August 1, 1949

To the Committee on Graduate Study:

I am submitting to you a thesis written by Robert Jackson Park entitled "Quality of Tennessee Produced Eggs." I recommend that it be accepted for twelve quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Poultry.

O. E. Goff
Major Professor

We have read this thesis
and recommend its acceptance:

B. J. McSpadden

O. E. Goff

Accepted for the Committee

C. A. Waters
Dean of the Graduate School

QUALITY OF TENNESSEE-PRODUCED EGGS

A THESIS

Submitted to
The Committee on Graduate Study
of
The University of Tennessee
in
Partial Fulfillment of the Requirements
for the degree of
Master of Science
in
The Department of Poultry

by

Robert Jackson Park

August 1949

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ABSTRACT

A study of 2850 eggs produced by Barred Plymouth Rocks, New Hampshires, and S. C. White Leghorns during the spring months was made.

In examining the eggs for size, shape, exterior quality, interior quality, shell texture, shell color, and shell breaking strength it was found that egg quality was a characteristic of the individual; this was observed in all the breeds. Shell color was a breed characteristic and tended to be less variable in the white shell producing breed than in the brown shell producing breeds.

A portion of these eggs was treated in oil (room temperature), oil (140 degrees F., 10 min.), oil (212 degrees F., 5 sec.), water (140 degrees F., 10 min.) and water (212 degrees F., 5 sec.) then stored in a cooler (40 to 45 degrees F.), cellar (65 to 70 degrees F.), non-insulated room (68 to 94 degrees F.) and a forced draft incubator (99 to 100 degrees F.). It was found that the shell eggs which had been treated in oil tended to retain their original quality better than did the water treated eggs.

Chemicals (Soilax, Trend, and Vel) were used in washing soiled eggs. Soilax tended to remove the foreign materials and stains better than did Trend or Vel.

TABLE OF CONTENTS

LIST OF TABLES

(continued)

LIST OF FIGURES

INTRODUCTION

The consumers demand has changed from the time during the war when the quality of a product was passively considered to a time when products of higher quality are receiving more consideration. The demand for a food of higher quality is especially true when eggs are considered. It is recognized that egg quality is at its best when laid. Every effort should be made to conserve this quality while eggs are in the channel of trade. Poultrymen wishing to realize the maximum returns from their enterprise must produce eggs of a quality that conforms to the consumers demand.

An increase in population during the past ten years (1939 to 1949) has been accompanied with an increase in food production and consumption. The daily egg production in the United States (1947) was about 146,000,000 eggs, or approximately one egg per person per day.

The source and volume of the egg supply should be considered before attempting a study of the quality of Tennessee produced eggs. Eggs are produced on over five million farms throughout the United States. The surplus eggs from these farms are sufficient to supply the needs of an urban population of 90 million people. Specialized poultry farms for the production of eggs are few in number as compared with general farm flocks. According to the 1945 Agricultural Census, about 57.6 percent of the farms reporting egg production maintained flocks of less than 50. These flocks produced only 18 percent of the total egg yield. Approximately 21.6 percent of the farms kept flocks numbering from 50 to 99 hens and produced 19 percent of the total egg yield; about 14.7 percent had flocks ranging from 100 to 199 and produced approximately 26 percent of the total egg yield; some 4.8 percent had flocks ranging from 200 to 399 and produced 18 percent of the eggs; less than one percent of the farms had flocks ranging from 400 to 799 but produced 8 percent of the annual egg yield. Approximately one-third of one percent of the farms had flocks of over 800 hens or more, but produced nearly 11 percent of the eggs.

The distribution of the eggs produced in the United States is as follows: 60% reaches the consumer through the regular wholesale-retail channel, 15% is sold direct to the consumer, about 5% is used by hatcheries, while the remaining 20% is consumed at home.

The annual per capita egg production in Tennessee (1948) was 16 dozen. This was about one half the average per capita production for the entire United States. Because of the small flocks, poor handling facilities, and irregular markets, the quality of the Tennessee egg is often considered to be inferior by the time it reaches the produce merchant. If Tennessee produced eggs are to compete in the markets with eggs produced in other sections of the United States, producers must set up a program on a quality basis whereby they can produce and market eggs of a higher quality.

Quality is becoming the deciding factor when housewives are purchasing food. At present, producers in many sections are not producing and marketing the quality egg the consumer wants. A program to maintain quality of the egg from the farm to the consumer should include several factors. These factors may be divided into (1) breeding,

(2) pathological, (3) physiological, (4) feeding, (5) environment, (6) management, and (7) marketing.

These studies were undertaken to determine the quality of Tennessee produced eggs and their keeping quality under a variety of treatments and storage conditions.

REVIEW OF LITERATURE

It is the opinion of poultry breeders that the quality of certain eggs produced can be improved by selection and breeding. Poultry breeders in general are in agreement that a hen possesses certain genetic characteristics which contribute to the quality of the egg she produces. There is controversy in the field of breeding as to just how these characteristics are transmitted from parent to offspring.

Atwood and Weakley (1917) observed variations in the weight of eggs laid by individual hens. Benjamin (1920) stated that both sire and dam have an equal effect on the type of egg an offspring will produce. He also stated that large egg size was dominant over small egg size. Jull (1947) stated that Hurst and Kopec obtained results indicating small egg size was dominant over large egg size. Waters and Weldin (1929) concluded that egg size is neither sex-linked nor sex-limited and that the male and female have an equal influence in transmitting egg size. Their suggestion is that large egg size is dominant but it is modified by factors that tend to reduce size.

Hays (1937) observed that the inheritance of egg size was dependent upon three dominant genes A, B, C. Gene A was said to be epistatic to both B and C and resulted in the production of small eggs. Either gene B or C gives egg weight above 24 ounces per dozen in the normal hatching season. Genes B and C acting together give very large egg size. Later, Hayes (1940) stated that the sire and dam had an equal effect on the size of eggs produced by their daughters. Bennion and Price (1942) stated that U.S.D.A. Research Workers at Beltsville found that by selecting breeding males on the basis of their sisters' and their daughters' egg weight, the average December egg weight was increased from 21.0 ounces per dozen in 1934 to 24.6 ounces per dozen in 1938. It was reported that the pullets laid fewer small eggs at time of sexual maturity.

Waters (1940) through inbreeding of White Leghorns concluded that the maternal influence for egg weight character on daughters was far more important than that of the paternal influence and that there may be a W-chromosome in the female which had considerable influence on the egg weight. Contrary to earlier work, Waters (1941) stated that the sire had no effect on the egg weight of the daughters, but that the egg weight of the dam did influence the egg weight of the daughters.

Hutt and Bozivich (1946) observed from diallel matings that the sire could influence the egg weight of their daughters. This they proved by mating single males with a large number of females. Alp (1947) stated that egg size was just as much the result of breeding as was feather color, comb type, or body shape. Quinn (1947) stated that daughters of small-egg hens lay small eggs, and daughters of large-egg hens lay large eggs.

Jull (1947) stated that the specific nature of the inheritance of egg size was an extremely complicated one for the following reasons: (1) the size of the bird in a given strain, (2) the size of the yolk, (3) the size of the oviduct, (4) sexual maturity, (5) high temperatures, and (6) perhaps one or more of the hormones secreted by some of the endocrine glands. Quinn (1948) stated that over a five-year period, the U.S.D.A. Research Workers at Beltsville raised the average egg weight from 23.2 ounces to 25.4 ounces per dozen. These workers also shortened the time required for egg size to reach the maximum. In their earlier work, this maximum size was not reached until May of the year following sexual maturity. At the end of the five-year period, the time at which maximum egg size was reached advanced to December following age of maturity.

Jull (1947) stated that Ryder concluded the shape of the egg was due to the resistance of the oviduct in front of the egg and to the pressure behind the egg as it moved through the oviduct. Curtis (1941) observed that variations in egg shape was more pronounced in some individuals than others within the same breed, but, in general, eggs from a given hen varied less than the breed as a whole.

Benjamin (1920) observed that a strong correlation existed between the type egg produced by the individual and the type egg from which the individual was hatched. This same worker observed that egg shape was inherited and that the long, narrow egg was dominant to the short, round egg. The mating of parents each possessing a distinctly opposite character as to egg shape resulted in a progeny that produced eggs of an intermediate nature. When the parents possessed similar characteristics as to egg shape, the progeny produced nearly normal eggs. Jull (1947) stated that Kopec observed short, round egg shape was dominant to long, narrow egg shape.

Asmundson (1931) operated on the isthmus and uterus of hens to observe the eggs laid subsequent to the operation. He concluded there were three factors that determined the general shape of an egg: (1) the amount of albumen secreted in the albumen-secreting portion of the oviduct, (2) the size of the lumen of the isthmus, (3) the muscular activity of the wall of the isthmus. He further concluded that the shape was more or less altered in the uterus, which, together with the isthmus, gave each egg its shape.

Hayes (1937) stated that the shape of the eggs produced by the sister of a male was an indication of the shape of eggs his daughters might produce. Quinn (1948) reported that U.S.D.A. Research Workers at Beltsville changed egg shape rapidly by selection and breeding. Their conclusions were based upon the performance of two families. One of the families was bred to produce round eggs while the other was bred to produce eggs of "normal" shape.

Taylor and Martin (1928) observed that hens inherited the ability to produce eggs possessing strong shells. Almquist and Holst (1931) observed that shell porosity appeared to be rather constant for eggs of a particular hen, but varied for different individuals. Hall (1939) observed that shell quality varied between breeds.

Wilhelm (1940) found there was a seasonal trend in egg shell thickness which was definitely correlated with temperature, and that rate of production and position in the clutch had no effect on shell thickness. Bennion and Price (1942) stated that shell texture was affected by high temperatures and, to some extent, by the ration fed. Some hens produced eggs with a more desirable shell texture than did others under the same environment. This fact indicated shell texture was affected by heredity. Winter and Funk (1949) stated that shell quality declined with age of the bird and length of the laying season.

They suggested that birds producing eggs of good shell quality in August and September were the most desirable breeders.

Quinn, Gordon, and Godfrey (1945) found that weight loss of eggs was due to inherited characters. Quinn, Gordon, and Godfrey (1946) found there was 60 percent more shrinkage in eggs with poor shell quality than in eggs with good shell quality. Their studies also confirmed the work of Winter and Funk regarding the seasonal variation in shell quality. Berg (1949) stated that the breeding and feeding of a flock were perhaps the most important factors influencing shell quality. Other factors such as environmental, disease, and physiological changes in the birds themselves were of less importance.

Jull (1947) stated that Hurst and Benjamin obtained intermediate shell color in the F1 generation by crossing brown-shell and white-shell producing breeds. A similar conclusion was drawn by Hall (1944). Jull (1947) stated that Punnet and Bailey were of the opinion that a major gene was responsible for brown shell color. Intermediate shades depended upon the presence of one or more minor genes and white color upon the absence of both the major and the minor genes. Jull (1947) stated that Kopec reported shell color depended upon several factors, each of equal importance. Short round eggs were deeper pigmented than long eggs. The intensity of shell color decreased as production increased. Hays (1937) stated that shell flecking was probably independent of inheritance and that multiple factors were concerned in shell pigmentation. Quinn (1948) stated that shell color was a breed characteristic with variations in strains and families. Shell color may also be associated with shell thickness.

Jull (1947) stated that Holst and Almquist in a study of egg quality were among the first to show that the percentage of thick albumen was a characteristic dependent upon the individual hen. Lorenz, Taylor, and Almquist (1934) observed that data indicated the presence of genetic factors which controlled, at least partially, the percentage of firm albumen in the egg laid. Almquist and Lorenz (1935) observed that the percentage of firm white in stored eggs had a high correlation with that of the fresh eggs from the same hens. The eggs with the higher percentages of firm white showed a lower percentage of liquefaction of firm white during storage.

VanWagenen and Hall (1936) concluded that albumen quality was an inherited character and was probably dependent upon multiple factors. Knox and Godfrey (1938-1940) and Botsford (1939) in studies of egg albumen found that the quality was a characteristic of the individual hen. There were indications that a decrease in quality occurs as the laying season progressed; this was especially true with some individuals. Bennion and Price (1942) stated that the ratio of thick and thin albumen of an egg was an inherited characteristic, and was not influenced by the ration fed.

Quinn (1948) found that the thick albumen of eggs from individual hens might vary from a high of 70 percent to a low of 30 percent during the laying season. Improvement in this condition was brought about by U.S.D.A. Research Workers at Beltsville by a selective breeding program. Two lines of birds were produced, one of which produced eggs with 65 percent thick albumen, while the other line produced eggs of only 40 percent thick albumen. They also developed a heat resistant type of thick albumen in a flock of White Leghorns by seven years of selective breeding. The thick albumen held together well for 14 days when subjected to a temperature of 100 degrees F.

The industry is seriously affected by the frequent occurence of blood spots in eggs. Producers are aware of this unwholesome condition since these eggs constitute a loss. The consumer tends to eliminate eggs from his grocery list and menu for a few days when unwholesome eggs are broken out.

Jeffrey and Pino (1943) presented data showing that heredity was of major importance in the incidence of blood spots and, at the same time, recognized the importance of environmental factors. Nelbandov and Card (1944) observed inheritable differences and, in addition, reported that access to range decreased the occurence of blood spots. The decrease seemed to be due to some nutritional factor the grass possessed. Quinn (1947) indicated there was a hereditary basis for the occurence of blood spots by presenting data showing the occurence of blood spots could either be increased or decreased by selective breeding. Environmental factors did not appear to affect the incidence of blood spots.

Taylor and Martin (1928) stated that pathological conditions of the oviduct affected shell thickness. Berg, Bearse, and Hamilton (1947) reported that the quality of eggs produced by hens after recovery from Newcastle disease might not reach the quality egg they laid prior to an attack of the disease. Shell thickness usually returned to normal but albumen and smoothness of shell usually remained inferior.

Atwood (1914) concluded that the average weight of eggs varied from month to month, reaching a maximum in the early spring when fowls were heaviest and laying at a high rate. Curtis (1914) observed that egg weight and the weight of the parts increased as the bird matured. Each part of the egg showed a seasonal fluctuation in weight which was apparently related to the general seasonal fluctuations in the physiological activities of the bird. The rate of production and position in the clutch also affected egg weight. Atwood (1923) observed that the position of the egg within the clutch affected the size of egg produced. Atwood (1926) concluded that, as a rule, the greater the productive capacity of a bird, the smaller the average decrease in the weight of eggs laid on consecutive days.

Marble (1931) observed that body weight was of major importance in obtaining satisfactory egg weights. Warren (1936) stated that within a breed, egg size was related to body size and age at sexual maturity. Large hens tended to lay larger eggs than small hens of the same breed. Bennion and Price (1942) stated there was a correlation of body size and egg size within the breed. Within breeds, the larger birds had a tendency to produce the largest eggs. The larger hens not only produced larger eggs, but they were of a better qualty.

Jull (1924) showed the increase in yolk size was directly proportional to the increase in body size of the hen.

Atwood (1914) concluded that the quality and quantity of feed affected the number and size of eggs produced. Sherwood (1928) reported data which indicated rations containing over 6 percent cottonseed meal reduced the storage quality of eggs. His data tended to show that the feeding of a liberal supply of fresh, succulent green feed improved the storage quality of eggs. Titus and Nestler (1935) observed that the source and quality of vitamin D affected the quality of the eggs a hen produced. Warren (1936) stated that feed was not an important factor in the improvement of egg size, unless the constituents of the ration were extremely off balance. Sowell and Morgan (1936) observed that protein supplemented had no material effect upon the interior physical quality of eggs produced.

Ringrose and Morgan (1939) observed that the feeding of green feed did not affect the interior quality of eggs. Gish, Payne, and Peterson, (1940) reported that grass silage when fed to chickens produced a darker colored yolk than did fresh cereal grasses. Denton and Titus (1941) observed that the ingestion of either green or dried grass failed to affect the interior quality of eggs. However, the color of the yolk appeared darker before the candle. The fresh green grass gave a deeper yolk color than did dried grass.

Bennion and Price (1942) stated that generally speaking, well-balanced rations designed for high egg production would produce eggs of good quality. Variations in yolk color were the most noticeable characteristics of eggs influenced by ration. Yolks were uniform in color and not too dark if the ration did not contain more than 20 to 30 percent corn and less than 5 percent alfalfa.

Taylor and Martin (1928) pointed out that a lack of such nutriional factors as calcium and vitamin D adversely affected the production of strong shelled eggs. Bennion and Price (1942) stated that thin-shelled eggs might be caused by the lack of calcium or vitamin D in the ration. Although an adequate supply of calcium and vitamin D was necessary to produce shells of good quality, there was no indication that excessive feeding of these nutrients would improve shell texture. Heusen and Norris (1945) found by restricting calcium in the hens' diet that egg shells became progressively thinner before production ceases.

Atwood and Weakley (1917) reported that the presence of a considerable amount of animal protein in the ration of laying hens tended to weaken the vitelline membrane. Eggs and egg yolks produced by hens fed wheat were somewhat heavier than eggs and yolks from corn fed fowls. The percent yolk in an egg could be varied by the quantity of meat scraps in the ration. Parker (1927) found no definite seasonal trend in yolk color but believed it to be closely correlated with the amount of green feed the birds received. On the other hand, Kent (1932) suggested that production rather than feed was the factor that determined yolk color. The hens laying fewer eggs had more pigment to distribute among them. McCannon, Pittman, and Wilhelm (1934) reported that yolk color was affected by the type ration fed.

Payne (1925) observed that dark colored yolks were produced when hens were turned on pasture. He found that Shepherds purse and Penny cress caused hens to produce eggs with olive colored yolks. Parker (1946) observed that hens fed a high protein ration (33 to 43 percent) produced eggs with slightly darker yolks than hens fed a ration containing 22 percent protein. The feeding of whole grains separately, free choice, resulted in lighter colored yolks than if the grains were fed mixed, free choice. There was a tendency for yolks to become a little darker when the birds were turned on pasture in the afternoon.

