

FACTORS AFFECTING QUALITY OF MARKET EGGS

by

KUM-SEONG LEONG

B.S., National Taiwan University, Taipei, Free China, 1960

A MASTER'S REPORT

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Poultry Science

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1963

Approved by:

Jack L. Fry
Major Professor

LD
2668
R4
1963
L584
C.2
Doku-
ments

TABLE OF CONTENTS

INTRODUCTION	1
DEFINITION OF EGG QUALITY	3
Exterior Quality Factors	3
Interior Quality Factors	6
Abnormalities in Eggs	6
METHODS OF MEASUREMENT OF EGG QUALITY	7
Interior Egg Quality	7
Candled Quality	8
Yolk Measurement	8
Albumen Measurement	10
Exterior Egg Quality	13
Porosity	14
Shell Thickness	15
Specific Gravity	15
Shell Strength	16
Shell Weight	17
FACTORS AFFECTING INITIAL EGG QUALITY	17
Disease	17
Strain	21
Drugs	23
Management	26
Season	29
Age	31
Ration	32
FACTORS AFFECTING QUALITY OF STORED EGGS	38

Temperature and Time	38
Humidity	40
Atmosphere	42
Shell Treatment	44
Overwrapping	47
RELATIONSHIP OF QUALITY TO CONSUMER PREFERENCES AND PER CAPITA CONSUMPTION LEVELS	48
SUMMARY	50
ACKNOWLEDGMENTS	52
REFERENCES	53

INTRODUCTION

The egg of the domestic fowl contains all the essentials necessary for the development of a chick embryo. Eggs rank with milk as a general source of essential food elements for growth and maintenance of health in the human body. Nature has so completely balanced the food nutrients in the egg that it is almost a perfect food for man. The protein of eggs contains a great number of amino acids that are so essential to a complete diet. Eggs are rich in iron and phosphorus, and fairly rich in riboflavin and vitamin A. They are a good source of calcium, a mineral required for normal bone and tooth formation. Since eggs contain so many essential nutrients, eggs should be included in the daily diet and will provide a considerable portion of the protein, vitamin and mineral requirements of the body. Low in calories and easily digested, eggs are an excellent food for all ages (Parnell, 1957). Besides these, eggs have many uses, are easy to prepare, and are liked by most people. As a result, the egg becomes an important and economic food in human nutrition.

The initial quality of an egg can be affected by many factors such as environmental conditions, management, feeds, breeds, diseases, the condition of the hen, and others. Blood and meat spots in eggs result from an abnormal function of the oviduct of the hen or from an unbalanced ration. Diseases like Newcastle disease and infectious bronchitis will cause abnormal shell quality and poor interior quality. Poor shells will result if calcium is deficient in the ration. Different breeds lay different quality eggs because of different genetic make-up. This initial quality of an egg can be improved if these factors can be properly handled.

The interior quality of an egg is at its maximum at the time it is laid.

The quality can not be improved and deterioration begins immediately. Deterioration can be affected by many factors such as temperature, humidity, time and improper handling. Eggs are among the most delicate and perishable food products, are subject to rapid deterioration, and are easily affected by unfavorable surroundings. The most important part of this nutritive food is that it is very unstable and subject to very rapid quality decline under the influence of various factors of which temperature, time and humidity are the most important.

In food value, the quality of a market egg is high and is not greatly affected by a decline in market quality. Flavor and general attractiveness are better when first laid than at any later time. Low egg quality means low return per dozen because the functional and esthetic values of the eggs are low. The demand for high-quality eggs is growing and is likely to continue to grow for some time to come. Because consumers are relatively quick to discriminate against poor eggs, they are willing to pay well for the assurance of being able to secure a particular grade or quality of eggs. It is important not only that the right kinds of eggs be produced, but that they be so handled as to reach the consumer with least possible loss of their original quality. Therefore, maintaining as high a quality of market eggs as possible is always welcomed by consumers.

The purpose of this report is to review the literature concerning factors affecting egg quality. Some factors affecting quality of eggs can be controlled by proper handling; others can not. More experiments are needed to solve all the problems involved in the marketing of shell eggs.

