicate that perhaps further investigation is necessary with an oil bath at the higher temperature levels.

The yolk index of lot 27 was higher in general than for the other lots in this group. However, in many of the lots there was a tendency for the yolk index to decrease until the fourth month and then increase to a point sometimes even higher than at the original breaking. In four of the six lots, the final yolk index was higher than the index taken at the beginning of the experiment. In view of the previous discussion on the relationship between the deterioration of the albumen and the yolk, it

would seem logical to expect poorer yolk indices in the oldest eggs with poor albumen indices. One would not expect, therefore, to find yolk indices higher after a seven-month storage period. Since no record of this nature has been reported in the literature, it becomes necessary to develop some explanation for this phenomenon.

Since one normally expects the yolk to flatten with age, it is apparent that there may be one or several factors that tend to maintain and even increase the height of the yolk. Funk (1943) reported that the yolk may be stabilized so that the vitelline membrane retains its strength longer than usual. This was definitely true when eggs were rotated in warm oil at 140°F. for 15 minutes. This indicated that if the yolk is subjected to relatively high temperatures for a short time, the vitelline membrane is stabilized against subsequent deterioration, at least the rate at which this membrane weakens is retarded. It was also reported that eggs treated soon after laying possessed stronger vitelline membranes than those several days old when treated.

There is perhaps some degree of agreement between our results and those of Funk although none of Funk's eggs in the above experiment were held under storage conditions. Assuming that the vitelline membrane is strengthened, there was nevertheless a general decrease in yolk index until the fourth month. This point coincides with the rapid drop in albumen height which occurs at this time.

This is in agreement with previous work, Sharp (1929) Holst and Almquist (1932) Bose and Stewart (1948), on the deterioration of eggs. However, some explanation is necessary for the improvement in yolk index which occurs from the fourth to the seventh month.

Perhaps as the egg reaches a certain age, the movement of liquid albumen is reversed because of pH changes and passes from the yolk outward. This would involve the assumption that as the fluid passed into the albumen the vitelline membrane would tend to approach its original condition. Holst and Almquist (1932) reported that the various changes in egg yolks are attributable to osmotic forces operating so as to cause a passage of water from the albumen to the yolk. Their differences in concentration of water creates a tendency for water to pass into and dilute the yolk. The water which thus diffuses into the yolk produces two effects, both of which are undesirable. To make room for incoming water, the yolk membrane is compelled to stretch and is thereby weakened. Perhaps the more serious effect is the increase in fluidity of the yolk substance.

The experiments of Holst and Almquist showed that where thick white liquefaction did not occur, the osmotic processes by which water enters the yolk are inhibited, as shown by the fact that the average yolk weight of their eggs did not increase. While the fact that the yolk has a higher osmotic pressure than does the white accounts for

the passage of water from the albumen to the yolk, the pH of the white markedly influences the rate of this passage, because, of course, the pH of liquids bathing a membrane (in this case the vitelline membrane) markedly influences the rate of passage of the solvent under osmotic gradient.

It might be possible therefore, that in our case, a high pH was not attained until the fourth month, which caused liquefaction of the albumen and the sharp decline in score. The decline in yolk index at this time, since it is relatively small, might have been due to yolk deterioration. However, as the albumen liquefied, the pH of the liquid albumen and membrane might have favored the entrance of water into the yolk. This could possibly have caused the contents of the yolk membrane to become turgid and increased its height while decreasing its width, thus increasing the yolk index in the later stages of storage. This assumes, of course, that the yolk membrane is not weakened at storage temperatures to the same extent that it is at high temperatures.