Henderson and Wilcke (1933) concluded that the pigment in the ration was primarily responsible for the color of the egg yolk. Albright and Thompson (1935) and Wilhelm and Heiman (1937) reported that yolk color was affected by the ration fed laying hens. Titus, Fritz, and Kauffman (1938) observed that yolk color of hens' eggs could be readily changed by varying the amount of carotinoid pigment in the diet given the hens.

Atwood (1926) and Parker (1946) found that albumen quality was not influenced by the ration fed. Albright and Thompson (1935) observed that the color or flavor of albumen was not affected by changing feed.

Vondell (1933) reported that a "fishy" flavor in eggs might be due to inheritance rather than to environment or feeding. McCammon, Pittman, and Wilhelm (1934) reported that the type ration fed laying hens affected both odor and flavor of eggs produced. Albright and Thompson (1935) observed that the flavor of eggs could be changed by feed nutrients. Bennion and Price (1942) stated that off-flavored eggs usually were traced to the type ration fed or to faulty storage conditions. Occasionally some individual hen would continue to produce off-flavored eggs regardless of the feed.

Bennion and Warren (1933) reported that when temperatures were above 85 degrees F. there was a sharp decline in egg weight. In proportion to their weight, the shell and albumen decreased considerably more than did the yolk, which indicated that the oviduct was more sensitive to temperature changes than was the ovary. Warren (1936) stated that high temperatures during the summer months reduced egg size.

Lorenz and Almquist (1936) observed that egg weight was decreased by increasing the air temperatures during the formation of the egg, but the percentage of firm albumen and shell weight were not affected by air temperatures during that time. The percentage of firm albumen was not dependent upon the size of the egg. Alp, Ashby, and Card (1938) observed that during the summer months, egg weights decreased as temperature increased. Bennion and Price (1942) stated that when temperatures rose above 80 degrees F. there was a sharp reduction in egg size.

Bennion and Warren (1933) and Bennion and Price (1942) stated that when temperatures rose above 80 to 85 degrees F., the shells became thinner and more fragile. Birds kept in a cool, insulated, well-ventilated house during summer months produced shells of better quality than if subjected to normal summer temperatures. Warren and Schnepel (1940) reported that high temperatures reduced the calcium content of the blood, thereby causing shell thickness to be reduced.

Regardless of how successful the breeder and the nutritionist might be, there are certain management practices the producer must adopt if he is to produce a high quality market egg. Alp, Ashby, and Card (1938) stated that better quality eggs were usually produced from large flocks. This was probably due to better care and feeding methods given larger flocks. These workers also reported that better quality eggs were produced under confinement or semi-confinement rather than under range conditions.

Bennion and Price (1942) stated that cell division was initiated in a fertile egg when the temperature was above 68 degrees F. When cell division took place, the quality deteriorated rapidly. In contrast, Lippincott and Card (1946) and Winter and Funk (1949) stated that cell division ceased when the temperature of fertile eggs was allowed to fall below 80 to 82 degrees F.

King and Chestnut (1943) stated that it was estimated that Southern farmers lost one-quarter of a million dollars annually because male birds were not moved from the flock when the breeding season was over.

Bennion and Price (1942), Jull (1943), King and Chestnut (1943), and Cooper (1944) were in general agreement when they stated that if clean eggs were to be produced, such factors as floor space, litter, ventilation, nest, screening of dropping pits, and confinement should be considered.

Funk (1948a) found that the most effective method in the prevention of egg spoilage in storage was thermo-stabilization, applied either during the process of washing or soon thereafter. In this process, heat must penetrate the eggs in order to be effective. Funk (1948a) also stated that in washing eggs, the temperature of the water should be higher than the temperature of the eggs. The use of germicidal solutions such as 1 percent lye water was helpful in preventing loss in cool weather.

Card and Henderson (1933), Botsford (1939), Alp (1939), Skoglund and Tomhave (1940), Bennion and Price (1942), and Cooper (1944) were of the opinion that consideration should be given the following factors in conserving the quality of eggs while waiting to market them:

1. Gather eggs at least twice each day.

2. Use a wire basket when gathering eggs.

3. Cool eggs to a temperature between 45 and 55 degrees F. as quickly as possible after gathering.

4. Hold eggs in a storage room with temperature between 45 and 55 degrees F. with a relative humidity of 75 percent or above.

5. Keep eggs away from foreign odors.

The U.S.D.A. Production Marketing Administration has set up standards of quality for individual shell eggs, wholesale grades, consumer grades, and government purchase requirements for shell eggs. Many states comply with these requirements through a Federal-State agreement.

Card and Henderson (1933), Botsford (1939), Alp (1939), Jull (1943), Bennion and Price (1942), Cooper (1944), Norton, Hathorn, and Broadbent, (1948), and Benjamin, Pierce, and Termohlen (1949) were of the opinion that the quality of eggs placed on the market was improved by properly grading before offering them for sale. Exact methods of grading vary with the different markets. However, in general, eggs are graded according to both external and internal quality. External factors such as size, shape, shell color, checks, and cleanliness should be considered. Internal factors, including condition of yolk, condition of albumen, size and condition of air cell, development of germ spot, and presence of blood or meat spots, are determined by candling.

Card and Henderson (1933), Botsford (1939), Bennion and Price (1942), Jull (1943), Cooper (1944), and Benjamin, Pierce, and Termohlen (1949) recommended the following practices when packaging eggs:

1. Be sure eggs are thoroughly cooled.

2. Use only clean flats and fillers.

3. Cool flats, fillers, and cases before casing eggs.

4. Package eggs with the small end down.

5. Package only eggs with clean, unbroken, strong shell.

Alp, Ashby, and Card (1938) observed that moisture applied artificially to egg storage rooms aided in the conservation of egg quality. Olsen (1939) reported that the quality of eggs was reduced rapidly when the eggs were subjected to high temperatures.

Jeffrey and Darago (1940) observed that (1) the interior egg quality, as expressed by height of the thick albumen, was not affected by the relative humidity of the egg-holding room; (2) the decline in interior egg quality was regulated by temperature; (3) a high relative humidity tended to reduce the rate of evaporation of the egg contents and reduced the indicence of eggs with severely mottled shells; (4) the tendency for eggs to be free from shell mottling was especially marked when the humidity was above 90 percent.

Bennion and Price (1942) stated that high temperatures and low humidity were potent factors in changing thick albumen to thin watery albumen during storage. In order to conserve the original quality, eggs were kept at a temperature ranging from 40 to 65 degrees F. with a relative humidity above 80 percent. Humidity was even more important than temperatures in preserving egg quality.

Funk (1944) found that temperature was a very important factor affecting egg quality. Both yolk and albumen retained their desirable qualities to a great degree when held at temperatures ranging from 30 to

50 degrees F. but deteriorated rapidly when temperatures ranged from 70 to 100 degrees F. Humidity of the air around the eggs was found to have but little or no influence on the deterioration of the albumen or yolk of eggs. Humidity in the air surrounding the shell eggs did control quite largely the amount of evaporation from the eggs. High temperatures increased evaporation. Fertile eggs deteriorated more rapidly than infertile eggs when temperatures ranged above 80 degrees F. Dossin (1948) stated that it was a combination of both temperature and humidity that affected the quality of eggs in storage.

Almquist and Burmster (1934) and Pennington (1934) stated that "glassy" shelled eggs did not keep as well in cold storage as did normal shelled eggs. Retention of carbon dioxide caused cloudiness and liquefaction of the albumen.

Alp (1939), Botsford (1939), Bennion and Price (1942), and Cooper (1944) offered the following recommendations when marketing eggs: market eggs at least twice each week; sell eggs on grade; avoid rough handling; use quick, convenient transportation; protect eggs from extreme, external temperatures while enroute; sell eggs to dealers who are equipped to properly care for eggs.

Sharp and VanWagenen (1935) observed that dipping eggs in oil immediately after they were laid better preserved the quality during storage. Funk (1943b) observed that the interior quality of eggs was conserved through the process of stabilization by applying heat so that the heat penetrated the entire egg. This was done by immersing eggs in liquids, or by circulating air about the eggs. A temperature of about 140 degrees F. was used. The time required was about 10 to 15 minutes.

Romanoff and Yushok (1948) reduced the permeability of eggs to water vapor by treating eggs with mineral oil, stearic and lactic acid. Stewart and Bose (1948) reported that egg quality could be conserved greatly by dipping them in a mixture of pentane and mineral oil.

Winter and Cotterill (1949) observed that oil treatment materially reduced weight and grade losses, especially when the eggs were held at room temperature. However, the temperature of the oil used for dipping the eggs made no appreciable difference in their keeping qualities. Oils with a viscosity of 50 to 80 Saybolt seconds at 100 degrees F., pour point at 25 to 35 degrees F., and specific gravity of 0.825 to 0.845 were used. As the viscosity of the oils used increased, the weight losses of the treated eggs declined. The viscosity of the oils was more important than the brand of the oils used.

Lorenz (1949) stated that the efficiency of the oil in preventing moisture loss of eggs during storage was most closely related to oil persistency, as estimated by measuring evaporation rate of the oil itself. Viscosity was at most only slightly so related to the efficiency in the oils used. By raising the pour point with the addition of wax, the efficiency of some of the oils used was increased significantly. Hall (1945) reported that at low temperatures (34 to 36 degrees F.) egg quality was well conserved in a water glass solution.

PROCEDURE

Six pens of birds at the University of Tennessee Poultry Farm were used in this experiment. Pens A-1, A-2, A-3, and A-4 were Barred Plymouth Rocks containing 25 pullets each. Pen number 1-1 consisted of New Hampshire pullets; the first 25 birds listed on the trap nest record sheets were used. Pen number 4-2 consisted of S. C. White Leghorn pullets; the first 25 birds listed on the trap nest record sheets were used.

Hens in pen A-1 were given limited range by turning them on Italian rye grass pasture at 1 p.m. daily. Pen A-4 was given unlimited range throughout the daylight hours. Birds were given access to range as stated, beginning February 16th.

All birds were fed an all-purpose ration considered to be adequate in all known nutrients. Grit and limestone or oyster shells were made accessible to birds at all times.

Eggs laid on the first three days of each month and on regular trapping days were collected and pedigreed for individual study. All females were housed and kept confined from December until this study was undertaken. A preliminary study of eggs from pens A-1 and A-4 was made with eggs laid on February 13, 14, and 15 to determine the rate of change in yolk color when the confined birds were turned on range.

All eggs were collected and placed in a nest not accessible to hens each time traps were run. Eggs were gathered daily at 4 p.m. and stored in a cooler (40 to 45° F.) at the Poultry Farm Headquarters Building immediately after gathering. Eggs were examined the following morning.

Data concerning the following conditions and items were collected:

1. Fresh eggs (eggs gathered and cooled under refrigeration) were examined and data recorded for external condition as dirt, checks, and abnormalities; interior quality by candling; shell strength (Romanoff 1929); and interior quality by breaking out (Heiman-Carver Yolk Color Rotor and VanWagenen Index Score).

2. Treated eggs. Only eggs of known quality were used. Prior to treatment each egg was candled to determine interior quality. The eggs were assigned to a group and treated by one of the following methods: (1) oil at room temperature (Lorenz 1949), (2) oil at 140 degrees F. for 10 min., (3) water at 140 degrees F. for 10 min., (4) oil at 212 degrees F. for 5 sec., (5) water at 212 degrees F. for 5 sec. (Funk 1943a), (6) water glass (Wyo. Agr. Exp. Sta., 1947-1948). Following treatment, each egg was weighed and cased in clean 2 x 6 egg cartons and arranged in standard egg cases.

The eggs were stored in (1) a walk-in cooler at the Poultry Farm Headquarters Building, held at a temperature which ranged from 40 to 45 degrees F. and a relative humidity of 75 percent; (2) conference room at the Poultry Farm Headquarters Building, which is a non-insulated room on the second floor of the building; the range in temperature was from 68 to 94 degrees F.; and (3) basement of a brooder house on the poultry farm; the range in temperature was from 65 to 70 degrees F.

The eggs were left in storage for 74 to 107 days. At time of removal from storage, each egg was weighed and recandled before breaking out. Yolk color was determined by Heiman-Carver yolk color rotor.

Interior quality was determined by VanWagenen Index Score.

3. High temperature storage. Five hundred seventy-six eggs were divided into six equal lots. One lot received no treatment (control). Five of the lots were treated as described for treated eggs, page 22. All the eggs were held in an incubator at a temperature of 99 to 100 degrees F. and a relative humidity of 56 percent. The storage period was from 4 to 16 days. During the holding period, each egg was candled and weighed every 4 days. Twenty-four eggs from each lot were broken out each weigh day. The last eggs were broken out on the 16th day. This procedure was followed to get a more accurate measure of decrease in interior quality than was possible to get by candling.

4. Range conditions, body weight, and feed consumption were periodically checked.

5. Soiled eggs. The dirty eggs were secured from all the flocks on the University of Tennessee Poultry Farm. One lot of the eggs were smeared with fecal material in the laying house. To secure an adequate supply of dirty eggs, it was necessary to accumulate them over a period of several days.

Eggs were cleaned by (1) placing eggs in a wire basket and rotating or dipping eggs in water for 1 minute at 120 to 140°F. The water contained one tablespoon of detergent per gallon. The eggs were then rinsed with hot tap water (about 120°F.), (2) rubbing eggs with a cloth that had been dampened in tap water, (3) scouring with sandpaper, (4) brushing with steel wool, (5) washing under running tap water.

After cleaning, the soiled eggs were treated and stored under the same conditions as previously described.

Control lots of eggs were placed in storage along with treated eggs for comparison.

EXPERIMENTAL

Shell breaking strength was determined for all eggs produced by all hens under observation on the first three days of March, April, May, and June. The shell breaking strength of eggs produced by pens A-1 and A-4 on February 13, 14, and 15 were also determined.

There was a variation of shell breaking strength between the breeds and within the breeds, as shown in Tables I through VI. Pen 1-1 (New Hampshires) in confinement exhibited an average breaking strength of 4.33 Kgs. in March, 4.25 Kgs. in April, 4.39 Kgs. in May, with an increase in June to 4.81 Kgs. Pen 4-2 (S. C. White Leghorns) in confinement produced eggs that had a breaking strength of 4.43 Kgs. in March, 4.25 Kgs. in April, 4.54 Kgs. in May, then declined to 4.16 Kgs. in June. Pen A-3 (Barred Plymouth Rocks) in confinement produced eggs that had a breaking strength of 3.89 Kgs. in March, 4.04 Kgs. in April, 4.09 Kgs. in May, dropping slightly in June to 4.06 Kgs. Breaking strength of pen A-3 was more consistent than any of the other pens observed.

In comparing the shell breaking strength of eggs within the breed, it was observed that pen A-2 (a replicate of A-3) exhibited a different trend in breaking strength. Breaking strength was 3.70 Kgs. in March, 3.57 Kgs. in April, 3.63 Kgs. in May, and 3.64 Kgs. by the first of June.

Further comparison of shell breaking strength within the breed was made with pens A-1 and A-4. Feed and management practices for these two pens were the same as for the hens in confinement except the hens in these two pens were given access to Italian ryegrass pasture beginning February 16. Hens in pen A-1 were given limited range by allowing them access to pasture from one o'clock until dark each afternoon. Hens in pen A-4 were given unlimited range throughout the daylight hours. Shell breaking strength in pen A-1 was 3.52 Kgs. in February, 3.83 Kgs. in March, 3.72 Kgs. in April, 3.88 Kgs. in May, and 3.78 Kgs. in June. Eggs from pen A-4 gave a different picture. Their breaking strength was 3.74 Kgs. in February, 3.46 Kgs. in March, 3.80 Kgs. in April, reaching a peak of 4.14 Kgs. in May, and declining to 3.91 Kgs. by the first of June (Figure 1).

In the breeds and pens observed, there was a general tendency for breaking strength to reach a peak in May. As the spring season progressed toward summer, there was a tendency for breaking strength to decline. An exception occurred in pen 1-1 (New Hampshires) as shown in Figure 1.

A wider variation of breaking strength was exhibited by individuals than by the breeds or pens observed.

Most of the hens laid eggs which had a rather uniform shell breaking strength. Three hens in particular produced eggs with marked variations in breaking strength. These variations occurred not only during the periods of observation but also on successive days. Hen number 700 (Barred Plymouth Rock) laid eggs which varied in breaking strength from 5.85 Kgs. in March to 1.40 Kgs. in May. Hen number 434 (New Hampshire) laid eggs which ranged from 5.20 Kgs. in March to 7.00 Kgs. in June. Hen number 1184 (Barred Plymouth Rock) laid eggs which ranged from 1.15 Kgs. in February to 3.95 Kgs. in June.

This observation indicated that breaking strength was a characteristic of the individual and may increase or decrease as the season progresses. This agrees with work reported by Taylor and Martin in 1928.

Of the breeds observed, the New Hampshires tended to produce eggs with the stronger shells. However, a few individual hens were responsible for the lower average breaking strength exhibited by the Barred Plymouth Rocks (Tables I through VI).

About 20 percent of the eggs laid by pen A-3 (Barred Plymouth Rocks) were checks. Fifty-five percent of these were produced in April. The checks produced by this pen were equal to the number produced by all the other pens combined. This large percentage of checks was not due to management practices, since all the pens received the same care.

Observation of shell texture and egg shape was made of all eggs used in this experiment.

Data show that the eggs of the Barred Plymouth Rocks were more variable in texture and shape than were the eggs produced by the New Hampshires and S. C. White Leghorns. This is in agreement with work reported by Hall in 1939. This may have been due to the breeding program carried on with the Barred Plymouth Rocks. Emphasis had not been placed on shell quality in the breeding of the Barred Plymouth Rocks. The New Hampshires and S. C. White Leghorns were introduced on the farm in the spring of 1948. Special attention may have been given to breeding for the improvement of shell texture and egg shape in these two breeds.