DEFINITION OF EGG QUALITY

Quality may be defined as the inherent properties of a product which determine its degree of excellence. Those conditions and characteristics which consumers want and for which they are willing to pay are in a broad sense factors of quality. The quality of an egg is determined by comparing a number of factors. However, the relative merit of one factor alone may determine the quality score of the egg in as much as the final quality score can be no higher than the lowest score given to any one of the quality factors.

Standards of quality have been developed as a means of classifying individual eggs according to various groups of conditions and characteristics that experience and research have shown to be wanted by consumers and for which they are willing to pay. Grades differ from standards in that they provide tolerances for individual eggs within a lot to be of lower quality than the grade name indicates.

Quality factors may be divided into two general groups: exterior quality factors, apparent from external observation; and interior quality factors which involve the contents of the shell.

Exterior Quality Factors

Size. Egg size is determined by the weight because it measures the quantity received by the buyer. The size of individual eggs is established by regulations and is expressed in ounces per dozen (Table 1). Uniformity in size of individual eggs used in dozen or case lots is important. Variance of such eggs should not exceed 3 ounces per dozen.

Shape. It is difficult to describe the ideal shape of an egg. The normal egg has an oval shape with one end larger than the other, and it tapers toward

Table 1. U. S. weight classes for consumer grades of shell eggs.

Size or weight class	Minimum net weight (ounces) per dozen	Minimum net weight (pounds) per 30 dozen
Jumbo	30	56
Extra Large	27	50.5
Large	24	45
Medium	21	39.5
Small	18	34
Peewee	15	28

the smaller end. Eggs that are unusual in shape, such as those having ridges, rough areas, or thin spots, are placed in the lower grades (Table 2).

Soundness of Shell. A sound-shelled egg is one whose shell is unbroken. The shell may be unbroken or broken in varying degrees. Shells with thin spots should be judged in grading according to protective strength. Some shells may contain hairline checks that are visible only before the candling light. These blind checks, and other checks, may also be detected by belling.

Cleanliness of Shell. A clean shell is one that is free from foreign material and from stains or discolorations that are readily visible. Grade regulations require the shell to be clean in "AA" and "A" qualities. Slight stain is allowed in "B" quality; when the stain is localized, approximately 1/32 of the shell surface may be slightly stained, and when the slightly stained areas are scattered, approximately 1/16 of the shell surface may be slightly stained. Prominent stains are classed as dirty (Table 2).

Shell Color. Shell color does not affect the quality of eggs. The color of shell is an inherited character. It is important in marketing because certain markets pay higher prices for white eggs; others prefer brown eggs.

Table 2. Summary of U.S. Standards for Consumer Grades of Individual Shell Eggs

Quality Factor	AA Quality	A Quality	B Quality
Shell	Clean	Clean	Clean; to very slightly stained.
	Unbroken Practically normal	Unbroken Practically normal	Unbroken May be slightly abnormal
Air Cell	1/8 inch or less in depth	3/16 or less in depth	3/8 inch or less in depth
	Practically regular	Practically regular	May be free but not bubbly
White	Clear	Clear	Clear
	Firm	May be reasonably firm	May be slightly weak
Yolk	Outline slightly defined	Outline may be fairly well defined	Outline may be well defined
	Free from defects	Practically free from defects	May be slightly enlarged and flattened May show definite but not serious defects

For eggs with dirty or broken shells, the standards of quality provide the following three additional classifications:

Dirty	Check	Leaker
Unbroken May be dirty	Checked or cracked but not leaking	Broken so contents are leaking

Interior Quality Factors

The U. S. Standards for consumer grades of individual shell eggs (Table 2) are applicable only to eggs of the domesticated chicken that are in the shell. They are based on candled appearance and take into consideration the size of the air cell and the condition of the yolk and albumen. As of August 1, 1963 Grade C has been deleted from the U. S. consumer grades of shell eggs since this grade is seldom used.

Abnormalities in Eggs

Through the process of candling, many abnormalities in eggs will be noted. They are grouped below according to their acceptability for sale as shell eggs.

Acceptable.

Double Yolked Eggs. Two yolks dropped into the oviduct at or about the same time result in double yolked eggs.