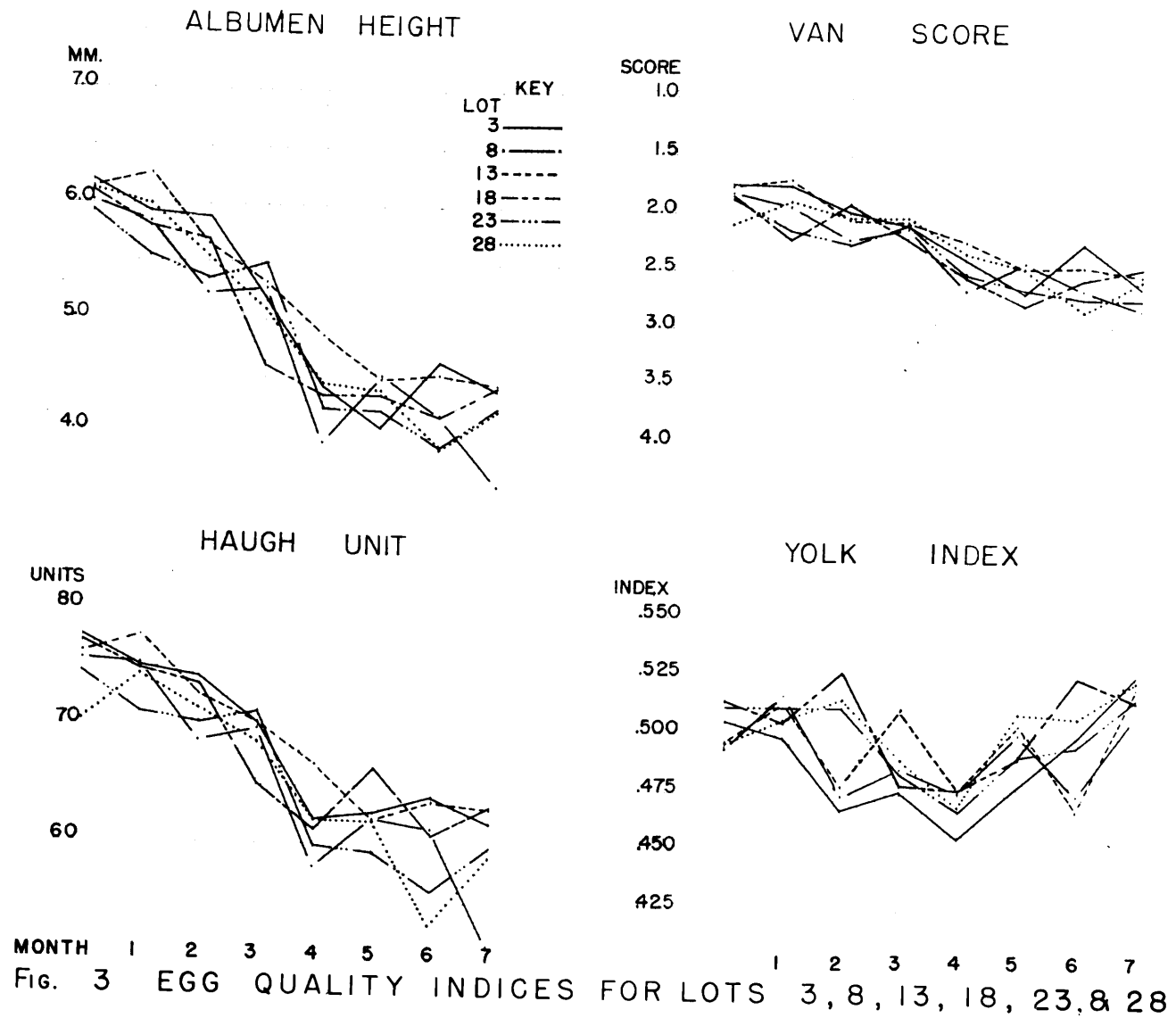
There is also the possibility that the pH condition, which is conducive to the shrinkage of the thick albumen, may also affect the yolk, causing it to shrink and thus favoring a higher yolk index.

Then again, it may be that water diffuses into the yolk until the fourth month and then because of increased liquefaction and changes in pH, the direction of water diffusion is reversed. The increase in water tends to

flatten the yolk while water loss at later stages would allow the yolk to assume its original measurements.

In view of the complexity of the problem and the lack of research with eggs held over four months under storage conditions, it is only possible to theorize as to the cause for the increase in yolk index during the later stages of storage. This experiment was not designed to provide an explanation for this particular phenomenon; however, its occurrence is of great interest, since to the writer's knowledge it has not previously been reported in the literature. In most of the experiments designed to study deterioration, the eggs were generally held at high temperatures, thus hastening deterioration. Consequently, the eggs in many of the experiments by other workers were much poorer than eggs in my experiment even at 7 months of age. It is possible, therefore, to compare the results of the earlier experiments with the results secured in this present work. Stewart and Bose (1948) mentioned the fact that much of the data in past experiments were based on candling measurements, which at best only roughly estimate the interior quality of shell eggs.