Within the breeds observed, especially the Barred Plymouth Rocks, there was a wide variation of shell texture and egg shape. Three selected hens demonstrate this variation. Hen number 700 (Barred Plymouth Rock) laid conically shaped eggs with a thin, pebbly shell at the large end. Hen number 1078 (Barred Plymouth Rock) laid eggs that were round. Long eggs were characteristic of hen number 1226 (Barred Plymouth Rock). Crease-pointed, thin shelled eggs were characteristic of hen number 1091 (Barred Plymouth Rock).

From the number of eggs observed, there was evidence that shell texture and egg shape were characteristic of the individual hen. This is in agreement with a report by Bennion and Price in 1942.

Shell color varied from a creamy white to a dark brown in the Barred Plymouth Rocks. Variations of shell color in the New Hampshires was from a light brown to a dark brown. The S. C. White Leghorns produced eggs with a uniform white shell color. There was no observation of change in shell color during the period. Shell color was observed to be characteristic of the breed; this is in agreement with observations made by Jull in 1948 and Quinn in 1948.

When broken out and graded by the VanWagenen method, there was a tendency for the interior quality of the eggs produced in confinement to improve from March to May (Figure 2). The lower the score, the higher the interior quality of the egg when graded by this method.

Pen 1-1 (New Hampshires) produced eggs with an average interior quality of 2.61 in March, 2.22 in April, 1.77 in May, 2.19 in June. Pen 4-2 (S. C. White Leghorns) produced eggs with an interior quality of 2.22 in March, 1.98 in April, 1.90 in May, and 2.19 in June.

TABLE I

AVERAGE BREAKING STRENGTH OF EGGS
FROM BARRED PLYMOUTH ROCKS GIVEN LIMITED RANGE

Leg Band	Feb. Eggs No.	Feb. Brkg. Stgth.	March Eggs No.	March Brkg. Strth.	April Eggs No.	April Brkg. Stgth.	May Eggs No.	May Brkg. Stgth.	June Eggs No.	June Brkg. Stgth.
614	2	2.00	2	3.40	2	3.60	2	3.85	2	2.80
619	1	3.60	2	3.87	2	4.45	3	3.83	2	3.77
630	2	3.42	3	3.40	2	3.55	3	3.67	3	3.40
637	3	4.47	2	4.10	3	4.13	2	5.27	3	4.13
642	3	3.55	2	3.17	2	3.47	1	3.55	2	2.07
655	1	3.25	2	3.37	3	2.67	-	——	-	——
1078	3	1.97	2	2.80	3	2.97	3	3.45	2	3.10
1085	3	3.98	-	——	3	3.50	1	4.35	1	3.50
1184	1	1.15	2	2.77	1	2.50	2	2.55	2	3.47
1208	3	3.50	2	4.05	3	3.88	3	3.72	2	3.52
1218	1	4.05	2	4.20	2	4.00	3	4.00	2	5.10
1239	-	——	-	——	3	3.32	3	3.82	1	3.40
1263	-	——	2	4.37	3	4.18	1	4.55	-	——
1268	2	4.52	2	4.95	2	3.72	2	4.15	2	3.35
1277	2	3.60	-	——	3	3.92	2	4.30	3	4.17
1283	1	3.80	3	4.37	2	4.10	2	4.65	2	4.57
1305	3	3.83	3	4.00	2	4.35	1	2.30	3	4.30
1311	1	3.65	3	3.48	2	2.85	2	2.97	2	3.30
1312	-	——	1	4.10	2	4.02	2	4.07	-	——
1336	1	2.90	2	3.47	-	——	2	4.05	2	4.25
1343	3	4.22	3	4.38	1	3.85	3	4.22	2	4.87
1393	2	4.27	2	4.50	2	3.92	1	4.20	3	3.98
1423	2	4.70	1	3.85	1	4.80	-	——	3	4.52
Average		3.52		3.83		3.72		3.88		3.78

Breaking strength in kilograms

TABLE II

AVERAGE BREAKING STRENGTH OF EGGS FROM
BARRED PLYMOUTH ROCKS IN CONFINEMENT

Leg Band	March		April		May		June	
	Eggs No.	Brkg. Stgth.	Eggs No.	Brkg. Stgth.	Eggs No.	Brkg. Stgth.	Eggs No.	Brkg. Stgth.
617	2	2.77	3	4.70	2	2.92	2	5.15
643	2	4.55	2	3.70	-	----	2	3.65
691	2	4.67	-	----	-	----	-	----
700	2	5.67	3	2.05	3	2.50	3	1.97
710	2	3.37	2	3.22	2	3.57	1	3.15
725	1	5.00	-	----	1	4.00	1	3.00
736	-	----	2	4.82	2	4.67	3	3.70
769	3	4.18	2	4.20	1	5.90	2	4.95
782	2	3.42	1	3.90	1	2.90	1	4.15
787	2	2.10	3	2.40	2	2.32	3	3.80
790	1	2.10	2	2.20	-	----	-	----
1029	1	1.90	2	----	2	3.12	3	4.44
1041	3	3.60	3	3.37	2	3.75	3	4.40
1067	2	3.97	-	----	1	3.90	1	4.00
1094	-	----	3	3.60	1	2.55	-	----
1130	-	----	2	3.35	1	2.65	1	1.00
1159	2	3.52	2	2.40	-	----	-	----
1190	2	4.35	3	4.02	3	3.80	3	3.38
1205	2	3.47	2	4.55	3	4.33	2	3.85
1230	3	3.55	-	----	-	----	2	2.67
1249	2	5.00	1	5.60	3	3.87	1	4.20
1416	2	3.17	2	2.67	1	4.90	1	4.15
Average		3.70		3.57		3.63		3.64

Breaking strength in kilograms

TABLE III

AVERAGE BREAKING STRENGTH OF EGGS FROM
BARRED PLYMOUTH ROCKS IN CONFINEMENT

	March		April		May		June	
Leg Band	Eggs No.	Brkg. Stgth.	Eggs No.	Brkg. Stgth.	Eggs No.	Brkg. Stgth.	Eggs No.	Brkg. Stgth.
602	2	4.12	-	----	1	4.15	-	----
658	2	4.10	2	3.90	2	4.12	1	4.50
660	-	----	1	3.95	-	----	1	3.50
1052	-	----	1	2.80	2	4.45	-	----
1091	3	3.65	-	----	2	3.30	-	----
1093	2	4.65	-	----	1	3.05	-	----
1116	-	----	1	3.60	2	4.10	2	3.75
1137	3	3.70	2	3.62	1	3.80	2	3.77
1158	2	4.15	2	4.10	3	4.23	1	3.85
1172	-	----	-	----	-	----	1	3.25
1209	3	4.15	2	4.27	2	5.17	2	4.67
1219	3	4.15	2	4.10	3	3.62	-	----
1235	-	----	2	5.20	-	----	1	3.30
1260	2	4.37	-	----	2	5.80	-	----
1286	2	3.65	1	5.20	2	4.20	3	3.72
1297	2	3.25	2	3.85	3	3.48	2	4.20
1315	1	1.50	-	----	-	----	-	----
1326	2	4.65	-	----	1	4.15	1	5.60
1366	1	3.80	2	2.75	1	3.95	-	----
1394	2	3.97	1	4.60	-	----	-	----
1406	1	3.10	-	----	-	----	-	----
1427	2	5.15	3	4.58	1	3.90	1	4.60
Average		3.89		4.04		4.09		4.06

Breaking strength in kilograms

TABLE IV

AVERAGE BREAKING STRENGTH OF EGGS
FROM BARRED PLYMOUTH ROCKS GIVEN UNLIMITED RANGE

Leg Band	Feb. Eggs No.	Feb. Brkg. Stgth.	March Eggs No.	March Brkg. Stgth.	April Eggs No.	April Brkg. Stgth.	May Eggs No.	May Brkg. Stgth.	June Eggs No.	June Brkg. Stgth.
601	2	3.67	2	4.17	2	4.27	2	5.32	3	5.18
652	3	3.27	3	2.87	2	3.95	2	3.72	2	3.75
668	3	4.07	3	3.97	3	3.40	2	4.27	2	4.75
781	3	3.80	3	2.95	2	3.57	2	2.90	3	3.05
1055	3	4.77	2	3.90	2	4.30	2	3.75	3	4.23
1074	-	----	-	----	-	----	-	----	1	3.50
1079	3	1.82	2	2.65	-	----	-	----	1	3.25
1100	2	4.15	3	3.85	3	2.87	-	----	2	3.95
1117	1	4.55	1	3.90	1	3.35	1	3.30	2	4.35
1121	3	3.80	3	3.72	2	3.65	2	4.75	3	4.80
1128	1	3.15	2	2.02	3	2.37	-	----	-	----
1167	3	3.17	1	2.80	-	----	1	3.25	1	3.90
1192	3	3.48	3	3.67	1	4.45	2	5.70	1	3.70
1193	2	4.80	2	4.80	2	5.75	2	4.32	2	4.40
1211	-	----	-	----	1	2.45	-	----	1	3.55
1226	1	2.35	3	2.73	-	----	-	----	-	----
1289	1	4.15	1	4.90	1	2.20	2	4.37	-	----
1304	1	3.60	2	2.90	3	3.75	1	3.25	2	3.82
1319	3	5.23	2	1.40	-	----	-	----	1	2.90
1345	3	3.83	-	----	-	----	-	----	1	2.50
1358	3	3.87	3	3.92	-	----	-	----	-	----
1373	2	4.70	3	3.85	2	5.27	3	4.37	1	5.25
1380	1	1.10	1	4.75	2	3.70	2	4.12	2	3.27
1417	-	----	-	----	3	4.97	2	4.82	2	4.77
1421	2	4.90	2	2.97	3	4.13	2	4.05	1	3.35
Average		3.74		3.46		3.80		4.14		3.91

Breaking strength in kilograms

TABLE V

AVERAGE BREAKING STRENGTH OF EGGS FROM NEW HAMPSHIRES IN CONFINEMENT

Leg Band	March Eggs No.	March Brkg. Stgth.	April Eggs No.	April Brkg. Stgth.	May Eggs No.	May Brkg. Stgth.	June Eggs No.	June Brkg. Stgth.
422	1	4.30	2	4.90	-	----	1	4.45
424	1	5.20	2	4.25	1	4.20	1	4.40
425	-	----	3	3.38	1	5.00	-	----
426	2	4.15	3	3.87	3	3.67	2	4.42
427	-	----	1	4.00	1	3.50	1	3.40
428	-	----	1	5.40	1	4.70	1	5.20
430	2	4.00	1	5.90	1	4.50	2	5.10
431	1	4.50	1	3.30	2	2.95	2	3.82
434	1	5.20	2	5.92	1	5.70	2	6.05
436	1	4.80	2	5.37	2	5.07	2	4.20
437	2	4.30	-	----	2	3.80	-	----
441	2	3.42	1	4.40	-	----	2	4.20
442	2	3.67	3	4.07	2	3.70	-	----
443	-	----	3	3.80	-	----	1	4.95
458	1	3.05	2	4.22	3	4.13	2	4.77
460	-	----	2	5.00	1	4.90	1	5.15
461	2	4.72	3	4.45	-	----	-	----
462	1	3.60	2	3.40	-	----	1	5.80
463	1	4.70	3	4.19	-	----	2	4.67
465	2	4.22	-	----	-	----	-	----
466	1	2.90	1	1.00	-	----	-	----
467	2	5.33	3	3.73	2	5.25	2	5.92
468	1	5.45	1	4.70	1	4.80	1	5.30
471	3	4.70	-	----	-	----	1	4.75
Average		4.33		4.25		4.39		4.81

Breaking strength in kilograms

TABLE VI

AVERAGE BREAKING STRENGTH OF EGGS FROM
S. C. WHITE LEGHORNS IN CONFINEMENT

Log Band	March Eggs No.	March Brkg. Stgth.	April Eggs No.	April Brkg. Stgth.	May Eggs No.	May Brkg. Stgth.	June Eggs No.	June Brkg. Stgth.
794	1	4.85	3	3.87	2	4.67	2	3.67
795	2	5.22	1	4.80	1	7.15	2	5.47
800	-	----	2	4.77	-	----	2	4.82
802	1	3.00	3	3.53	2	3.05	2	3.00
804	-	----	1	3.15	1	3.35	-	----
805	1	4.00	1	3.55	-	----	2	4.20
810	3	4.42	3	5.10	3	4.03	3	4.40
811	1	4.50	-	----	-	----	1	5.00
813	-	----	1	1.40	-	----	-	----
816	1	3.60	2	4.35	2	4.10	2	3.60
817	1	4.50	2	4.22	2	4.62	-	----
820	2	5.12	3	4.80	2	4.50	3	4.03
821	3	5.32	2	5.65	2	4.95	2	5.25
824	3	3.90	1	4.00	2	3.87	2	3.20
830	3	4.67	-	----	3	3.97	3	2.10
831	1	4.95	2	4.20	2	5.22	1	5.00
832	1	3.75	-	----	3	2.97	3	3.35
834	-	----	-	----	3	4.82	2	3.40
835	2	4.10	3	3.57	2	4.83	2	4.00
836	1	5.60	2	5.42	2	5.25	1	5.80
837	2	4.05	2	3.32	3	3.90	2	4.20
839	2	4.22	1	5.85	1	6.45	2	4.50
859	-	----	1	4.45	-	----	-	----
864	-	----	1	5.30	-	----	-	----
Average		4.43		4.25		4.54		4.16

Breaking strength in kilograms

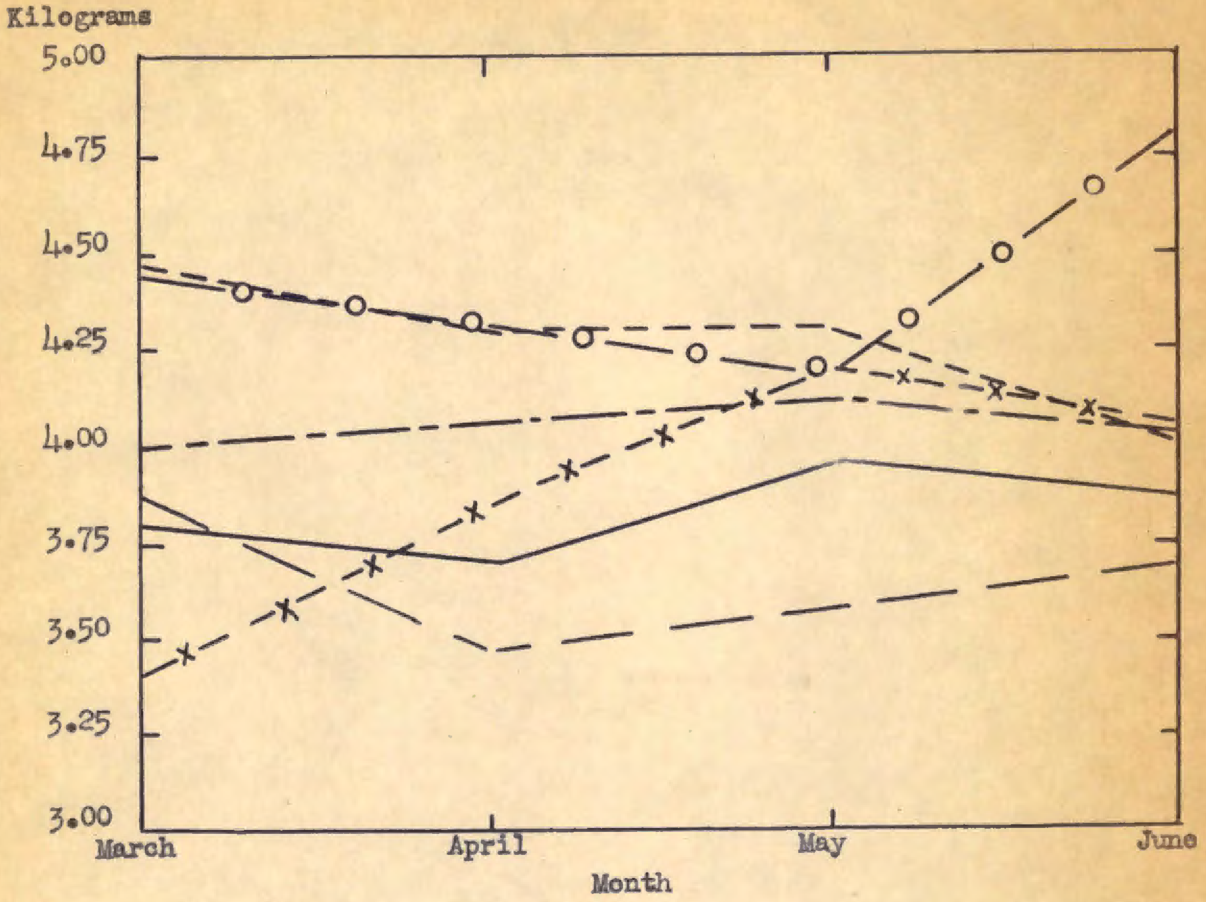

Figure 1

Shell Breaking Strength of Eggs

A-1 A-2 A-3 A-4 1-1 4-2

Interior quality range in pen A-2 (Barred Plymouth Rocks) was 2.30 in March, 2.26 in April, 2.07 in May, and 2.60 in June. Range of interior quality in pen A-3 (Barred Plymouth Rocks) was 2.20 in March, 2.26 in April, 2.03 in May, and 2.38 in June. This breed difference, as shown, indicates that interior quality of S. C. White Leghorns was better than interior quality of either New Hampshires or Barred Plymouth Rocks. This is in agreement with work reported by VanWagenen, Hall, and Wilgus in 1937.