Thin Shelled Eggs. These are caused by deficiencies in the diet, environmental temperature, condition of the bird, age of the bird, and/or heredity. The shell must be sound to be acceptable in market channels.

Acceptable Depending on Degree of Abnormality.

Off-Colored Yolks. The composition of the feed affects the yolk color or off-color. Grading is according to the degree of off-color.

Blood Spots. Blood spots are caused by rupture of a blood vessel in the follicle at the time of ovulation. Small blood spots may be placed in Grade C (no longer a consumer grade). Large blood spots should be classified as loss.

Meat Spots. They are caused by bits of tissue being sloughed off the oviduct or may sometimes be the result of blood spots which have lost their bright red color. Brown shelled eggs have more tendency to have colored meat spots than do white shelled eggs. Eggs containing meat spots of any reasonable

size should be considered as loss.

Out of Grade.

Egg Within an Egg. The rather unusual condition of an egg within an egg is due to a reversal of direction of passage of the egg by the wall of the oviduct followed by enclosure of the egg in another shell with some additional albumen but usually not a second yolk.

Soft Shelled Eggs. Prematurely laid, soft shelled eggs may be due to certain diseases.

Off-Flavored Eggs. Sometimes feed ingredients will affect egg flavor; the egg also may pick up off-flavors from storage atmospheres.

Inedible or Loss Eggs.

Stuck Yolk. Stuck yolks most commonly occur in stale and badly shrunken eggs when the yolk has been in one position for a long time in contact with the shell. The yolk membrane adheres to the shell membrane, preventing the yolk from moving freely when the egg is twirled.

Sour Eggs. This is a form of deterioration that is not easily detected before the candling light. The white appears thin, watery and frequently cloudy. When broken, such eggs have a distinctive sour odor.

Black Rot, White Rot, Mixed Rot, and Moldy Eggs. These loss eggs are the result of microbial deterioration.

METHODS OF MEASUREMENT OF EGG QUALITY

Methods of Measurement of Interior Egg Quality

It is widely accepted that there are many different methods which can be used to determine interior egg quality. The most commonly used ones, past and present, are herein discussed.

I. Candled Quality. This method consists of holding the egg before a suitable light and looking at the illuminated shell to determine the condition of its contents. A 60 watt bulb is generally used. Candling quality is determined on the basis of the condition of shell, air cell, albumen, yolk and abnormalities such as blood spots, meat spots, and yolk defects. Candling is not an infallible method for measuring interior quality because of the human judgement factor and the necessity of estimating the opened egg condition by colors, lights and shadows seen through the shell. A major problem in classifying eggs into various quality categories is the lack of an objective means of determining differences among eggs of varying interior quality. Candling is the primary method used commercially at the present time.

II. Yolk Measurement.

A. Yolk Index. The first yolk index method was developed by Sharp and Powell (1930). Procedure for this method is to remove the yolk from the albumen and wait 5 minutes for the yolk to spread. Measure its height and width two ways at right angles; then the yolk index is obtained by dividing the height of the yolk by its average diameter. Average values for fresh eggs usually fall between 0.42 and 0.40. The disadvantages are: (1) it is time consuming, and (2) the separation cannot be made on low quality eggs without rupturing the yolk.

The method of Sharp and Powell was modified by Funk (1948). His method involves measuring height and width of yolk without removing it from the albumen, and without waiting 5 minutes. Average values for fresh eggs are usually near 0.45. Funk compared the two methods and suggested that the value determined by his method should be reduced by 10% for comparison with values determined by the Sharp and Powell method. In 1951, Sauter, Stadelman, Harns and McLaren compared these two methods. The result was that for eggs with high

interior quality, the reduction of yolk index as measured by Funk should be 20%, for eggs of lower interior quality about 15% and for stale eggs the 10% originally suggested should be used.

B. Yolk Centering. A set of yolk centering scores was developed by Lorenz (1953) and each egg is compared with this set of scores. Scoring ranges are from one through ten with the yolk being most out of center having a score of ten. These scores are based on the condition of the broken out egg; centering of the yolk as a means of determining candled grade has recently been deleted.