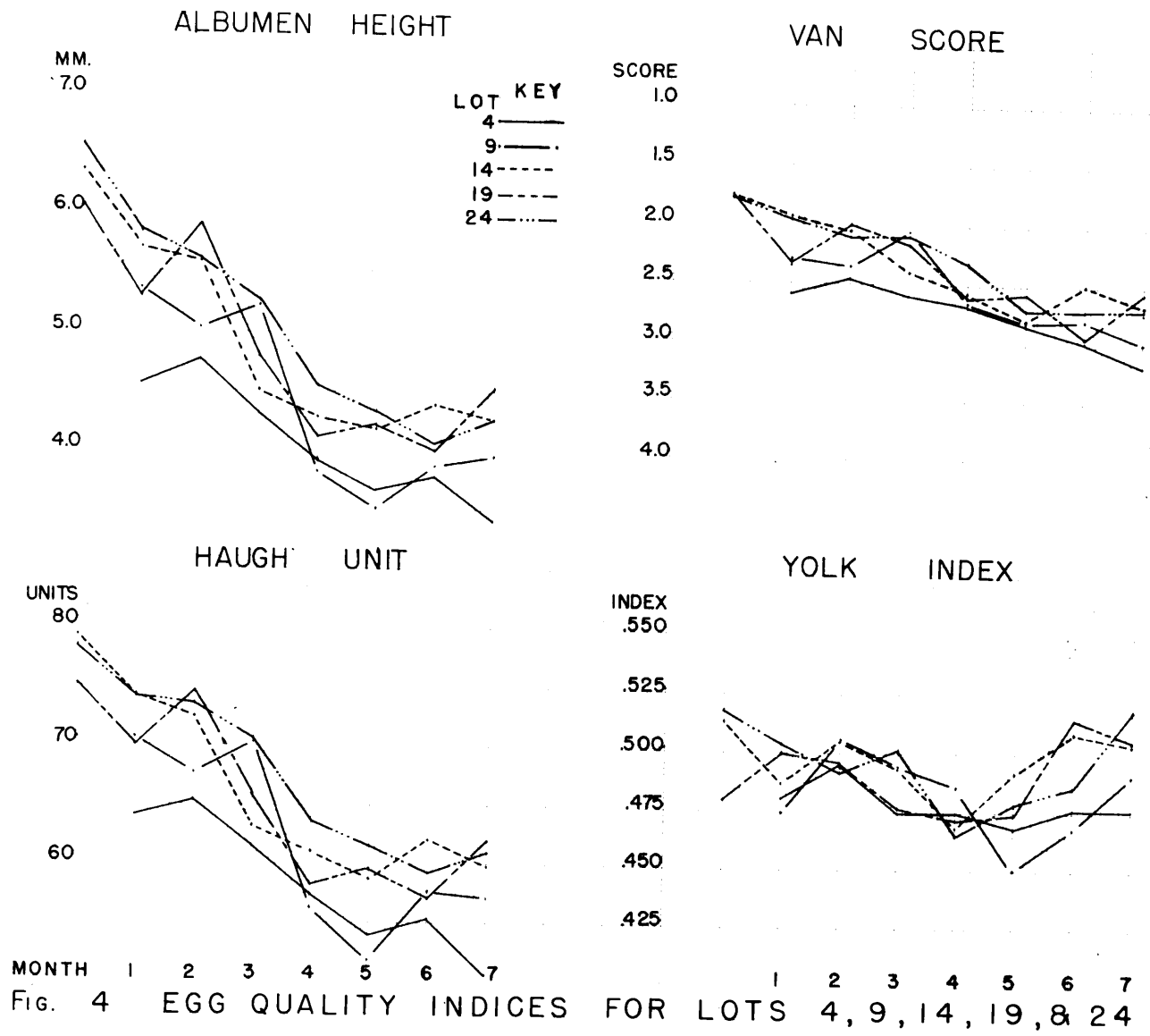
Figure 3 presents the quality indices for lots 3, 8, 13, 18, 23, and 28. These lots all had a common time of treatment, 20 seconds, and the temperature varied from 80°F. to 160°F. Although the temperature of lot 23 is twice that of lot 3, the indices for these two lots, and the other lots as well, are quite comparable. In view of



the relatively close agreement among the different lots, it appears that these various treatments do not have any outstanding influence on egg quality.

Figure 4 presents the quality indices for lots 4, 9, 14, 19 and 24. All of these lots had a common time of treatment, 40 seconds. The temperature varied from 80°F. in lot 4 to 140°F. in lot 24. In the latter case, there is some indication that this treatment is quite desirable and has some influence in retarding deterioration. It can be observed that the albumen height, Haugh Unit, and Van Score for lot 24 are in general better than for the other lots in this group. It is felt that perhaps the influence of the heat treatment commenced to effect the albumen in a favorable direction. However, the influence of heat appeared to have a detrimental effect on the yolk, particularly up to the fourth month.

The differences between lot 24 and the others in this group are not of great magnitude. It is felt, however, that the consistently higher quality indices over a seven-month period indicate a desirable influence of this treatment. A comparison of lot 24 with lots 13 and 25 reveals a considerable degree of resemblance. These three lots were treated at 140°F., 120°F., and 120°F. respectively. The time periods for the above lots in the order named were: 40 seconds, 20 seconds, and 80 seconds. It appears that this range of time and temperature treatments are more favorable to the maintenance of egg quality than



other treatments within the respective groups.

Lot 4 figure 4 was the poorest for the group, followed by lot 7. The general pattern of deterioration in this group is similar to other groups. There is, however, a low point for yolk index at the fourth month which is different from the other groups. There are four lots in this group which have yolk indices below .475 at this age. This is the largest number of lots which fall below this index at the fourth month when compared with the groups previously considered. With the exception of one of these 4 lots, the treatment was 110°F. or higher for 40 seconds. This is an indication that these heat treatments at the longer time periods have a deleterious effect on the yolk index up to the fourth month. According to previous investigators, one would expect to find the poorest yolk indices in eggs with the poorest albumen. This certainly is not true of these lots up to the fourth month in storage.

Figure 5 presents the egg quality indices for lots 5, 10, 15, 20, 25 and 30. These lots all had a common time of treatment, 80 seconds, and the temperature varied from 80°F. to 140°F. It appears that the lowest (80°F.) and the highest (140°F.) temperature treatments, for lots 5 and 30, respectively, produced the least favorable results in this group. Lot 25 (120°F. for 80 seconds) had the best egg quality indices for the group. However, the quality indices for lots 10 and 20 are quite favorable. In view of the several lots which show favorable results