Observations of interior quality of eggs produced by hens first given access to Italian ryegrass in February 16 were of interest. Hens in pen A-1 (Barred Plymouth Rocks) were turned on pasture at one o'clock each afternoon and allowed to remain on pasture the remainder of the day. The average interior quality of eggs was 2.40 in February, 2.30 in March, 2.27 in April, 2.19 in May, and 2.54 in June. Pen A-4 (Barred Plymouth Rocks), which was given access to the pasture throughout the daylight hours, produced eggs with an average interior quality of 2.45 in February, 2.21 in March, 2.27 in April, 2.25 in May, and 2.49 in June.

Observations of interior quality of eggs within the breed were made in the four pens of Barred Plymouth Rocks. The interior quality of eggs produced by the pens A-2 and A-3 in confinement increased from March to May. On the other hand, the interior quality of eggs produced by the pens A-1 and A-4, which had access to ryegrass pasture,

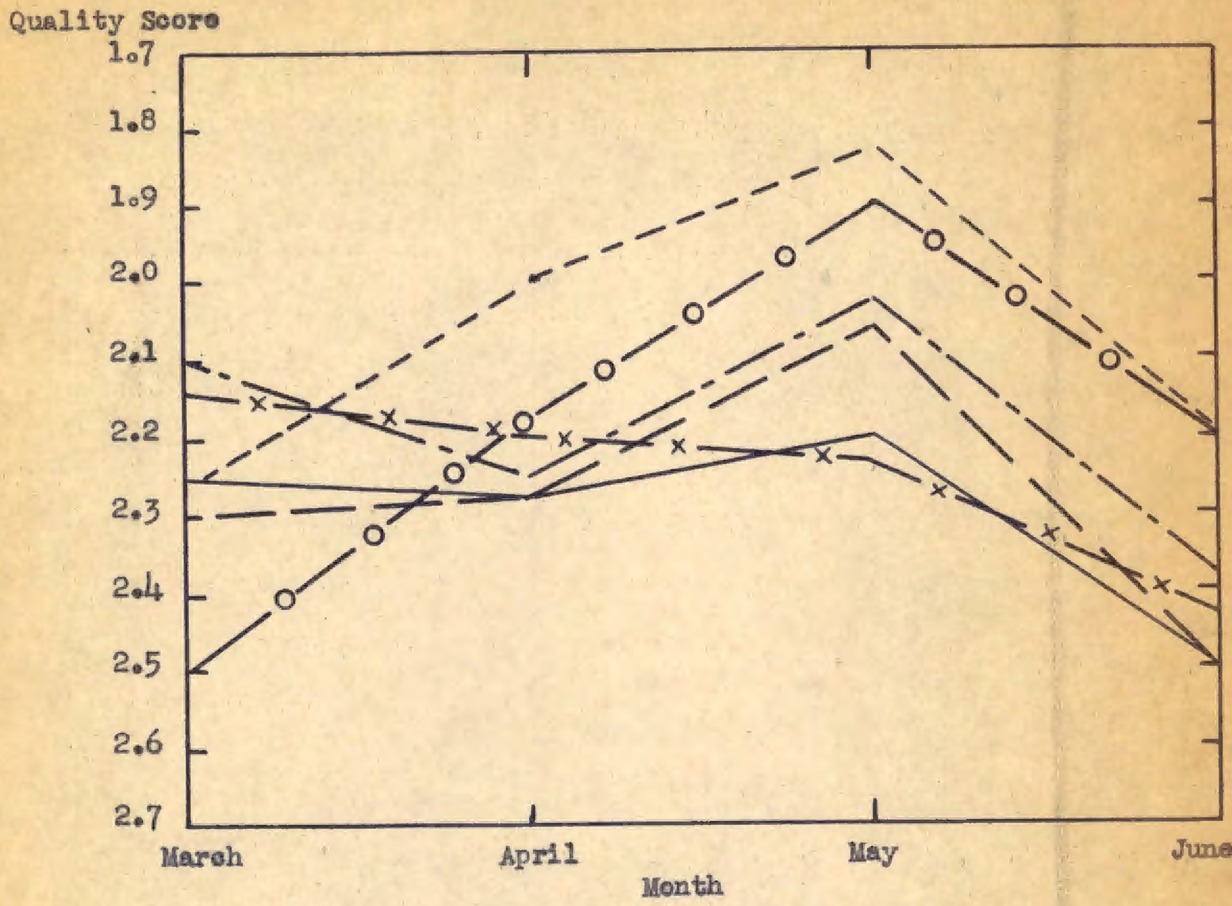

Figure 2

Quality Score of Eggs

A-1 A-3 1-1

A-2 A-4 4-2

remained about constant from March to May. Environmental conditions and green feed may have contributed to this variation. By the first of June, the Italian ryegrass was in an advanced stage of maturity.

The desirable interior quality of eggs during the spring months together with peak production and usually lower prices accounts for the storage of eggs during the spring season.

It was observed that the interior quality was a characteristic of the individual hen (Tables VII through XII). This is in agreement with reports made by Knox and Godfrey in 1938-40, and Botsford in 1939. Hen number 1311 (Barred Plymouth Rock), given access to ryegrass pasture, produced eggs that varied in interior quality from 3.00 in February to 4.50 in March and continued to produce eggs within that range throughout the period. Hen number 642 (Barred Plymouth Rock), in the same pen and under identical conditions as hen 1311, produced eggs with an interior quality that varied from 1.00 to 2.00 in February and continued to produce eggs in that range throughout the period.

Hen number 1091 (Barred Plymouth Rock) in confinement produced eggs with an interior quality that varied from 5.00 in March to 3.00 in April. Hen number 1260 (Barred Plymouth Rock), in the same pen and under identical conditions, produced eggs with an interior quality range from 1.00 in March to 1.50 in May.

Hen number 830 (S. C. White Leghorn) in confinement produced eggs with an interior quality that varied from 1.00 in March to 2.00

in June. Hen number 839 (S. C. White Leghorn), in the same pen and under identical conditions, produced eggs that varied in interior quality from 4.00 in March to 2.50 in April then back to 4.00 in June. From this data it is obvious that interior quality is a characteristic of each individual hen.

Eggs laid on the first three days of March, April, May, and June were observed for blood or meat spots. Eggs from pens A-1 and A-4 on the 13, 14, and 15 of February were also observed. The range in the incidence of eggs produced which contained blood or meat spots follows:

Pen No.	Feb. Percent	March Percent	April Percent	May Percent	June Percent
A-1 B. P. Rocks	17.5	22.2	13.4	6.3	22.7
A-2 B. P. Rocks	----	20.0	19.5	12.1	25.7
A-3 B. P. Rocks	----	20.5	15.4	5.9	23.8
A-4 B. P. Rocks	20.0	16.6	5.1	3.2	13.5
1-1 New Hampshires	----	10.0	13.3	---	20.7
4-2 S.C.White Leghorns	----	3.2	5.4	---	4.8

The average range of blood or meat spots in the pens in confinement was 3.4 percent for pen 4-2 (S. C. White Leghorns), 11.0 percent for pen 1-1 (New Hampshires), 19.3 percent for pen A-2 (Barred Plymouth Rocks), and 15.2 percent for pen A-3 (Barred Plymouth Rocks).

The range in the two pens of Barred Plymouth Rocks given access to pasture was 16.4 percent for pen A-1 and 12.5 percent for pen A-4.

There was a tendency for the incidence of blood spots or meat spots to vary within the breeds. The eggs produced by the S. C. White Leghorns had a lower percentage of blood spots than did the eggs produced by the New Hampshires or Barred Plymouth Rocks. This is in agreement with work reported by Quinn in 1948b.

There was no indication that access to succulent green pasture decreased the incidence of blood spots, as was reported by Nelbandov and Card in 1944. However, the number of eggs observed was insufficient to draw final conclusions as to the value of a nutritive factor in grass affecting the number of blood or meat spots found in eggs from hens on range.

The lowest incidence of blood or meat spots occurred in May. This is not accounted for, since the hens both in confinement and with access to pasture responded likewise. This phenomenon might account for some packers placing spring produced eggs in storage without candling prior to storage.

There was evidence that some individuals had a tendency to produce eggs containing blood spots more often than others. Some hens produced eggs free of blood spots during the entire period of observation.

Hen number 614 (Barred Plymouth Rock), with access to ryegrass pasture from one o'clock until dark, produced eggs free of blood

TABLE VII

INTERIOR QUALITY* OF EGGS FROM
BARRED PLYMOUTH ROCKS GIVEN LIMITED RANGE

Leg	Feb.		March		April		May		June	
Band	Eggs No.	Qual. Score	Eggs No.	Qual. Score	Eggs No.	Qual. Score	Eggs No.	Qual. Score	Eggs No.	Qual. Score
614	2	2.00	2	2.50	2	2.00	2	2.50	2	3.00
619	1	3.00	2	2.25	2	2.75	3	2.20	2	2.25
630	2	2.50	3	1.80	2	2.50	3	2.00	3	2.30
637	3	1.80	2	2.75	3	2.50	2	2.50	3	3.20
642	3	1.50	3	1.00	2	2.00	1	1.00	2	1.50
655	1	2.50	2	2.00	3	2.50	-	----	-	----
1078	3	3.00	2	3.00	3	2.80	3	2.20	2	2.00
1085	3	2.25	-	----	3	1.50	2	2.25	1	3.00
1184	1	3.00	2	2.00	3	2.50	2	2.25	2	2.50
1208	3	1.70	2	1.50	3	1.50	3	1.80	2	2.25
1218	1	3.00	2	2.50	2	2.25	3	2.50	2	2.75
1239	-	----	-	----	3	2.50	3	2.75	1	3.00
1263	-	----	2	2.00	3	1.30	2	1.50	-	----
1268	2	2.75	2	3.00	2	2.25	2	2.75	2	2.75
1277	2	2.25	1	3.00	3	2.50	2	2.50	3	2.80
1283	1	2.00	3	2.50	2	2.25	2	2.25	2	2.25
1305	3	1.50	3	1.00	2	1.50	1	1.00	3	1.50
1311	1	3.00	3	3.80	2	3.25	2	3.75	2	3.50
1312	-	----	1	2.50	2	2.25	2	1.50	-	----
1336	1	2.50	2	1.00	-	----	3	1.50	2	1.75
1343	3	2.30	3	2.70	1	2.00	3	2.30	2	2.50
1393	2	2.25	2	3.00	2	2.50	1	3.00	3	3.20
1423	2	3.25	1	2.50	2	2.75	-	----	3	2.80
Average		2.40		2.30		2.27		2.19		2.54

*VanWagenen Index Score

TABLE VIII

INTERIOR QUALITY* OF EGGS FROM
BARRED PLYMOUTH ROCKS IN CONFINEMENT

Leg Band	March Eggs No.	March Qual. Score	April Eggs No.	April Qual. Score	May Eggs No.	May Qual. Score	June Eggs No.	June Qual. Score
617	2	3.50	3	2.50	2	2.50	2	3.25
643	2	1.25	2	2.00	-	----	2	1.25
691	2	1.50	-	----	-	----	-	----
700	2	2.75	3	1.50	3	1.50	3	1.80
710	2	2.00	2	2.50	2	2.25	1	3.00
725	1	1.50	-	----	1	1.00	1	2.00
736	-	----	2	2.00	2	2.00	3	2.50
769	3	2.80	2	2.50	1	2.00	2	2.75
782	2	3.25	2	2.50	1	3.00	1	3.00
787	2	2.50	3	2.50	2	1.75	3	3.00
790	1	4.00	2	2.50	1	1.50	-	----
1029	1	1.50	-	----	2	2.50	3	2.50
1041	3	1.70	3	1.80	2	2.00	3	2.30
1067	2	2.00	1	3.00	1	2.00	1	3.00
1094	-	----	3	2.70	1	2.00	-	----
1130	2	3.00	3	3.00	1	3.00	1	3.00
1159	2	1.50	2	1.50	-	----	-	----
1190	2	2.75	3	2.50	3	2.50	3	2.70
1205	2	1.75	2	2.75	3	2.20	2	2.75
1230	3	2.70	-	----	-	----	2	2.50
1249	2	2.50	1	2.0	3	2.30	1	2.50
1416	2	1.50	2	1.0	2	1.25	1	3.00
Average		2.30		2.26		2.07		2.60

*VanWagenen Index Score

TABLE IX

INTERIOR QUALITY* OF EGGS FROM
BARRED PLYMOUTH ROCKS IN CONFINEMENT

Leg Band	March		April		May		June	
	Eggs No.	Qual. Score	Eggs No.	Qual. Score	Eggs No.	Qual. Score	Eggs No.	Qual. Score
602	3	2.0	2	3.0	1	2.5	-	----
658	2	2.0	2	3.0	2	2.0	1	2.0
660	-	----	1	3.0	-	----	1	3.5
1052	-	----	2	1.25	2	1.25	-	----
1091	3	4.5	2	3.25	2	3.5	-	----
1093	2	2.0	-	----	1	2.5	-	----
1116	1	3.0	3	2.5	2	2.5	2	2.5
1137	3	2.33	3	2.33	1	2.0	2	2.5
1158	2	2.5	2	2.5	3	2.17	1	2.5
1172	2	2.5	3	1.67	2	2.75	1	2.5
1209	3	2.8	3	2.7	2	2.25	3	2.5
1219	3	1.8	2	2.0	3	1.8	-	----
1235	-	----	2	2.5	-	----	1	4.0
1260	2	1.0	-	----	2	1.25	1	1.0
1286	2	1.0	2	1.25	2	1.0	3	2.0
1297	2	3.0	2	2.25	3	2.5	2	2.75
1315	1	3.0	1	2.5	-	----	-	----
1326	2	1.25	1	1.0	2	1.0	1	1.0
1366	1	1.5	2	1.25	1	2.0	-	----
1394	2	1.25	1	2.5	1	2.0	1	2.5
1406	1	1.0	-	----	-	----	-	----
1427	2	2.25	3	2.3	2	2.75	1	2.5
Average		2.20		2.26		2.03		2.38

*VanWagenen Index Score

TABLE X

INTERIOR QUALITY* OF EGGS FROM
BARRED PLYMOUTH ROCKS GIVEN UNLIMITED RANGE

Leg Band	Feb. Eggs No.	Feb. Qual. Score	March Eggs No.	March Qual. Score	April Eggs No.	April Qual. Score	May Eggs No.	May Qual. Score	June Eggs No.	June Qual. Score
601	2	2.00	2	1.50	2	1.25	2	2.00	3	2.00
652	3	2.30	3	1.50	2	1.75	2	2.25	2	1.75
668	3	2.20	3	2.80	3	2.70	2	2.25	2	2.75
781	3	2.20	3	1.80	2	2.50	2	2.00	3	2.00
1055	3	2.30	2	2.25	2	2.25	2	2.25	3	2.50
1074	-	----	-	----	-	----	-	----	1	2.50
1079	3	2.30	2	2.25	1	2.50	1	2.50	1	2.50
1100	2	2.50	3	1.90	3	2.20	-	----	2	2.00
1117	1	2.50	1	3.00	1	3.50	1	3.50	2	4.00
1121	3	2.20	3	1.80	2	2.20	2	1.75	3	2.50
1128	1	3.00	2	1.75	3	2.50	-	----	-	----
1167	3	2.20	1	2.50	-	----	1	2.50	1	2.50
1192	3	2.20	3	2.00	1	2.50	2	2.00	1	2.00
1193	2	2.50	2	2.50	2	2.75	2	2.50	2	2.50
1211	-	----	-	----	1	2.50	-	----	1	2.50
1226	1	2.50	3	2.50	-	----	-	----	-	----
1289	1	2.50	1	2.00	1	1.50	2	1.50	-	----
1304	2	2.25	2	1.25	3	1.00	1	2.50	2	2.50
1319	3	3.80	2	3.00	-	----	-	----	1	3.50
1345	3	3.30	-	----	-	----	-	----	1	3.00
1358	3	2.70	3	2.80	-	----	-	----	1	3.00
1373	2	2.25	3	2.50	2	2.50	3	2.70	1	2.00
1380	1	2.50	1	3.00	2	2.75	2	2.00	2	2.00
1417	-	----	-	----	3	2.30	2	2.00	2	2.25
1421	2	1.75	2	1.75	3	2.00	2	2.00	1	3.00
Average		2.45		2.21		2.27		2.25		2.49

*VanWagenen Index Score

TABLE XI

INTERIOR QUALITY* OF EGGS FROM
NEW HAMPSHIRES IN CONFINEMENT

Leg Band	March Eggs No.	March Qual. Score	April Eggs No.	April Qual. Score	May Eggs No.	May Qual. Score	June Eggs No.	June Qual. Score
422	1	2.0	2	2.0	-	---	2	1.5
424	1	3.0	2	2.5	1	2.0	1	3.5
425	-	---	3	1.0	1	1.0	-	---
426	2	1.75	3	2.2	3	1.2	2	2.25
427	-	---	1	2.0	1	2.0	1	2.0
428	-	---	1	2.0	1	2.0	1	2.0
430	2	2.25	1	1.5	1	1.0	2	2.75
431	1	2.5	2	2.5	2	2.25	2	2.25
434	1	2.5	2	1.75	1	1.5	2	1.25
436	1	4.0	2	2.75	2	2.25	2	3.00
437	2	3.0	2	2.00	2	1.50	-	---
441	2	3.0	1	2.5	-	---	2	2.25
442	2	2.25	3	2.3	3	2.3	-	---
443	-	---	3	1.8	-	---	1	2.00
458	1	4.0	2	3.5	3	3.3	2	2.75
460	1	2.5	2	2.0	1	2.0	1	2.00
461	2	2.75	3	2.5	-	---	-	---
462	1	2.00	2	2.00	-	---	1	2.00
463	1	2.50	3	2.00	-	---	2	2.75
465	2	2.25	-	---	-	---	-	---
466	1	4.50	1	3.00	-	---	-	---
467	2	1.75	3	2.00	2	1.25	2	1.75
468	1	2.00	1	3.00	1	1.00	1	1.50
471	3	1.80	-	---	-	---	2	2.00
Average		2.61		2.22		1.77		2.19

*VanWagenen Index Score

TABLE XII

INTERIOR QUALITY* OF EGGS FROM
S. C. WHITE LEGHORNS IN CONFINEMENT

Leg Band	March Eggs No.	March Qual. Score	April Eggs No.	April Qual. Score	May Eggs No.	May Qual. Score	June Eggs No.	June Qual. Score
794	1	2.5	3	2.2	2	2.0	3	2.0
795	2	2.5	1	2.0	1	2.0	2	2.25
800	-	---	2	2.25	-	---	2	2.0
802	1	2.0	3	2.25	2	1.5	2	1.75
804	-	---	1	3.00	1	2.2	-	---
805	1	2.5	1	2.5	-	---	2	3.25
810	3	2.2	3	2.5	3	2.2	3	2.30
811	1	1.5	-	---	-	---	1	1.5
813	-	---	1	1.5	-	---	1	4.0
816	1	1.5	2	1.5	2	2.25	2	2.0
817	1	2.0	2	1.5	2	1.5	1	1.5
820	2	2.25	3	2.0	2	2.0	3	2.2
821	3	3.00	2	2.00	2	2.0	2	2.0
824	3	2.0	1	1.0	2	1.25	2	1.5
830	3	1.3	-	---	3	1.2	3	1.67
831	1	1.5	2	1.25	2	1.25	1	2.0
832	1	3.0	-	---	3	1.8	3	2.5
834	-	---	-	---	3	1.8	2	2.25
835	2	2.75	3	2.67	2	2.5	2	2.5
836	1	2.0	2	1.75	2	2.0	1	1.5
837	2	1.75	2	1.75	3	1.5	2	1.75
839	2	3.75	1	2.5	1	3.0	2	3.5
859	-	---	1	1.5	-	---	-	---
864	-	---	1	2.0	-	---	-	---
Average		2.22		1.98		1.90		2.19

*VanWagenen Index Score

or meat spots during the entire period of observation. Hen number 1423 (Barred Plymouth Rock), in the same pen and under identical conditions as hen number 614, produced eggs of which 75 percent contained blood or meat spots.

Hen number 1209 (Barred Plymouth Rock) in confinement produced eggs of which 9.1 percent contained blood or meat spots. Hen number 1427, in the same pen and under identical conditions as hen 1209, produced eggs of which 50.0 percent contained blood or meat spots.

Eggs laid on the first three days of March, April, May, and June were observed for yolk color. A preliminary study of yolk color was made of the eggs from pens A-1 and A-4 before they were turned on ryegrass pasture February 16.

Yolk color was found to vary with the individuals irrespective of the breed. Yolk color of eggs from hen number 821 (S. C. White Leghorn) in confinement varied from 17.0 in March to 15.0 in June. While in the same pen and under identical conditions, hen number 835 (S. C. White Leghorn) produced eggs that varied in yolk color from 16.0 in March to 15.0 in May and 17.0 in June. In using the Heiman-Carver yolk color rotor, attention should be called to the fact that the lower the score, the lighter the color. A rating of 16.0 to 18.0 is considered a desirable, medium yellow yolk.

Hen number 1172 (Barred Plymouth Rock) in confinement laid eggs with an average yolk color of 17.0 in March, 16.0 in April, 18.0 in May and 17.0 in June. While in the same pen and under identical conditions, the eggs from hen number 1219 (Barred Plymouth Rock) had only 0.5 variation, a range of 16.0 in March to 15.5 in May. Variations as cited were characteristic of individuals in the breeds observed. This occurrence in variation was about the same in all the breeds observed.

It was observed that yolk color of eggs laid by the birds given access to range appeared darker before the candle and when broken out. This change in yolk color occurred during the first two weeks the birds were given access to the ryegrass pasture. No observations were made between February 16, when the hens were turned on the pasture, and March 1 to determine the exact number of days required to change the yolk color. It might be assumed that about one week was required, as poultry physiologists agree that approximately 90 percent of the yolk content is deposited in 8 or 9 days prior to ovulation.

Yolk color from pen A-1 (Barred Plymouth Rocks), which was given access to pasture from one o'clock until dark each day, was 16.0 in February, 17.2 in March, 16.9 in April, 16.9 in May, and 17.4 in June. Pen A-4 (Barred Plymouth Rocks), given access to pasture during daylight hours, produced eggs with a yolk color range of 16.0 in February, 17.3 in March and April, 17.0 in May, and 17.3 again in June.

This change in yolk color, which occurred when the hens were turned on pasture, is in agreement with similar work reported by Parker in 1946.

A comparison of the yolk color of New Hampshires, S. C. White Leghorns, and two pens of Barred Plymouth Rocks, all of which were kept in confinement, was of interest. Pen 1-1 (New Hampshires) produced eggs with a yolk color of 16.5 in March, 15.9 in April, 15.7 in May, and 16.3 in June. Pen 4-2 (S. C. White Leghorns) produced eggs with a yolk color of 16.5 in March, 15.9 in April and May, and 16.3 in June. Pen A-2 (Barred Plymouth Rocks) produced eggs varying in yolk color from 16.2 in March and April, to 16.0 in May, and 16.3 in June. Pen A-3 (Barred Plymouth Rocks) produced eggs varying from 16.1 in March, April, and May, to 16.3 in June. This variation in yolk color is probably not statistically significant but does indicate that uniform yolk color can be secured regardless of breed.

During the period of observation, the average yolk color of the breeds and pens was more consistant than for the individuals. The range in yolk color produced by given individuals ranged from 2.5 to 0.5. Of the pens in confinement, the S. C. White Leghorns produced eggs that varied 0.6 in yolk color; the New Hampshires produced eggs that varied 0.8 in yolk color; and the Barred Plymouth Rocks (Pens A-2 and A-3 combined) produced eggs that varied 0.3 in yolk color.

The range in yolk color of eggs produced by the pens on pasture (A-1 and A-4, Barred Plymouth Rocks) was from 16.0 in February, before having access to range, to 17.4 in June---access to range beginning February 16.

Only infertile, grade A eggs were used for storage in this problem. The eggs produced between March 10 and April 11 by Barred Plymouth Rocks both in confinement and on Italiam ryegrass pasture were treated and stored. The length of the storage period was from 74 to 107 days.

The eggs were candled, treated, and weighed before storage in the cooler, cellar, and non-insulated conference room (page 22). Upon removing the eggs from storage, they were again candled and weighed.

Temperature variations in the storage rooms were recorded during the storage period. The percent relative humidity in the cooler was determined. It was observed that the temperature range in the cooler was from 40 to 45 degrees F. with a relative humidity of about 75 percent. The temperature ranged from 65 to 70 degrees F. in the cellar and from 68 to 94 degrees F. in the conference room.

The egg cooler was refrigerated with a between-the-rail unit. Air was circulated in the cooler by means of a fan. There was no forced ventilation provided for the cellar. Ventilation in the non-insulated conference room was provided by raising or lowering of windows in the room.

As determined by weight, the average percent moisture loss of eggs after treatment and storage for from 74 to 107 days was:

	Cooler	Cellar	Conference Room
Method of Treatment	Percent	Percent	Percent
Control	5.7	5.4	25.9
Water 140°F., 10 min.	5.7	6.4	34.2
Water 212°F., 5 sec.	3.1	4.5	24.5
Oil Room Temperature	1.6	3.6	11.5
Oil 140°F., 10 min.	0.5	2.7	8.2
Oil 212°F., 5 sec.	0.3	3.6	7.9
Oil over 212°F., 5 sec.	---	1.7	6.6
Water glass	1.2	1.2	0.3

TABLE XIII

AVERAGE YOLK COLOR* OF EGGS FROM
BARRED PLYMOUTH ROCKS GIVEN LIMITED RANGE

Leg Band	Eggs No.	Yolk Color	Eggs No.	Yolk Color	Eggs No.	Yolk Color	Eggs No.	Yolk Color	Eggs No.	Yolk Color
614	2	16.5	2	17.0	2	16.0	2	16.2	2	17.5
619	1	16.0	2	17.0	2	16.7	3	17.2	2	17.7
630	2	16.0	3	17.3	2	17.5	3	17.3	3	17.7
637	3	16.3	2	17.0	3	17.0	2	16.2	3	17.5
642	3	16.0	3	17.5	2	17.0	1	17.0	2	17.0
655	1	16.0	2	17.7	3	17.7	-	——	-	——
1078	3	16.0	2	17.0	3	16.5	3	17.7	2	16.2
1085	3	16.0	-	——	3	16.2	2	16.7	1	17.5
1184	1	16.0	2	16.7	3	17.2	2	17.5	2	17.7
1208	3	15.3	2	17.0	3	16.7	3	17.0	2	17.2
1218	1	16.0	2	17.0	2	16.5	3	17.3	2	17.5
1239	-	——	-	——	3	17.0	3	17.0	1	16.0
1263	-	——	2	17.0	3	16.8	2	17.0	-	——
1268	2	16.0	2	17.5	2	17.2	2	17.7	2	18.0
1277	2	16.0	1	18.0	3	17.2	2	16.7	3	17.5
1283	1	16.0	3	17.3	2	17.2	2	17.7	2	18.0
1305	3	15.3	3	16.0	2	16.2	1	13.0	3	16.3
1311	1	16.0	3	17.3	2	17.5	2	17.0	2	18.0
1312	-	——	1	17.0	2	16.7	2	17.0	-	——
1336	1	16.0	2	16.5	-	——	3	16.3	2	17.0
1343	3	16.3	3	17.0	1	16.0	3	17.2	2	17.7
1393	2	16.0	2	17.5	2	17.0	1	18.0	3	18.2
1423	2	16.0	1	18.0	2	17.2	-	——	3	18.2
Average		16.0		17.2		16.9		16.9		17.4

*Heiman-Carver Yolk Color Rotor

TABLE XIV

AVERAGE YOLK COLOR* OF EGGS FROM BARRED PLYMOUTH ROCKS IN CONFINEMENT

Leg Band	March		April		May		June	
	Eggs No.	Yolk Color	Eggs No.	Yolk Color	Eggs No.	Yolk Color	Eggs No.	Yolk Color
617	2	17.0	3	16.3	2	15.0	2	16.7
643	2	16.0	2	16.0	-	----	2	15.7
691	2	16.2	-	----	-	----	-	----
700	2	17.5	3	16.7	3	16.0	3	16.2
710	2	16.0	2	16.5	2	16.5	1	17.0
725	1	16.0	-	----	1	16.0	1	16.0
736	-	----	2	16.2	2	16.2	3	16.2
769	3	16.0	2	16.5	1	17.0	2	17.0
782	2	16.0	2	16.5	1	16.0	1	17.5
787	2	16.0	3	16.2	2	16.0	3	16.7
790	1	17.0	2	17.0	1	16.0	-	----
1029	1	16.0	-	----	2	15.7	3	16.0
1041	3	16.0	3	16.0	2	16.2	3	16.3
1067	2	16.0	1	16.5	1	16.5	1	16.5
1094	-	----	3	16.0	1	16.0	-	----
1130	2	16.0	3	16.7	1	16.5	1	16.0
1159	2	16.0	2	15.5	-	----	-	----
1190	2	16.0	3	16.0	3	15.7	3	15.7
1205	2	16.0	2	15.0	3	15.5	2	15.5
1230	3	16.5	-	----	-	----	2	16.7
1249	2	16.0	1	16.0	3	16.0	1	15.0
1416	2	16.0	2	15.5	2	15.7	1	17.0
Average		16.2		16.2		16.0		16.3

*Heiman-Carver Yolk Color Rotor

TABLE XV

AVERAGE YOLK COLOR* OF EGGS FROM
BARRED PLYMOUTH ROCKS IN CONFINEMENT

Leg Band	March Eggs No.	March Yolk Color	April Eggs No.	April Yolk Color	May Eggs No.	May Yolk Color	June Eggs No.	June Yolk Color
602	3	16.3	2	16.2	1	16.5	-	----
658	2	16.0	2	16.2	2	16.0	1	16.5
660	-	----	1	16.0	-	----	1	17.0
1052	-	----	2	16.5	2	16.2	-	----
1091	3	16.2	2	16.5	2	16.5	-	----
1093	2	16.0	-	----	1	17.0	-	----
1116	1	16.5	3	16.3	2	16.2	2	16.2
1137	3	16.3	3	16.2	1	16.0	2	16.0
1158	2	16.0	2	16.2	3	16.3	1	16.5
1172	2	16.7	3	16.0	2	17.5	1	17.0
1209	3	16.2	3	16.0	2	16.2	3	16.2
1219	3	16.0	2	16.0	3	15.7	-	----
1235	-	----	2	16.0	-	----	1	17.0
1260	2	16.0	-	----	2	16.0	1	16.0
1286	2	16.0	2	15.5	2	16.0	3	16.2
1297	2	16.0	2	16.0	3	15.7	2	16.2
1315	1	16.0	1	17.0	-	----	-	----
1326	2	16.0	1	15.0	2	15.2	1	16.0
1366	1	16.0	2	16.2	1	15.0	-	----
1394	2	16.0	1	15.0	1	16.0	1	16.5
1406	1	16.0	-	----	-	----	-	----
1427	2	16.0	3	16.2	2	16.0	1	16.0
Average		16.1		16.1		16.1		16.3

*Heiman -Carver Yolk Color Rotor

TABLE XVI

AVERAGE YOLK COLOR* OF EGGS FROM
BARRED PLYMOUTH ROCKS GIVEN UNLIMITED RANGE

Leg Band	Feb. Eggs No.	Feb. Yolk Color	March Eggs No.	March Yolk Color	April Eggs No.	April Yolk Color	May Eggs No.	May Yolk Color	June Eggs No.	June Yolk. Color
601	2	16.5	2	16.7	2	16.0	2	16.0	3	16.7
652	3	16.0	3	17.0	2	16.7	2	16.7	2	17.5
668	3	16.0	3	17.5	3	17.7	2	16.7	2	17.5
781	3	16.0	3	17.0	2	16.5	2	16.0	3	15.0
1055	3	16.0	2	16.7	2	17.0	2	16.7	3	17.5
1074	-	----	-	----	-	----	-	----	1	18.0
1079	3	16.0	2	17.5	1	17.5	1	16.0	1	16.0
1100	2	16.0	3	17.0	3	17.7	-	----	2	17.5
1117	1	16.0	1	18.0	1	18.0	1	18.0	2	18.0
1121	3	16.0	3	17.2	2	17.2	2	17.2	3	17.5
1128	1	16.0	2	17.7	3	17.3	-	----	-	----
1167	3	16.0	1	17.0	-	----	1	16.5	1	17.0
1192	3	16.0	3	17.2	1	18.0	2	17.5	1	17.5
1193	2	16.0	2	17.2	2	17.2	2	17.0	2	17.0
1211	-	----	-	----	1	17.5	-	----	1	18.0
1226	1	16.0	3	17.5	-	----	-	----	-	----
1289	1	16.0	1	17.5	1	17.5	2	17.7	-	----
1304	2	16.0	2	17.0	3	17.0	1	18.0	2	17.0
1319	3	16.0	2	17.5	-	----	-	----	1	17.0
1345	3	16.0	-	----	-	----	-	----	1	18.0
1358	3	16.0	3	17.7	-	----	-	----	-	----
1373	2	16.0	3	18.0	2	17.0	3	18.0	1	18.0
1380	1	16.0	1	18.0	2	17.5	2	16.5	2	17.0
1417	-	----	-	----	3	17.7	2	17.7	2	17.7
1421	2	16.0	2	17.0	3	17.3	2	17.0	1	17.0
Average		16.0		17.3		17.3		17.0		17.3

*Heiman-Carver Yolk Color Rotor

TABLE XVII

AVERAGE YOLK COLOR* OF EGGS FROM
NEW HAMPSHIRES IN CONFINEMENT

Leg Band	March Eggs No.	March Yolk Color	April Eggs No.	April Yolk Color	May Eggs No.	May Yolk Color	June Eggs No.	June Yolk Color
422	1	17.0	2	16.5	-	----	2	16.7
424	1	16.5	2	15.0	1	15.0	1	16.5
425	-	----	3	15.7	1	15.0	-	----
426	2	16.2	3	15.0	3	15.0	2	16.7
427	-	----	1	16.0	1	17.0	1	16.0
428	-	----	1	16.0	1	15.0	1	16.0
430	2	16.5	1	16.0	1	16.5	2	16.7
431	1	16.0	2	15.2	2	15.5	2	16.0
434	1	16.0	2	15.5	1	16.0	2	16.0
436	1	16.0	2	16.0	2	15.0	2	16.5
437	2	16.7	2	16.2	2	16.0	-	----
441	2	16.0	1	15.0	-	----	2	16.5
442	2	16.0	3	16.0	3	16.0	-	----
443	-	----	3	16.5	-	----	1	16.0
458	1	17.0	2	16.0	3	15.3	2	16.5
460	1	17.0	2	15.5	1	16.5	1	16.0
461	2	16.7	3	16.3	-	----	-	----
462	1	16.0	2	15.5	-	----	1	16.0
463	1	16.0	3	16.3	-	----	2	16.7
465	2	16.2	-	----	-	----	-	----
466	1	18.0	1	17.0	-	----	-	----
467	2	16.7	3	17.0	2	16.7	2	16.7
468	1	17.0	1	15.0	1	15.0	1	16.0
471	3	16.0	-	----	-	----	2	16.0
Average		16.5		15.9		15.7		16.3

*Heiman-Carver Yolk Color Rotor

TABLE XVIII

AVERAGE YOLK COLOR* OF EGGS FROM
S.C. WHITE LEGHORNS IN CONFINEMENT

Leg Band	March Eggs No.	March Yolk Color	April Eggs No.	April Yolk Color	May Eggs No.	May Yolk Color	June Eggs No.	June Yolk Color
794	1	17	3	16.2	2	15.5	3	16.7
795	2	17	1	17.0	1	17.5	2	16.7
800	-	--	2	16.0	-	----	2	16.7
802	1	16	3	16.2	2	16.7	2	16.0
804	-	--	1	17.0	1	16.0	-	----
805	1	16	1	15.0	-	----	2	16.2
810	3	16.7	3	16.3	3	16.2	3	16.3
811	1	17.0	-	----	-	----	1	16.5
813	-	--	1	15.5	-	----	1	17.0
816	1	16.0	2	15.2	2	16	2	16.2
817	1	17	2	15.5	2	16	1	16.5
820	2	16	3	16	2	15	3	16.2
821	3	16.3	2	15.5	2	16	2	15
824	3	16.2	1	15	2	15	2	16.2
830	3	16.7	-	----	3	15.5	3	16.2
831	1	17	2	16	2	16.2	1	16
832	1	17	-	----	3	15.7	3	16.5
834	-	--	-	----	3	16.5	2	16.5
835	2	16	3	15.5	2	15	2	16.7
836	1	16	2	15.2	2	16	1	16
837	2	16.7	2	16	3	15.5	2	16.2
839	2	16.7	1	16	1	16	2	16.5
859	-	--	1	16	-	----	-	----
864	-	--	1	16	-	----	-	----
Average		16.5		15.9		15.9		16.3

*Heiman-Carver Yolk Color Rotor

It was observed that by shell treatment, a large percentage of the original moisture content of eggs was conserved while in storage. There was less moisture loss from eggs treated in oil or water glass before storage than in the control or water treated groups regardless of place stored.