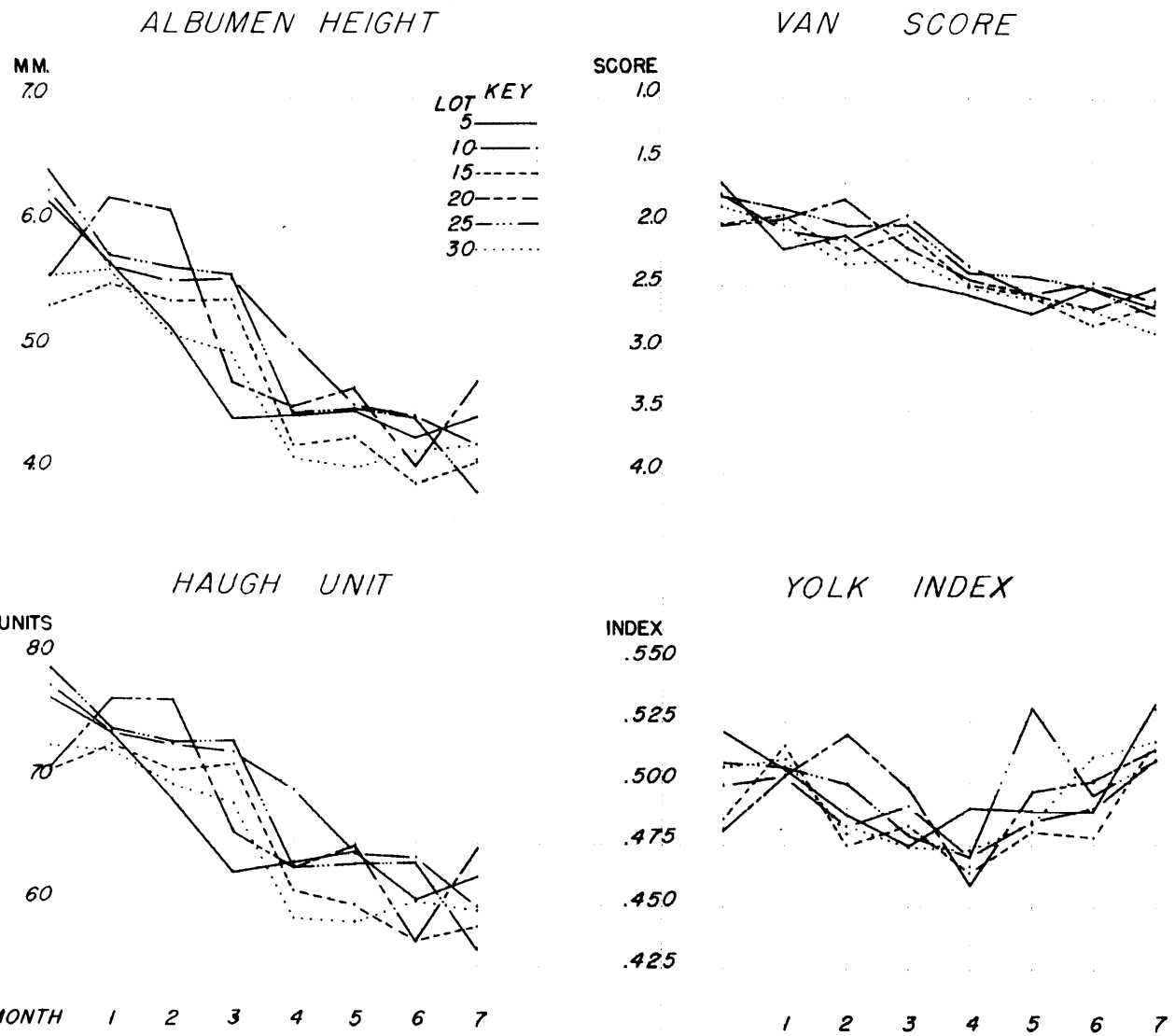


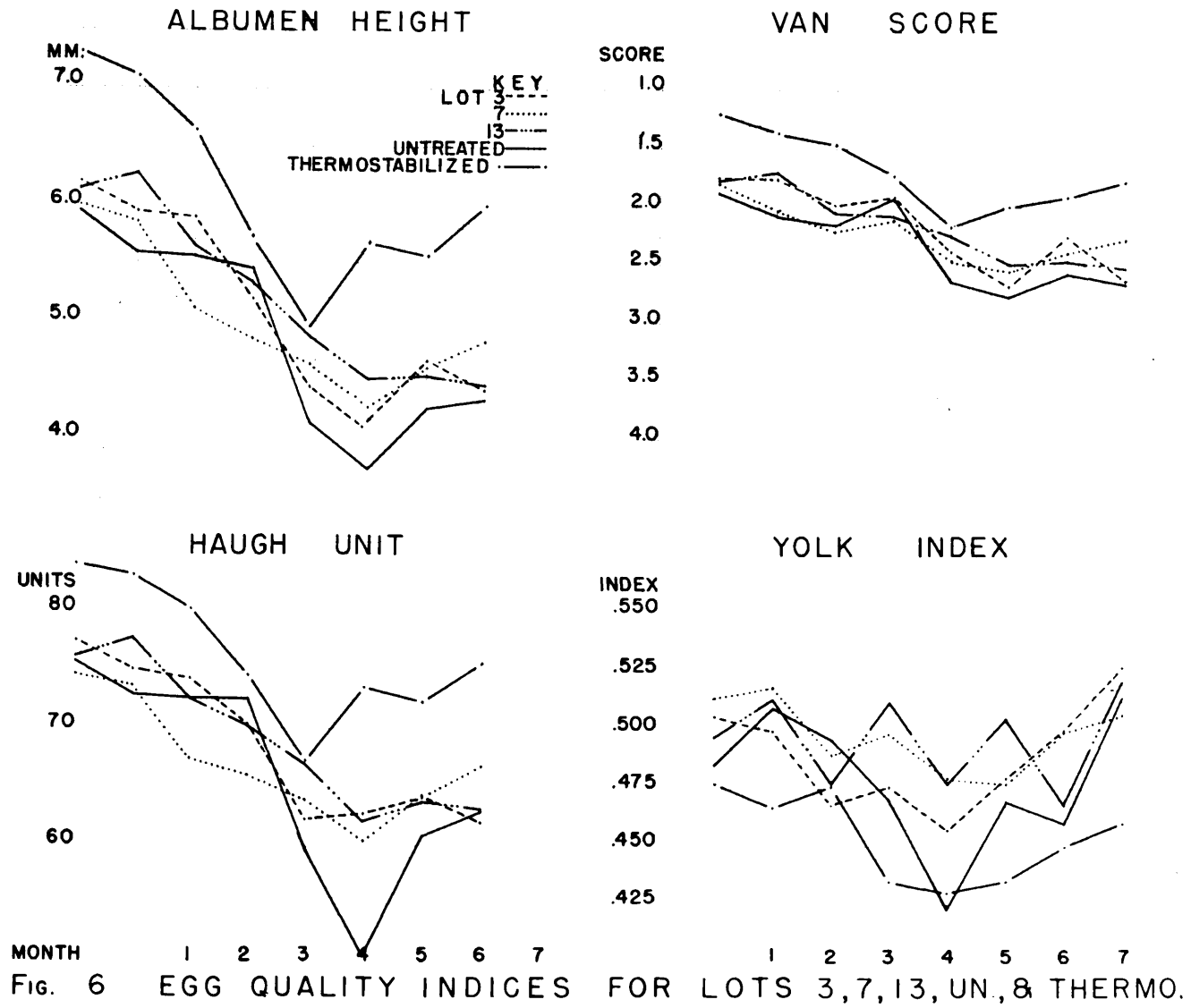
Fig. 5 EGG QUALITY INDICES FOR LOTS 5, 10, 15, 20, 25, & 30

it appears that the 80-second period of treatment is desirable within the temperature range from 90°F. to 120°F. The 80-second treatment did not prove as desirable when the temperature was 140°F. Favorable results were obtained at the latter temperature (lot 24) when the period of treatment was limited to 40 seconds. This would indicate that favorable oil treatment results can be obtained by controlling temperatures between 90°F. and 140°F., provided the time of treatment is also controlled. It is possible that oil treatment at lower temperature levels would be favorable, provided the time of treatment was increased. However, this would tend to reduce the practical application of the oil treating process.

In order to determine the results which might be expected when recommendations of processors are followed, some of the more common treatments are compared in figure 6. In addition to these treatments the thermostabilized and untreated lots are also included for comparisons. The following lots and treatments are presented:

Lot	Temperature	Time
3	80°F.	20 seconds
7	100°F.	10 seconds
13	120°F.	20 seconds
Thermostabilized	140°F.	15 minutes
Untreated	-	-

Lots 3, 7, and 13 are treatment used in present-day processing or oil treating of shell eggs. Under the conditions