When the place of storage was considered as a factor in conserving moisture in eggs, it was observed that, irrespective of treatment, the eggs stored in the cooler lost less moisture than the eggs stored in the cellar or non-insulated conference room. The only exception was in the eggs in water glass stored in the non-insulated conference room.

The range of moisture loss of eggs stored in the cooler was from 0.3 percent in oil treated (212 degrees F., 5 sec.) to 5.7 percent in water treated (140 degrees F., 10 min.). In the cellar the range was from 1.2 percent in water glass (1 qt. water glass to 9 qts. water) to 6.4 percent in water treated (140 degrees F., 10 min.). The eggs stored in the non-insulated conference room gave a wide variation from 0.3 percent in water glass to 34.2 percent in water treated (140 degrees F., 10 min.).

Irrespective of storage conditions, the eggs treated in water at 140 degrees F. for 10 minutes lost a greater percentage of their original moisture than did any of the other eggs stored.

Interior quality of eggs after treatment* and storage** for 74 to 107 days was:

Treatment	Place Stored		
	Cooler	Cellar	Conference Room
Control	3.2	4.8	5.0
Water 140°F., 10 min.	2.8	4.3	---
Water 212°F., 5 sec.	3.3	4.3	5.0
Oil room temperature	2.9	3.8	4.7
Oil 140°F., 10 min.	2.9	3.7	4.3
Oil 212°F., 5 sec.	3.1	3.7	4.5
Oil over 212°F., 5 sec.	---	3.7	4.5
Water glass	2.8	3.0	3.6

It was observed that the interior quality of all the eggs declined irrespective of treatment or storage conditions. In general, the eggs treated in oil and water glass retained their original quality better than did the control or water treated (Tables XIX, XX, XXI).

When considering the decrease in interior quality of eggs on a grade basis, it was observed that the eggs stored in the cooler irrespective of treatment, decreased approximately one grade (from grade A to grade B) during their storage period of 75 to 104 days.

It was observed that the interior quality of the eggs stored in the cooler was superior to that of the eggs stored in the cellar or non-insulated conference room. The range in interior quality of eggs stored in the cooler was from 2.8 for eggs in water glass and the eggs treated in water at 140 degrees F. for 10 minutes, to 3.3 for the eggs treated in water at 212 degrees F. for 5 seconds. This was a variation of 0.5.

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* Treatment, page 22
**Place of storage, page 22

The eggs stored in the cellar exhibited a wider variation than the eggs stored in the cooler. They varied from 3.0 in water glass to 4.8 for the controls stored under the same conditions. This gave a variation of 1.8 for the interior quality of the cellar stored eggs.

Eggs stored in the non-insulated conference room varied in interior quality from 3.6 in water glass to 5.0 for the eggs stored under control and treated in water at 212 degrees F. for 5 seconds. The eggs treated in water at 140 degrees F. for 10 minutes contained only a small quantity of thick albumen and no thin albumen. These latter eggs would be considered a loss on a commercial market.

In general, the eggs stored in the cellar and in the non-insulated conference room contained an albumen consistency that graded within the range for grade C eggs. Due to mold and stuck yolk observed in these eggs, they were considered a loss.

Yolk color as observed after treatment and storage for 74 to 107 days was:

	Place Stored		
Method of Treatment	Cooler	Cellar	Conference Room
Control	17.2	17.3	17.6
Water 140°F., 10 min.	17.4	17.3	18.2
Water 212°F., 5 sec.	17.1	17.2	17.3
Oil room temperature	16.6	16.9	17.2
Oil 140°F., 10 min.	17.1	17.1	17.2
Oil 212°F., 5 sec.	17.2	17.1	17.2
Oil over 212°F., 5 sec.	----	17.1	17.2
Water glass	17.1	17.2	17.3

It was apparent that yolk color of eggs tended to become slightly darker during storage. This was observed both in candling and breaking out (Tables XIII through XXI).

The range in yolk color of eggs stored in the cooler was 16.6 for eggs treated in oil at room temperature to 17.4 for eggs treated in water at 140 degrees F. for 10 minutes. Cellar stored eggs ranged from 16.9 in oil treated (room temperature) to 17.3 in control and water treated (140 degrees F., 10 min.).

The average yolk color for eggs stored irrespective of treatment was 17.1 in the cooler and cellar and 17.4 in the non-insulated conference room.

No stuck yolks or molded eggs were observed in the cooler stored eggs. Stuck yolks or molded conditions of eggs stored in the cellar were (1) 17.6 percent stuck yolks and no mold in the eggs treated in water glass, (2) 42.0 percent stuck yolks and 12.5 percent molded in eggs treated in oil (212 degrees F., 5 sec.), (3) 85.0 percent stuck yolks and 60.0 percent molded in eggs treated in oil (over 212 degrees F., 5 sec.), (4) 95.5 percent stuck yolks and 95.5 percent molded in eggs in oil at room temperature, (5) 96 percent stuck yolk and 73 percent molded in oil (140°F., 10 min.), (6) 100 percent of the control eggs and those treated in water (140° F., 10 min. and 212°F., 5 sec.) had both stuck yolks and mold.

There was no mold observed in the eggs stored in the non-insulated conference room. The percent of stuck yolks observed in the eggs stored in the non-insulated room was (1) 17.0 percent in eggs treated in oil (over 212 degrees F., 5 sec.), (2) 20.0 percent in eggs treated in oil (140 degrees F., 10 min.), (3) 38.5 percent in eggs treated in water (212 degrees F., 5 sec.), (4) 40.5 percent in eggs treated in water glass, (5) 42.0 percent in eggs treated in oil at room temperature, (6) 55.0 percent in eggs treated in oil (212 degrees F., 5 sec.), and (7) 100 percent in the control group and those treated in water (140 degrees F., 10 min.).

The yolks of the eggs stored in the cooler satisfactorily retained their original shape when broken out. The yolks of the eggs stored in the cellar and conference room appeared inferior in quality when compared with the yolks from the cooler storage eggs. This was evidenced by the fact that the eggs stored in these two places were, in general, a loss. The principal deterioration was due to moldy eggs in the cellar and stuck yolks in the eggs in the non-insulated room.

A total of 263 eggs were washed, treated, and stored as described on page 22. Both chemical and mechanical means were employed in cleaning the eggs.

The materials used in washing the eggs were Soilax, Trend, and Vel. None of these were considered to be entirely satisfactory in removing all foreign materials and stains from the eggs. Better results were obtained when the temperature of the water in which the eggs were dipped or rotated and rinsed was 140 degrees F. or more. Soilax removed the foreign materials and stains from the eggs better than did Trend or Vel.

The most efficient and satisfactory means to remove all the foreign materials and stains from the eggs was by mechanical means

TABLE XIX

BREAKING STRENGTH, PERCENT WEIGHT LOSS, YOLK COLOR, AND ALBUMEN SCORE OF EGGS AFTER TREATMENT AND STORAGE IN COOLER (1)

Pen	Method of Treatment	Days in Storage	Eggs No.	Av. Wt. Gms. Beg.	Av. Wt. Gms. End	Av. Wt. Loss %	Av. Brkg. Strength	Av. Yolk Color*	Av. Alb. Score**	Stuck Yolk No.	Molded No.
A-1	Control	104	10	64.0	62.1	3.0	4.1	17.8	3.3	----	----
A-2			15	67.5	65.2	3.4	4.5	16.6	3.3	----	----
A-3			7	68.7	65.9	4.1	5.6	16.4	3.0	----	----
A-4			15	62.3	59.6	4.3	4.2	17.9	3.2	----	----
Average				65.6	63.2	3.7	4.6	17.2	3.2		
A-1	Water 140	106	13	66.2	62.9	5.0	4.4	17.7	2.7	----	----
A-2	Degrees F.		14	66.3	62.3	6.0	4.2	16.9	2.8	----	----
A-3	10 Minutes		8	66.5	63.0	5.3	4.2	17.2	3.1	----	----
A-4			13	63.8	59.7	6.4	4.7	17.7	2.8	----	----
Average				65.7	62.0	5.7	4.4	17.4	2.8		
A-1	Water 212	92	15	65.0	63.6	2.1	3.7	17.5	3.3	----	----
A-2	Degrees F.		12	68.1	65.1	4.4	3.1	16.7	3.2	----	----
A-3	5 Seconds		9	67.3	66.2	1.6	4.1	16.6	3.4	----	----
A-4			12	59.8	57.3	4.2	3.5	17.6	3.2	----	----
Average				65.0	63.0	3.1	3.6	17.1	3.3		
A-1	Oil at	84	13	65.8	64.9	1.4	4.7	16.8	3.0	----	----
A-2	Room		12	69.0	68.2	1.2	4.1	16.4	3.0	----	----
A-3	Temp.		5	65.9	64.0	2.9	4.2	16.1	2.8	----	----
A-4			12	62.7	62.1	1.0	4.9	17.3	3.0	----	----
Average				65.8	64.8	1.6	4.5	16.6	2.9		

(continued)

TABLE XIX

BREAKING STRENGTH, PERCENT WEIGHT LOSS, YOLK COLOR, AND ALBUMEN SCORE OF EGGS AFTER TREATMENT AND STORAGE IN COOLER(1) (CONTINUED)

Pen	Method of Treatment	Days in Storage	Eggs No.	Av. Wt. Gms. Beg.	Av. Wt. Gms. End	Av. Wt. Loss %	Av. Brkg. Strength	Av. Yolk Color*	Av. Alb. Score**	Stuck Yolk No.	Molded No.
A-1	Oil 140	77	16	65.8	65.6	0.3	4.2	17.8	2.8	----	----
A-2	Degrees F.		12	67.6	67.3	0.4	4.3	16.3	2.9	----	----
A-3	10 Minutes		8	65.5	65.1	0.6	4.7	16.4	3.1	----	----
A-4			12	62.2	61.7	0.8	4.1	18.0	2.8	----	----
Average				65.3	64.9	0.5	4.3	17.1	2.9		
A-1	Oil 212	75	17	65.1	65.0	0.1	3.8	17.7	3.2	----	----
A-2	Degrees F.		12	66.8	66.3	0.7	3.5	16.6	3.0	----	----
A-3	5 Seconds		3	67.8	67.8	0.0	4.7	17.2	3.2	----	----
A-4			11	61.7	61.4	0.5	3.7	17.4	2.9	----	----
Average				65.3	65.1	0.3	3.9	17.2	3.1		
A-1	Water	97	11	76.0	75.0	1.1	4.1	17.8	2.9	----	----
A-2	Glass		14	68.7	68.0	1.0	3.9	16.5	2.8	----	----
A-3			8	70.2	69.4	1.2	5.0	16.2	2.9	----	----
A-4			12	63.0	62.0	1.6	4.2	18.0	2.7	----	----
Average				69.5	68.6	1.2	4.3	17.1	2.8		

(1) Temperature - 40-45°F. and Relative Humidity of 75%

* Heiman-Carver Yolk Color Rotor

** VanWagenen Index Score

TABLE XX

BREAKING STRENGTH, PERCENT WEIGHT LOSS, YOLK COLOR, AND ALBUMEN SCORE OF EGGS AFTER TREATMENT AND STORAGE IN CELLAR (1)

Pen	Method of Treatment	Days in Storage	Eggs No.	Av. Wt. Beg	Gms. End	Av. Wt. Loss %	Av. Brkg. Strength	Av. Yolk Color*	Av. Alb. Score**	Stuck Yolk No.	Molded No.
A-1	Control	101	14	67.5	64.4	4.6	3.9	17.7	4.5	14	14
A-2			12	69.4	65.8	5.2	4.1	17.0	4.7	12	12
A-3			10	65.4	60.8	7.0	4.8	16.9	5.0	10	10
A-4			12	62.0	59.0	4.8	3.6	17.8	5.0	12	12
Average				66.1	62.5	5.4	4.1	17.3	4.8		
A-1	Water 140	82	11	66.3	62.7	5.4	4.0	17.8	4.0	11	11
A-2	Degrees F.		13	68.0	63.7	6.3	3.8	17.0	4.7	13	13
A-3	10 Minutes		10	64.5	60.0	7.0	4.3	16.5	4.4	10	10
A-4			12	61.9	57.5	7.1	4.0	18.0	4.2	12	12
Average				65.2	61.0	6.4	4.0	17.3	4.3		
A-1	Water 212	93	12	67.3	64.3	4.5	3.9	17.3	4.1	11	11
A-2	Degrees F.		14	67.6	64.6	4.4	3.9	17.4	4.6	14	14
A-3	5 Seconds		10	66.6	64.4	3.3	4.5	16.2	4.5	10	10
A-4			12	63.0	59.3	5.9	4.0	17.8	4.1	12	12
Average				66.1	63.1	4.5	4.1	17.2	4.3		
A-1	Oil Room	86	14	65.5	62.9	4.0	3.8	17.1	3.9	14	14
A-2	Temp.		12	67.2	65.3	2.8	4.1	16.7	3.8	12	12
A-3			8	64.5	63.1	2.2	4.7	16.2	3.9	8	8
A-4			11	62.7	59.4	5.3	4.1	17.5	3.8	11	11
Average				65.0	62.7	3.6	4.2	16.9	3.8		

(continued)

TABLE XX

BREAKING STRENGTH, PERCENT WEIGHT LOSS, YOLK COLOR, AND ALBUMEN SCORE OF EGGS AFTER TREATMENT AND STORAGE IN CELLAR[1] (CONTINUED)

Pen	Method of Treatment	Days in Storage	Eggs No.	Av. Wt. Gms. Beg.	Av. Wt. Gms. End	Av. Wt. Loss %	Av. Brkg. Strength	Av. Yolk Color*	Av. Alb. Score**	Stuck Yolk No.	Molded No.
A-1	Oil 140	81	15	65.6	63.9	2.6	4.2	17.9	3.6	15	14
A-2	Degrees F.		9	67.3	65.9	2.1	4.4	16.4	3.7	8	6
A-3	10 Minutes		10	65.4	64.2	1.8	4.7	16.2	3.8	9	9
A-4			14	64.1	61.3	4.4	4.0	18.1	3.7	14	6
Average				65.6	63.8	2.7	4.3	17.1	3.7		
A-1	Oil 212	75	13	65.0	63.1	2.9	4.3	17.9	3.8	3	0
A-2	Degrees F.		11	65.4	63.5	2.9	4.3	16.3	3.5	6	2
A-3	5 Seconds		7	68.3	65.1	4.7	5.6	16.6	3.7	4	1
A-4			17	63.3	60.8	3.9	4.4	17.8	3.7	7	3
Average				65.5	63.1	3.6	4.6	17.1	3.7		
A-1	Oil over	79	7	66.5	65.3	1.8	4.3	18.0	3.8	6	2
A-2	212 Degrees		7	69.4	68.1	1.6	4.2	16.3	3.9	7	6
A-3	F. 5 Seconds		4	64.0	63.0	1.6	4.2	16.2	3.7	4	2
A-4			15	63.4	62.1	2.0	4.2	17.8	3.4	11	9
Average				65.8	64.6	1.7	4.2	17.1	3.7		
A-1	Water	101	14	64.3	63.2	1.7	4.2	17.7	3.1	2	—
A-2	Glass		12	66.6	65.3	1.9	3.5	16.6	2.9	3	—
A-3			7	65.4	65.1	0.5	4.4	16.8	2.9	-	—
A-4			11	63.8	63.4	0.6	4.5	17.7	3.0	1	—
Average				65.0	64.2	1.2	4.1	17.2	3.0		

(1) Temperature 65-70°F.

* Heiman-Carver Yolk Color Rotor

**VanWagenen Index Score

TABLE XXI

BREAKING STRENGTH, PERCENT WEIGHT LOSS, YOLK COLOR, AND ALBUMEN SCORE OF EGGS AFTER TREATMENT AND STORAGE IN CONFERENCE ROOM[1]

Pen	Method of Treatment	Days in Storage	Eggs No.	Av. Wt. Beg.	Gms. End	Av. Wt. Loss %	Av. Brkg. Strength	Av. Yolk Color*	Av. Alb. Score**	Stuck Yolk No.	Molded No.
A-1	Control	102	17	66.2	48.6	26.6	4.2	18.0	5.0	17	--
A-2			12	66.9	48.1	28.1	4.5	17.0	5.0	12	--
A-3			7	67.9	56.1	17.4	4.7	17.0	5.0	7	--
A-4			12	64.5	44.1	31.6	3.9	18.4	5.0	12	--
Average				66.4	49.2	25.9	4.3	17.6	5.0		
A-1	Water 140	107	12	64.3	46.2	28.1	4.6	18.8	***	12	--
A-2	Degrees F.		11	63.9	43.5	31.9	4.1	17.0		11	--
A-3	10 Minutes		7	62.7	40.7	35.1	4.3	18.0		7	--
A-4			7	60.8	35.4	41.8	4.1	19.0		7	--
Average				62.9	41.4	34.2	4.3	18.2			
A-1	Water 212	93	13	65.4	51.2	21.7	3.9	17.1	5.0	13	--
A-2	Degrees F.		12	67.2	50.5	24.8	3.7	16.8	5.0	12	--
A-3	5 Seconds		10	64.3	50.1	22.1	4.6	17.1	5.0	10	--
A-4			12	63.2	44.7	29.3	3.7	18.2	5.0	12	--
Average				65.0	49.1	24.5	4.0	17.3	5.0		
A-1	Oil at	84	13	68.0	60.1	11.6	3.9	17.6	4.9	6	--
A-2	Room		12	67.8	58.6	13.6	4.1	16.6	4.7	5	--
A-3	Temp.		7	65.8	58.7	10.8	4.8	16.7	4.9	4	--
A-4			13	62.2	56.0	10.0	4.5	17.8	4.5	4	--
Average				65.9	58.3	11.5	4.3	17.2	4.7		

(continued)

TABLE XXI

BREAKING STRENGTH, PERCENT WEIGHT LOSS, YOLK COLOR, AND ALBUMEN SCORE OF EGGS AFTER TREATMENT AND STORAGE IN CONFERENCE ROOM(1) (CONTINUED)

Pen	Method of Treatment	Days in Storage	Eggs No.	Av. Wt. Gms. Beg.	Av. Wt. Gms. End	Av. Wt. Loss %	Av. Brkg. Strength	Av. Yolk Color*	Av. Alb. Score**	Stuck Yolk No.	Molded No.
A-1	Oil 140	80	14	65.4	60.3	7.8	4.2	18.0	4.5	1	--
A-2	Degrees F.		9	65.9	58.1	11.8	4.6	16.5	4.3	3	--
A-3	10 Minutes		9	66.4	62.2	6.3	4.4	16.4	4.3	3	--
A-4			14	64.2	59.8	6.8	4.0	17.9	4.2	2	--
Average				65.5	60.1	8.2	4.3	17.2	4.3		
A-1	Oil 212	74	9	66.9	60.1	10.2	4.6	18.0	4.6	3	--
A-2	Degrees F.		7	64.4	57.6	10.6	4.6	16.4	4.6	3	--
A-3	5 Seconds		6	66.9	63.9	4.5	4.4	16.5	4.7	4	--
A-4			11	65.8	61.6	6.4	3.7	18.0	4.2	2	--
Average				66.0	60.8	7.9	4.3	17.2	4.5		
A-1	Oil over	76	12	65.8	62.2	5.5	4.2	17.7	4.3	1	--
A-2	212 Degrees		12	69.1	64.0	7.4	4.3	16.4	4.6	3	--
A-3	F. 5 Seconds		5	68.0	64.4	5.3	4.3	16.7	4.9	2	--
A-4			12	62.7	57.6	8.1	3.8	18.1	4.3	1	--
Average				66.4	62.0	6.6	4.1	17.2	4.5		
											Soured
A-1	Water	100	12	65.8	65.5	0.5	3.9	18.0	3.7	5	3
A-2	Glass		14	66.9	66.6	0.4	4.3	16.3	3.5	5	2
A-3			6	64.7	64.6	0.1	4.8	16.9	3.5	2	-
A-4			10	64.4	64.2	0.3	4.0	17.9	3.7	5	1
Average				65.4	65.2	0.3	4.2	17.3	3.6		

(1) Temperature 68-94°F.

* Heiman-Carver Yolk Color Rotor

** VanWagenen Index Score

*** Each egg had only a small amount of thick albumen such as buffing with sandpaper, scrubbing with steel wool under tap water, and rubbing with a cloth which had been dampened with water.

There was apparently no preservative or detrimental effect of any of the substances used. It was observed that in general the interior quality of the washed and stored eggs did not vary from that of unwashed eggs that received similar treatments (Tables VII through XXII). Few rotten and addled eggs were observed in the soiled lots which were washed and stored in the cellar and non-insulated room.

It was observed that fecal material in the poultry house was a source of interior contamination for the eggs which were smeared with it. This was apparent since 21.7 percent of the eggs soiled with manure and left over night, then washed in tap water with steel wool before storage in the cellar were rotten when they were removed from storage ninety-three days later. No rotten eggs were observed in clean eggs that were washed in the same way and stored with them (Table XXII).

Five hundred seventy-six infertile eggs produced by Barred Plymouth Rocks were used in studying the value of shell treatment in the conservation of quality when held at high temperatures. The eggs were treated and held in a Jamesway forced draft incubator at a temperature of 99 to 100 degrees F. with a relative humidity of 56 percent, as stated on page 22 and 23. Moisture loss, interior quality, and yolk color were observed every fourth day. The eggs were divided into six equal lots for study.

Moisture loss was calculated from the total number of eggs in

TABLE XXII

EFFECT OF WASHING AND TREATMENT ON STORAGE QUALITY OF EGGS

Treatment	Place Stored	Days in Storage	No. Eggs Examined	Av. Wt. Loss %	Av. Yolk Color*	Av. Alb. Score**	Stuck Yolk No.	Molded No.	Remarks
Eggs rubbed in droppings, stored over night in cooler, washed in tap water with steel wool	Cooler[1]	93	24	4.5	17.2	3.4	1	--	--------
Same as above	Cellar[2]	93	23	6.5	17.4	4.5	16	13	5-rots 1-grade C
Clean eggs washed in tap water with steel wool	Cooler	92	24	4.0	17.0	3.1	--	--	1-green sours
Same as above	Cellar	92	24	7.0	17.3	4.4	19	22	2-grade C
Clean eggs washed in Soilax	Cooler	90	24	3.5	17.0	3.2	--	--	--------
Same as above	Conference Room[3]	90	24	24.2	17.3	5.0	23	--	1-addled
Dirty eggs washed in Soilax	Cooler	91	12	1.8	16.3	2.8	--	--	--------
Same as above	Conference Room	91	12	29.9	17.0	5.0	9	3	1-addled

(continued)

TABLE XXII

EFFECT OF WASHING AND TREATMENT ON STORAGE QUALITY OF EGGS (CONTINUED)

Treatment	Place Stored	Days in Storage	No. Eggs Examined	Av. Wt. Loss %	Av. Yolk Color*	Av. Alb. Score**	Stuck Yolk No.	Molded No.	Remarks
Dirty eggs washed in Trend. Treated with oil room temperature	Cooler	68	12	----	16.1	2.7	--	--	------
Same as above	Conference Room	68	12	4.4	16.8	5.0	2	--	1-rot 2-addled 7-grade C
Dirty eggs washed in Trend	Cooler	68	12	----	16.2	2.8	--	--	------
Same as above	Conference Room	68	12	18.4	17.3	5.0	7	--	2-rots 3-grade C
Dirty eggs washed in Vel. Treated with oil room temperature	Cooler	75	12	1.2	16.2	3.0	--	--	------
Same as above	Conference Room	75	12	5.7	17.0	4.8	3	--	------
Dirty eggs washed in Vel	Cooler	75	12	----	16.6	3.0	--	--	------
Same as above	Conference Room	75	12	26.4	17.5	5.0	9	1	1-rot 1-addled 1-grade C

[1]Temperature 40-45°F. and Relative Humidity 75%
[2]Temperature 65-70°F.
[3]Temperature 68-94°F.

*Heiman-Carver Yolk Color Rotor
**VanWagenen Index Score

the incubator on each observation day. Interior quality and yolk color were obtained from 24 eggs which were broken out every fourth day during the holding period.

The average moisture loss on the fourth day varied from 0.8 percent in oil treated* eggs (212 degrees F., 5 sec.) to 4.6 percent in water treated eggs (212 degrees F., 5 sec.), on the eighth day varied from 2.0 percent in oil treated lot (212 degrees F., 5 sec.) to 8.0 percent in the water treated group (212 degrees F., 5 sec.), on the twelfth day varied from 3.0 percent in the oil treated eggs (212 degrees F., 5 sec.) to 11.2 percent in the control eggs, on the sixteenth day varied from 5.8 percent in oil treated eggs (212 degrees F., 5 sec. to 16.2 percent in control eggs.

The percent moisture loss is given for each method of treatment on the observation days in Table XXIII. It is supplemented with Figure 3.

The eggs treated in water (212 degrees F., 5 sec.) tended to lose the greatest percentage of moisture up to the eighth day. After that time, the control eggs tended to lose the greatest percentage of moisture. However, the difference was not over 0.9 percent in the control and water treated eggs during the last eight days of storage and only 1.1 percent during the first eight days (Table XXIII.).

It was observed that the eggs treated in oil at 212 degrees F. for 5 seconds lost a smaller percentage of moisture throughout the experimental period than did any of the other eggs. The eggs treated

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*Gulf-Gem Oil; gravity 34.5; viscosity S.U.V. 88 at 70°F., 46 at 130°F., 34 at 210 F.; pour point -5°F.; odorless; clear-water white.

in oil lost a smaller percentage or their original moisture during the period than did the control or water treated groups irrespective of the length of time in storage.

The control eggs and water treated eggs had lost as much moisture by the eighth day of storage as had the oil treated eggs on the sixteenth day of storage (Figure 3).

The average interior quality of the eggs held at high temperatures ranged from 2.58 in the oil treated lot (140 degrees F., 10 min.) to 3.25 in the water treated group (212 degrees F., 5 sec.) on the fourth day of observation, 2.90 in the oil treated (140 degrees F., 10 min.) to 3.95 in the control eggs on the eighth day of observation, from 3.35 in the oil treated eggs (212 degrees F., 5 sec.) to 4.50 in water treated eggs (212 degrees F., 5 sec.) on the twelfth day of observation, 3.35 in oil treated eggs (140 degrees F., 10 min.) to 4.70 in water treated eggs (212 degrees F., 5 sec.) on the sixteenth day of observation.

The eggs which received the hot oil treatments tended to retain their original interior quality better during the period held at high temperatures than did the eggs in the control lots or in lots treated by other methods (Table XXIII). The eggs treated in oil graded high in interior quality at the end of the period than did the eggs in the control lot or those treated in water (212 degrees F., 5 sec.) at the eighth day of observation. The eggs treated in water (140 degrees F., 10 min.) retained their interior quality up to twelve days of storage as well as did the oil treated eggs at that period (Figure 4).

Average yolk color of eggs held at high temperatures varied from 16.0 in control and oil treated eggs (140 degrees F., 10 min.) to 16.9 in water treated eggs (212 degrees F., 5 sec.) on the fourth day, 16.0 in oil treated lots (212 degrees F., 5 sec.) to 16.9 in the contro lot on the eighth day, 16.5 in oil treated (room temperature) to 16.9 in the control group on the twelfth day, 16.6 in the control and water treated group (140 degrees F., 10 min.) to 16.9 in water treated lot (212 degrees F., 5 sec.) and oil treated eggs (140 degrees F., 10 min.) on the sixteenth day. A maximum variation of 0.9 in yolk color was observed on the fourth and eighth days; it varied only 0.4 on the twelfth day and 0.3 on the sixteenth day of observation.

The average yolk color of all eggs held at high temperatures and broken out on the fourth day was 16.3; on the eighth day, 16.5; on the twelfth day, 16.7; and on the sixteenth day, 16.7. This observation indicated that yolk color gradually increased to the twelfth day of storage at high temperature then remained constant to the sixteenth day.

Weakening of the vitelline membrane was observed at an earlier period in the control and water treated eggs than in the oil treated eggs. Very few broken yolks were observed through the eighth day of storage. The percentage of broken yolks observed were as follows:

Treatment	Percent Broken Yolks Observed			
	4th day	8th day	12th day	16th day
Control	----	8.3	62.5	91.7
Water 140 F., 10 min.	---	25.0	29.2	66.7
Water 212 F., 5 sec.	4.1	4.1	58.3	95.8
Oil room temperature	---	4.1	58.3	20.8
Oil 140 F., 10 min.	---	---	29.2	29.2
Oil 212 F., 5 sec.	---	---	----	33.3

TABLE XXIII

EFFECT OF TREATMENT ON INTERIOR QUALITY OF EGGS HELD AT 100° F. AND RELATIVE HUMIDITY OF 56 PERCENT

Method Treated	Ave. Wt. Beg.	Average Weight	Ave. Wt. Loss %	Ave. Yolk Color*	Ave. Qual. Score**
		Fourth Day			
		96 Eggs Weighed		24 Eggs Broken Out	
Control	63.3	61.4	2.5	16.0	2.90
Water 212°F. 5 Sec.	64.1	61.0	4.6	16.2	3.25
Water 140°F. 10 Min.	64.1	62.1	3.1	16.9	2.70
Oil Room Temp.	63.1	61.9	1.8	16.2	2.80
Oil 212°F. 5 Sec.	63.3	62.8	0.8	16.5	3.10
Oil 140°F. 10 Min.	62.9	61.9	1.6	16.0	2.58
		Eighth Day			
		72 Eggs Weighed		24 Eggs Broken Out	
Control		58.6	7.4	16.9	3.95
Water 212°F. 5 Sec.		58.1	8.1	16.3	3.84
Water 140°F. 10 Min.		59.2	7.2	16.7	3.30
Oil Room Temp.		60.7	3.6	16.7	3.30
Oil 212°F. 5 Sec.		61.9	2.0	16.6	3.10
Oil 140°F. 10 Min.		61.1	2.8	16.0	2.90
		Twelfth Day			
		48 Eggs Weighed		24 Eggs Broken Out	
Control		56.1	11.2	16.9	4.40
Water 212°F. 5 Sec.		56.6	10.9	16.8	4.50
Water 140°F. 10 Min.		56.9	10.6	16.8	3.56
Oil Room Temp.		59.2	5.3	16.5	3.90
Oil 212°F. 5 Sec.		61.6	3.0	16.8	3.35
Oil 140°F. 10 Min.		60.4	3.9	16.6	3.50
		Sixteenth Day			
		24 Eggs Weighed		24 Eggs Broken Out	
Control		52.5	16.2	16.6	4.60
Water 212°F. 5 Sec.		53.4	15.5	16.9	4.70
Water 140°F. 10 Min.		54.2	15.3	16.6	4.20
Oil Room Temp.		58.2	7.5	16.8	3.70
Oil 212°F. 5 Sec.		57.9	5.8	16.7	3.60
Oil 140°F. 10 Min.		57.4	7.4	16.9	3.35

* Heiman-Carver Yolk Color Rotor

**VanWagenen Index Score

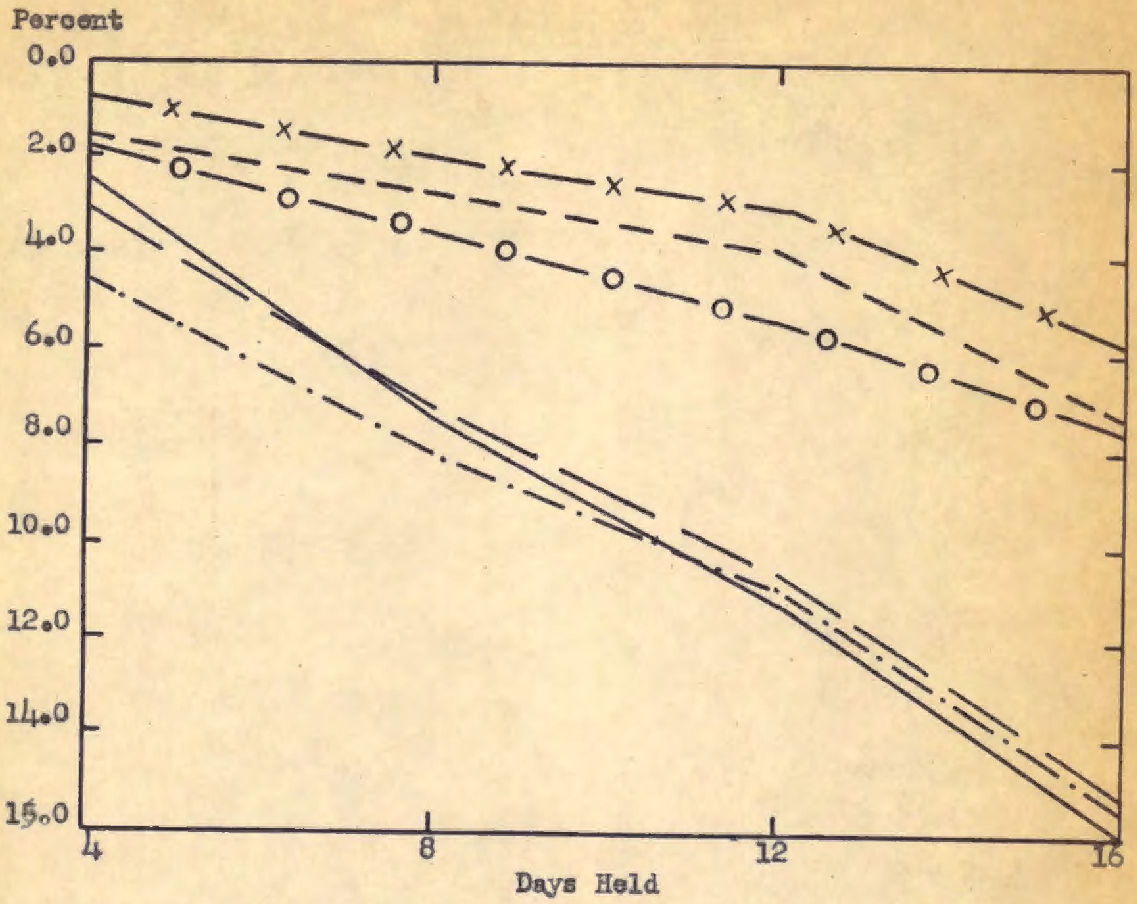

Figure 3

Percent Moisture Loss of Eggs
Held at 100° F. and Relative Humidity
of 56 Percent

Control	Oil 140°F. 10 Min.
Water 140°F. 10 Min.	o Oil room temp.
Water 212°F. 5 Sec.	x Oil 212°F. 5 sec.