of this experiment, it appears that lot 13 treated at 120°F. had the most desirable effect on the eggs. However, the differences in albumen height among lots 3, 7, and 13 are relatively small and it is doubtful whether these differences could be detected by candling. Since candling is the most practical method of determining egg quality, it is entirely possible that all three lots would candle favorably. All lots were candled before breaking; however, because of the temperature and the "sweaty" condition of the eggs, the results were used only for purposes of comparison. The greatest differences in candled appearance among these groups occurred in the untreated and thermo-stabilized lots. There were outstanding differences in these two lots in comparison with all of the other lots in the experiment.

First of all, the untreated lot had a decidedly poorer candled appearance as early as the fourth month in storage. At this age practically all eggs in this lot had air cells approximating 1/4 inch in depth. Other candling factors, such as mobility and position of yolk, were favorable, although many eggs were down graded because of the large air cell. From a practical standpoint this would prove most undesirable in getting good yields of quality eggs from storage eggs even when held for only four months. There is no question but that the oil treating of eggs retards the increase of air cell size measurably and thereby improves the candled grade.

Funk (1943) reported that oil treated eggs had smaller and less mobile air cells than untreated and water-heated eggs. In addition to the poorer candled grade, the untreated eggs in this experiment developed a few "stuck yolks" at the seventh month. There was also a very definite lack of "cloudiness" in this lot as compared with treated lots.