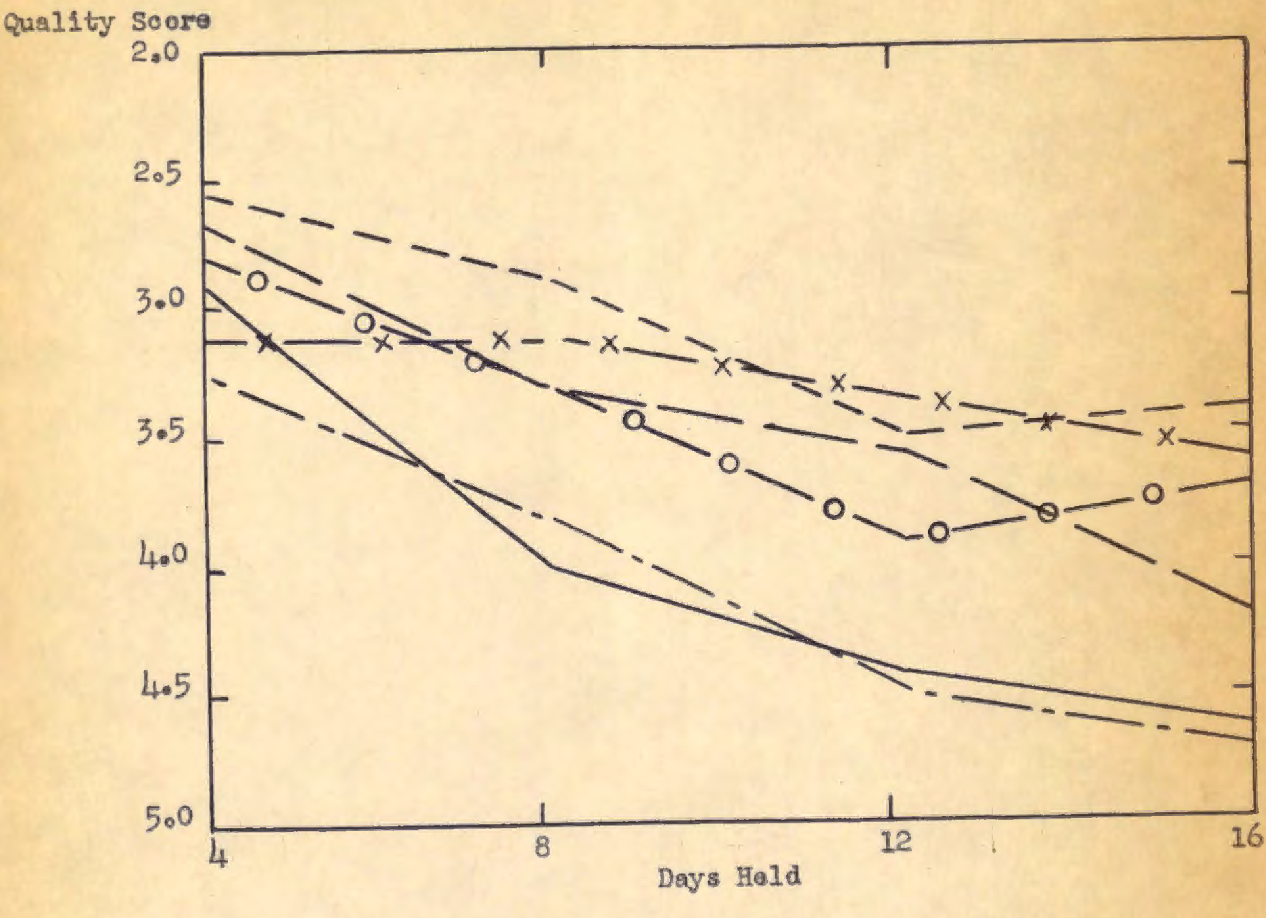

FIGURE 4

Decrease in Quality of Eggs
Held at 100° F. Relative Humidity 56 Percent

——— Control	— — — Oil 140°F. 10 Min.
—— —— Water 140°F. 10 Min.	— o — Oil room temp.
—— — —— Water 212°F. 5 Sec.	— x — Oil 212°F. 5 Sec.

SUMMARY

In this experiment 2850 eggs, which were produced by Barred Plymouth Rocks, New Hampshires, and S. C. White Leghorns, were examined for shell breaking strength, exterior quality, interior quality, yolk color, shell color, and keeping quality in storage after treatment with oil or water.

It was found that egg shape, size, shell texture, and interior quality were characteristics of the individual.

Shell color was a characteristic of the breed.

There was a tendency for the highest quality eggs to be produced during the month of May.

Eggs stored in a cooler retained their original quality better than eggs stored in a cellar or in a non-insulated room.

Oil treated eggs tended to retain their original quality better in storage than eggs treated in water.

Barred Plymouth Rocks, receiving a ration containing 10 percent alfalfa meal, produced eggs with darker colored yolks when given access to Italian ryegrass pasture.

All the foreign materials and stains were not removed from the soiled eggs by washing them with Soilax, Trend, or Vel.

REFERENCES

REFERENCES

Albright, W. P., and R. B. Thompson, 1935. Variations of egg yolk color and characteristics produced by feeding and environment. Poultry Sci., 16:373-375.

Almquist, H. J., and W. F. Holst, 1931, Variability of shell porosity in the hen's egg. Hilgardia, 6:61-71.

Almquist, H. J., and B. R. Burmster, 1934. Characteristics of an abnormal type egg shell. Poultry Sci., 13:116-122.

Almquist, H. J., and F. W. Lorenz, 1935. Firm white of fresh and storage eggs. Poultry Sci., 16:340-341.

Alp, H. H., R. C. Ashby, and L. E. Card, 1938. Studies of the market quality of eggs from 109 farms in Southeastern Illinois. Ill. Agr. Exp. Sta. Bull., 441:399-411.

Alp, H. H., 1939. High quality eggs for Illinois Markets. Ill. Agr. Exp. Sta. Cir., 494:3-16.

____, 1947. Who and what determines egg quality? Hoards Dairyman, July 10:583.

Asmundson, V. S., 1931. The formation of the hen's egg. Scientific Agr., 11:590, 662, 775.

Atwood, Horace, 1914. Some factors affecting the weight, composition, and hatchability of hen eggs. W.V. Agr. Exp. Sta. Bull., 145:73-102.

Atwood, Horace, and Chas. E. Weakley, Jr., 1917. Certain characteristics of hen eggs. W. V. Agr. Exp. Sta. Bull., 166:3-35.

Atwood, Horace, 1923. Certain correlations in the weight and number of eggs and the weight of the fowls. W. V. Agr. Exp. Sta. Bull., 182:1-16.

_____, 1926. Some factors affecting the weight of eggs, W. V. Agr. Exp. Sta. Bull., 201:1-30.

Benjamin, E. W., 1920. A study of selections for the size, shape, and color of hen's eggs. Cornell Agr. Exp. Sta. Memoir, 31:195-311.

Benjamin, E. W., H. C. Pierce, and W. D. Termohlen, 1949. Marketing Poultry Products. Fourth Edition:47-65. John Wiley and Sons.

Bennion, Noel, L., and D. C. Warren, 1933. Temperature and its effect on egg size in the domestic fowl. Poultry Sci., 12:69-82.

Bennion, N. L., and F. E. Price, 1942. Some factors that affect egg quality. U. S. Egg and Poultry Mag., 48:232-235, 255-256.

Berg, Lawrence R., Gordon E. Bearse, and C. M. Hamilton, 1947. The effect of Newcastle disease on egg production and egg quality. Poultry Sci., 26:614-622.

Berg, Lawrence R., 1949. How feed affects shell quality. Pacific Poultryman, May:7, 18.

Botsford, H. E., 1939. Handling eggs for market. Cornell Agr. Ext. Bull., 416:3-26.

Card, Leslie E., and Melvin Henderson, 1933. Farm Poultry Production. 152-164. Interstate Printing Company.

Cooper, James B., 1944. Poultry for Home and Market. 262-269. Turner E. Smith and Company.

Curtis, Mayrie R., 1914. Factors influencing the size, shape, and physical constitution of the egg of the domestic fowl. Me. Agr. Exp. Sta. Bull., 228:105-136.

Denton, Charles A., and Harry W. Titus, Effect of fresh cereal grass on interior quality of eggs. U. S. Egg and Poultry Mag., 47:474-476, 509-510.

Dossin, C. O., 1948. Keep more eggs in the top grade. Poultry Tribune, Nov.: 7, 25-26.

Funk, E. M., 1943. Stabilizing quality in shell eggs. U. S. Egg and Poultry Mag., 48:112-114.

______, 1943b. Stabilizing quality in shell eggs. Mo. Agr. Exp. Sta. Bull., 362:1-38.

______, 1944. Effect of temperature and humidity on the keeping quality of shell eggs. Mo. Agr. Exp. Sta. Bull., 382:3-27.

______, 1948a. Experiments in cleaning soiled eggs for storage. Mo. Agr. Exp. Sta. Bull. 426:1-35.

______, 1948b. Wash eggs the right way. U. S. Egg and Poultry Mag., 54:10.

Gish, Clarence L., Loyal F. Payne, and W. J. Peterson, 1940. The effect of grass silage on color of egg yolk. Poultry Sci., 19:154-156.

Hall, G. O., 1939. Breed variations in egg characteristics. Poultry Sci., 18:282-287.

_____, 1944. Egg shell color in crosses between white and brown shelled breeds. Poultry Sci., 23:259-265.

_____, 1945. Preserving eggs in water glass. Poultry Sci., 24:451-458.

Hays, F. A., 1937. Inheritance of egg size and egg character. Mass. Agr. Exp. Sta. Bull., 344:1-28.

_____, 1940. Transmitting ability in males of enes for egg size. Poultry Sci., 20:217-220.

Henderson, E. W., and H. L. Wilcke, 1933. Effect of ration on yolk color. Poultry Sci., 12:266-273.

Heusen, G. F., and L. C. Norris, 1945. Oyster shells, calcite grit, ground limestone, and granite grit in rations for hens. Poultry Sci., 25:173-179.

Hutt, F. B., and Helen Bozivich, 1946. On the supposed matriculous inheritance of egg size in the fowl. Poultry Sci., 25:554-561.

Jeffrey, F. P., and V. Darago, 1940. N. J. Agr. Exp. Sta. Bull., 682:3-16.

Jeffrey, F. P., and J. Pino, 1943. The effect of heredity and of certain environmental factors on the incidence of blood spots in chicken eggs. Poultry Sci., 22:230-234.

Jull, M. A., 1924. Egg weight in relation to production. I. The relation of the weights of the parts of the egg to total egg weight. Poultry Sci., 3:77-88.

_____, 1943. Successful Poultry Management. 325-363. McGraw-Hill Book Company.

_____, 1947. Poultry Breeding, Second Edition: 339-367. John Wiley and Sons.

Kent, O. B., 1932. Poultry and eggs on the farm. U. S. Egg and Poultry Mag., 38:34-39.

King, D. F., and S. L. Chestnut, 1943. Poultry Production in the South. 157-177. Interstate Publishers and Printers

Knox, Charles W., and Albert B. Godfrey, 1938. Factors influencing the percentage of thick albumen of hen's eggs. Poultry Sci., 17:159-162.

_____, 1940. Five years of breeding for high and low percentage of thick albumen in the eggs of Rhode Island Reds. Poultry Sci., 19:291-294.

Lippincott, William A., and Leslie E. Card, 1946. Poultry Production. Seventh Edition: 114-131. Lea and Febiger.

Lorenz, F. W., L. W. Taylor, and H. J. Almquist, 1934. Firmness of albumen as an inherited characteristic. Poultry Sci., 13:14-17.

Lorenz, F. W., and H. J. Almquist, 1936. Seasonal variations in egg quality. Poultry Sci., 15:14-17.

Lorenz. F. W., 1949. On the efficiency of egg processing oils. Poultry Sci., 28:119-127.

Marble, Dean R., 1931. A statistical study of factors affecting egg weight in the domestic fowl. Poultry Sci., 10:84-92.

McCammon, Ruth B., Martha S. Pittman, and L. A. Wilhelm, 1934. The odor and flavor of eggs. Poultry Sci., 13:95-101.

Nalbandov, A. V., and L. E. Card, 1944. The problem of blood clots and meat spots in chicken eggs. Poultry Sci., 23:170-180.

Norton, L. J., Scott Hathorn, and Emer Broadbent, 1948. Grading will improve the market for Illinois eggs. Ill. Agr. Exp. Sta. Cir., 631:3-12.

Olsen, M. W., 1939. Effects of high temperatures for short periods on the quality of infertile eggs. Poultry Sci., 18:123-124.

Parker, Sylvia L., 1927. Seasonal variations in yolk color. Poultry Sci., 6:259-273.

Parker, Jesse E., 1946. Relation of types of ration to the interior quality of hens' eggs. N. D. Agr. Exp. Sta. Bull., 6:3-7.

Payne, L. F., 1925. The cause of olive-colored egg yolks. Poultry Sci., 4:102-107.

Pennington, M. E., 1934. Characteristics of abnormal type of egg shell. U. S. Egg and Poultry Mag., 40:23-60.

Quinn, Joseph, Clement D. Gordon, and Albert B. Godfrey, 1945. Breeding for egg shell quality as indicated by egg weight loss. Poultry Sci., 24:399-403.

_____, 1946. Keeping quality of shell eggs can be improved through breeding. U. S. Egg and Poultry Mag., 52:349-380.

Quinn, Joseph, 1947. Produce top quality eggs by selection and breeding. Amer. Egg and Poultry Review, 8:98-101.

_____, 1948. Breeding for better eggs. Hatchery and Feed, Oct.: 12, 50.

Ringrose, R. C., and C. L. Morgan, 1939. A study of the effect of green feed upon interior egg quality. Poultry Sci., 18:125-128.

Romanoff, A. L., 1929. Study of the physical properties of the hens egg shell in relation to the function of the shell secretory glands. Biol. Bull., 56:351-356.

Romanoff, A. L., and W. D. Yushok, 1948. Preservation of intact eggs by sealing with chemical agents. Food Research, 13:331-335.

Sharp, P. F., and A. VanWagenen, 1935. Examination in November of several commercial lots of middle west oil dipped eggs. U. S. Egg and Poultry Mag., 41:23-62.

Sherwood, Ross M., 1928. The effects of various rations on the storage quality of eggs. Tex. Agr. Exp. Sta. Bull., 376:5-12.

Skoglund, W. C., and A. E. Tomhave, 1940. Frequency of gathering eggs and effect upon interior egg quality. Poultry Sci., 20:322-326.

Sowell, D. F., and C. L. Morgan, 1936. The relationship of protein supplement to interior egg quality. Poultry Sci., 15:219-222.

Stewart, George F., and S. Bose, 1948. Factors influencing the efficiency of solvent-oil mixtures in the preservation of shell eggs. Poultry Sci., 27:270-276.

Taylor, Lewis W., and J. Holmes Martin, 1928. Factors influencing thickness of egg shell. Poultry Sci., 8:39-44.

Tennessee Dept. of Agr., 1948. Agr. Trends in Tennessee. 115-122.

Titus, Harry W., and Ralph B. Nestler, 1935. Effect of vitamin D on production and some properties of eggs. Poultry Sci., 16:90-98.

Titus, Harry W., James C. Fritz, and W. R. Kauffman, 1938. Some observations on egg-yolk color. Poultry Sci., 17:38-45.

United States Dept. of Commerce, Bureau of the Census, 1945. Vol. I, Part 20:8.

United States Dept. of Agr., Bureau of the Census, 1947. Agr. Statistics, 432-439.

VanWagenen, A., and G. O. Hall, 1936. The inheritance of certain characters affecting egg quality. Poultry Sci., 15:405-410.

VanWagenen, A., G. O. Hall, and H. S. Wilgus, Jr., 1937. Variations in egg quality characters in certain breeds, varieties and strains of chickens. Jour. Agr. Res., 51:767.

Vondell, John H., 1933. Is the production of off-flavored eggs an individual bird characteristic? U. S. Egg and Poultry Mag., 39:18-19.

Warren, D. C., 1936. Breeding for egg size. U. S. Egg and Poultry Mag., 42:686-687, 696.

Warren, D. C., and Richard L. Schnepel, 1940. The effect of air temperatures on egg shell thickness in the fowl. Poultry Sci., 19:67-72.

Waters, Nelson F., and John C. Weldin, 1929. Studies on the inheritance of egg weight, R. I. Agr. Exp. Sta. Bull., 208:3-26.

Waters, Nelson F., 1940. Genetic aspects of egg weight observed during inbreeding experiments. Poultry Sci., 20:14-27.

_____, 1944. The weight of chicken eggs as influenced by diallel crossing. Poultry Sci., 24:81-82.

Wilhelm, L. A., and Victor Heiman, 1937. The effect on yolk color of various ingredients in poultry feeds. Poultry Sci., 16:416-418.

Wilhelm, L. A., 1940. Some factors affecting variations in egg shell quality. Poultry Sci., 19:246-253.

Winter, A. R., and Owen Cotterill, 1949. The preservation of shell egg quality by oil dipping right on the farm. Amer. Egg and Poultry Review, 10:14-16, 19.

Winter, A. R., and E. M. Funk, 1949. Poultry Science and Practices. Revised from 1941 Edition: 124-125, 142. J. B. Lippincott Company.