The thermostabilized eggs were the most unusual eggs observed throughout this experiment and during the many years that this worker has handled eggs. The highly superior albumen condition and height was quite evident, without the aid of measuring devices. This superior condition existed throughout the course of the experiment. The stabilization influence of the heat treatment not only improved the albumen condition but apparently was also responsible for improving its keeping qualities. This is in agreement with Funk (1934) and Bose and Stewart (1948), who found that heat treating increased the albumen quality and improved the keeping quality of shell eggs. These investigators held their eggs at room temperatures and also under desert conditions in one case in conjunction with U. S. Army trials. Even under such adverse conditions the heat-treated eggs were much superior to other lots of eggs handled under the same conditions. It is evident from the above that heat treated eggs will withstand warm temperatures. Funk (1944) also reported that heat-treated eggs placed in storage at 30°F. for 60 days deteriorated more

slowly than untreated eggs under the same conditions. At the termination of 60 days storage period the treated and untreated eggs were held at 70°F. for 30 days. Sample lots were broken periodically to ascertain the rate of deterioration. At the close of the experiment the treated eggs were of A quality while the untreated eggs were equivalent to poor grade B eggs. This serves to show the remarkable resistance to deterioration of heat-treated eggs both in and out of storage, thus simulating normal conditions of handling eggs.

Our work, figure 6, shows quite clearly that the thermostabilized eggs keep well under storage conditions. Actually, the results indicate that the thermostabilized eggs maintained an albumen height above 4.6 millimeters throughout the storage experiment. The Van Score reached its highest point during the fourth month when the average score for the lot was 2.17. This is only slightly above the 2.0 score, which is the dividing line between top grade (AA) eggs and second grade (A) eggs. It is almost unbelievable that the albumen condition could be preserved so well over such a long storage period.

In this experiment, the candled appearance of thermostabilized eggs is much different from other lots of eggs. This is in agreement with Funk (1944) who reported the following: "Because the contents of some of the thermostabilized eggs do not rotate freely, experienced candlers may be misled into believing that such eggs are "stuck".

Candlers should become familiar with thermostabilized eggs before attempting to judge them." In candling the eggs in this experiment, the yolk had little or no mobility and was generally well centered. This resulted in little or no yolk shadow and very little movement when the egg was twirled. Fourteen eggs out of the last sample (7 months old) were candled as AA grade. Thirteen of the eggs in this same sample also had Van Scores of 2.0 or above. It is very unusual to find eggs of such quality after being held in storage for seven months.

The writer encountered some difficulty in removing the egg contents from the shell when opening them onto a flat plate glass surface. There was a strong tendency for the albumen to adhere to the shell. After the contents were deposited on the glass, it was noted that some of the outer jelly-like thin clung to the halves of the shell. The egg contents deposited on the glass showed little or no evidence of outer thin white. It appeared as though the outer thin had become gelatinous and adhered to the shell.

The thermostabilized eggs not only had the best albumen score and condition but also had the poorest yolk indices of all of the lots in this experiment. This is not in agreement with Bose and Stewart (1948), who reported an improvement in yolk indices. Funk (1943) reported an increase in the rupturing strength of the vitelline membrane but did not record yolk index measurements. Not only is the deterioration in yolk index not in agreement with

these workers, but a satisfactory explanation for its occurrence is not available from the literature. One would expect that the albumen and the yolk would deteriorate progressively from the beginning to the end of the storage period. This is not the case, however, for there is an apparent recovery in both the albumen height and yolk index after the fourth month.

Since there is little or no outer thin in these eggs, it may be that the inner thin is responsible for the changes observed. It may be that as the egg ages there is a tendency for water to diffuse into the yolk, thus causing it to flatten. A flatter yolk and the loss of liquids might be the cause of the lowering of the height of thick albumen. At the fourth month this process may be reversed, thus allowing the yolk and thick albumen to become higher. This would assume that the vitelline membrane retains sufficient elasticity to approximate its original form as it loses moisture. It also assumes a change in pH and osmotic conditions which would favor this interchange of water. Needless to say, the quality measurements available are not sufficient to provide the real answer. Yolk weight determinations and pH readings might have shed more light on this matter had they been taken.

It is plainly evident after considering all of the various oil treatments that oiling in itself improves the keeping quality of treated eggs over untreated eggs. It is equally obvious that a certain number of treatments are

somewhat comparable with respect to results secured. However, the outstanding results obtained with thermo-stabilized eggs indicate that this method of treatment, in conjunction with oiling offers much greater possibilities than other methods of treatment. It is evident that eggs can be oiled and heat treated at the same time, thus increasing the possibility of practical application in processing eggs to preserve quality.

DISCUSSION

The data presented in this thesis show conclusively that thick albumen may be stabilized when eggs one day old are heated in mineral oil at 140°F. for 15 minutes. This is in agreement with Funk (1943) and Bose and Stewart (1948), who also observed the stabilizing influence of heat treatment, using water. The albumen height, Van score, and Haugh unit indices were all improved by the thermostabilization treatment. There is, however, some disagreement with regard to the improvement of the yolk index by the heat treatment. Funk (1943) reported that the vitelline membrane is strengthened by such treatment. He also showed that the yolk index deterioration occurred more slowly at 50°F. and 70°F. than at higher storage temperatures, although the eggs were held for only 63 days.

Rose and Stewart (1948) reported that the keeping quality of the yolk was greatly improved by the heat treatment when the eggs were held at 68°F. for 14 days. Unfortunately, their temperatures and storage periods were quite different from those in this experiment, consequently the results are not directly comparable. It was noted that in much of the research on egg quality deterioration, storage conditions are simulated by holding eggs at high temperatures. There is some question therefore, as to whether this practice approximates the deterioration which would occur under the usual normal storage conditions.

The findings in this experiment indicate that the yolk index is adversely affected when eggs are heat treated in oil at 140°F. for 15 minutes. Actually, the yolk index of the thermostabilized eggs was consistently lower than most of the other oil-treated eggs throughout the entire storage period. In this case the eggs were held at about 30°F. for 7 months. It appears that the deterioration of the heat-treated yolks at cooler temperatures is radically different from the deterioration which occurs at higher storage temperatures. Practically no research data are available on yolk deterioration, as measured by yolk index, for eggs held under normal storage conditions beyond four months. For this reason, it is not possible to compare our findings with those of others beyond the first four months of the storage period.

Previous mention has been made of the theories which exist with regard to the deterioration of the yolk as measured by yolk index. Most workers agree that the deterioration of the yolk is affected adversely by high temperatures and the high pH concentration of the albumen surrounding the vitelline membrane. Theoretically, as the egg ages, water diffuses into the yolk, thus weakening the membrane and lowering the yolk index. Assuming the above to be true, this condition may have existed up to about the fourth month in storage but at this point the yolk index began to increase in several lots of oil treated eggs. In 24 of the 32 lots of eggs, the final

yolk index for eggs 7 months old was higher than the initial yolk index taken the day after the eggs were treated. Even the untreated eggs had a higher yolk index at the seventh month than at the initial date of breaking. It seems therefore, that neither the heat treatment nor the oiling was responsible for these results. This phenomenon requires some explanation, which to the writer's knowledge has not as yet been reported in the literature. Recent discussions with other workers also conducting oiling and storage experiments lead to the suggestion that there is a strong possibility that the yolk index actually increases. No definite data are as yet available, however, to verify this suggestion.

It is possible that the progressive deterioration in yolk index until the fourth month occurs at a greatly reduced rate from that observed in eggs held at high temperatures. However, the rapid deterioration of the albumen during the fourth month and the resultant pH may favor the transfer of water from the yolk to the albumen, thus allowing the yolk to assume its original proportions. This would involve the assumption that the vitelline membrane is fairly elastic and is capable of assuming its original shape when moisture escapes. This assumption would differ from the commonly accepted theory that the yolk membrane weakens as water enters the yolk. It would also differ with the current belief that the loss of quality in the albumen is accompanied by a corresponding loss of quality

in the yolk.

Another explanation which seems logical, in view of the technique used in determining yolk index, is that the thick albumen provided a means of support for the yolk membrane. The height and width of the yolk were taken while the broken-out egg rested on a flat glass surface. It is possible that as the albumen deteriorated, there was less support to the yolk, which tended to flatten out, thus lowering the yolk index. This hypothesis is possible since the deterioration of the albumen occurred simultaneously with the decrease in yolk index until the fourth month in storage. At this point the albumen had presumably liquefied considerably and it is also likely that the pH had increased to a point which favors the diffusion of water into the yolk. This is in accord with the findings of Denton and Titus (1944), who found a linear relationship between the gain in water of the yolks and the pH of the whites in untreated eggs. In treated eggs they found that the escape of CO_2 from the egg was retarded and this in turn was reflected in smaller gains in water in the yolk. This would account for the relatively small decreases in yolk index throughout the experiment. Our work does not have comparable data to permit direct comparisons although our results are compared with published findings in an effort to explain some of the changes which took place.

This thesis was designed primarily to determine the optimum time and temperature for mineral oil treatments of shell eggs. The effects of various treatments were measured by egg-quality indices which are commonly used by other investigators. It was determined that shell eggs can be treated in mineral oil at various temperatures and for differing periods of time and achieve quite comparable results. A comparison of the 31 lots which were oil treated indicates that the following treatments are most desirable:

Lot	Temperature	Time
3	80°F.	20 seconds
6	100°F.	5 seconds
10	90°F.	80 seconds
13	120°F.	20 seconds
14	110°F.	40 seconds
15	100°F.	80 seconds
20	110°F.	80 seconds
22	160°F.	10 seconds
24	140°F.	40 seconds
25	120°F.	80 seconds
27	180°F.	10 seconds
29	200°F.	5 seconds
Thermostabilized	140°F.	15 minutes

These 13 treatments seemed to have the most desirable results among all of the lots.

A comparison of these treatments with the temperatures commonly used today by processors shows that 66 percent of the 12 oil-treated lots were within the 80°F. to 120°F. range. The period of treatment varied from 5 seconds to 80 seconds, which is perhaps longer than the present dipping time with modern machinery. One-third of the lots were treated for 80 seconds and the remaining lots were divided equally among the 5, 10, 20, and 40 seconds time

periods. The thermostabilized lot is not compared with the present day practice because it is not used to any great extent by the trade.

The 12 oil-treated lots yielded quite comparable results although there are some differences which should be discussed. For example, lot 29 had a particularly high initial albumen height, which is much higher than the other lots. It is felt that this may have been the result of a partial stabilization of the albumen. The effect, however, seems to be of short duration. This brings up the question as to the possibility of more complete stabilization at high temperatures for short time periods. It should also be pointed out that lot 29 had the highest yolk index in its group, figure 1. It appears that the oil treatment at 200°F. for 5 seconds had a beneficial effect on both the albumen and the yolk. This is contrary to the thermostabilized lot, figure 6, in which the treatment improved the albumen condition remarkably although at the same time it also had a very undesirable effect on the yolk index. It seems that up to a certain point the heat treatment may be beneficial to the yolk index but beyond that point the effect is reversed and the yolk deteriorates or is weakened.

Lot 27 is quite comparable, in some respects, to lot 29 in albumen condition and yolk index. It is believed that the albumen condition and the yolk index were affected in somewhat the same manner, but to a lesser

degree, by the oil treatment at 180°F. for 5 seconds.

The results in this experiment indicate quite clearly the complexity of the problem of oil treating eggs with particular regard to the deterioration which occurs within the egg. The various oil and heat treatments shed some light on the problem although they also call attention to some findings for which no answers are provided under the present theories of quality deterioration. One such finding is the rapid drop in albumen condition occurring between the third and fourth month of storage for all lots. No reference to this rapid quality loss is mentioned in the literature. It may well be that it occurs only in fresh eggs of a certain age. In this experiment, there is definite evidence that it does occur in eggs which are placed in storage at 30°F. when approximately 24 hours old. This point is exceedingly important from a practical and economic standpoint because the loss in albumen is reflected in poorer candling grades.

In many of the oil-treated lots, the greatest decline in albumen quality occurred during the fourth month of the storage period. Many eggs are "short held"; that is, they are kept in storage for 90 days or less, and it certainly is to the advantage of the storer to remove eggs from storage before the rapid decline in albumen condition is possible. Most of the lots of eggs have albumen heights over 5 millimeters at the end of the third month in storage. At the end of the fourth month in many of

these lots the albumen height dropped to about 4.5 millimeters. Since the dividing line in broken-out eggs between AA grade and A grade is at an albumen height of 5 millimeters, it is advantageous to dispose of eggs before they decrease in quality. It is recognized that these fine distinctions could not be determined accurately by candling, nevertheless eggs treated under similar conditions could be expected to have comparable quality indices. Therefore, if the processor and storer exercised due care, it is reasonable to expect that their shell eggs in storage would ultimately approximate the results secured in this experiment. One of the most serious drawbacks is the procurement problem, whereby it is difficult to have eggs at the receiving station before they are one-day old. It seems quite likely that eggs somewhat older could be oil treated, possibly thermostabilized to some degree, and thus retain better quality before being placed in normal market channels. It is fairly well established that oil-treated and thermostabilized eggs will retain their quality better than untreated eggs under similar conditions. Additional experiments within the high temperature ranges are necessary before a specific treatment can be recommended.

CONCLUSIONS

1. There is a wide range of time and temperature treatments with mineral oil which have favorable results on day-old eggs when held under storage conditions at 30°F.

2. The most favorable treatments under the conditions of this experiment were as follows:

Lot	Temperature	Time
3	80°F.	20 seconds
6	100°F.	5 seconds
10	90°F.	80 seconds
13	120°F.	20 seconds
14	110°F.	40 seconds
15	100°F.	80 seconds
20	110°F.	80 seconds
22	160°F.	10 seconds
24	140°F.	40 seconds
25	120°F.	80 seconds
27	180°F.	10 seconds
29	200°F.	5 seconds
Thermostabilized	140°F.	15 minutes

3. Oil treating reduces the amount of water loss from the egg as measured by air cell size. This resulted in improved candled grades for treated eggs.

4. The treated and untreated eggs all experienced the greatest loss in quality, as measured by albumen height, Van score, Haugh Unit and yolk index, during the fourth month in storage.

5. Treated and untreated eggs also reached their lowest yolk indices at the fourth month and then increased, sometimes to a point above the original reading.

6. Oil treating day-old eggs at 180°F. and 200°F.

had an apparent partial stabilization influence on the albumen condition during the first two months of the storage period.

7. Oil treating day-old eggs at 180°F. and 200°F. also had a beneficial effect on yolk index measurements throughout the seven-month storage period.

8. Untreated eggs had quality indices quite comparable to many treated eggs up to the third month of the storage period.

9. The thermostabilization treatment improved the albumen condition of day-old eggs and this superior albumen condition was maintained throughout the entire seven-month storage period.

10. The thermostabilization treatment had an undesirable effect upon the yolk which was reflected by poor yolk indices throughout the entire storage period.

11. The candled appearance of thermostabilized eggs was altered materially by the treatment and thus special consideration of this change is necessary in arriving at candled grades.

12. Thin and porous looking egg shells in the treated and untreated lots frequently had enlarged air cells, thereby lowering the candled appearance.

13. The deterioration of the yolk of treated day-old eggs under storage conditions is apparently radically different from that of yolks in eggs held at room temperatures.

14. There is evidence that heat treatment may be both beneficial and harmful to yolk deterioration, depending upon the intensity of heat and the length of treatment.

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