C. Yolk Mottling. Yolk mottling is scored by a rating system such as the one developed by Baker, Hill, Van Tienhoven and Bruckner (1957). This scoring system begins with one for no mottling and progresses through ten for severe mottling.

D. Yolk Color. Yolk color is currently measured by spectrophotometric means but has in the past been measured by comparison with standards.

(1) Color Rotor. Yolk color can be determined by the Heiman and Carver (1935) Color Rotor method. The egg yolk is compared to a series of 24 colors ranging from almost pure white to brick red.

(2) Fletcher Yolk Color Standard. This standard was developed by D. A. Fletcher, a Canadian worker. This scale is comprised of 15 concave colored discs with handles. These 15 standard color graduations range from light yellow (No. 1) to deep orange (No. 15). In Canada the Fletcher yolk color standard replaces the somewhat more elaborate American produced color rotor, now apparently unavailable (Snyder, 1961).

(3) NEPA and AOAC Yolk Color Method. Both the NEPA and AOAC methods are used routinely in the egg products industry to determine yolk color. A NEPA color of #4 of #5 (dark yolk) is desired by egg breakers. Both methods

utilize acetone for the extraction of yolk pigment and a spectrophotometer or photometer reading to determine intensity.

III. Albumen Measurement. Of the methods to be discussed, Albumen Score and Haugh Units are the two most commonly used in research work. Haugh Units are also used to determine quality for the Fresh Fancy Quality program.

A. Albumen Score (U.S.D.A. chart). Pictures show the top and side view of twelve eggs of different quality for broken out egg comparison. Scores 1, 2, and 3 represent the appearance of high, average, and low Grade AA quality. Scores 4, 5, and 6 represent the appearance of eggs of high, average, and low Grade A quality. Scores 7, 8, and 9 represent the appearance of broken out eggs of high, average, and low Grade B quality. Scores 10, 11, and 12 represent the appearance of high, average and low Grade C quality. This method is more rapid than Haugh Unit determinations since neither the egg weight nor the albumen height need be taken and no calculation is required. It is, however, less objective.

B. Albumen Index. With the use of outside calipers, the two widths of the thick albumen at a 90° angle are measured, added together, and divided by two. The height of albumen is measured and divided by the average width and the albumen index thus obtained. Albumen index of a fresh egg is usually 0.09 to 1.20.

C. Diameter of Albumen.

(1) Thick Albumen Diameter. With the use of outside calipers, the two widths of the thick albumen at a 90° angle are measured, added together, and divided by two. This average width constitutes the thick albumen diameter.

(2) Thin Albumen Diameter. The same procedure described for thick albumen is used in determination of thin albumen diameter.

D. Percentage of Albumen. To determine percentage of albumen portions, a sieve which has a diameter of 4 inches, a $\frac{1}{2}$ inch raised rim and a mesh of 9 per inch was constructed by Holst and Almquist (1931). The egg is broken into a petri dish. The yolk is removed, care being taken to separate the yolk and leave in the dish any adhering white. The white is then poured into the sieve. The portions are determined as follows.

(1) Percent Outer Thin Albumen. The outer thin albumen is allowed to pass through this sieve into a 50 ml. cylinder for a period of 6 minutes. This volumetrically measured amount constitutes outer thin albumen which is then computed as a percent of total albumen.

(2) Percent Inner Thin Albumen. The additional amount of albumen that passes through the sieve in 2 additional minutes after the thick albumen membrane is punctured in several places constitutes inner thin albumen.

(3) Percent Thick Albumen. The portion of albumen that will not pass through the sieve in 8 minutes constitutes thick albumen.

(4) Total Percent Thin Albumen. Inner and outer thin albumen are combined and computed as total percent thin of total albumen.

This method can be used as a measure of deterioration in storage experiments but is a very time consuming operation.

E. Shape of Albumen. The shape of both thick and thin albumen may be considered as a criteria. The shape of each is determined by developing a scoring system which ranges from one through five. Each egg is considered and rated according to the amount of spreading of the thin or thick albumen.

F. Chalazae Size. A dual scoring system is developed to determine chalazae size. This scoring system ranges from one through six for quantity of chalazae present, and the amount of chalazae visible over the yolk.

G. Haugh Units. The egg is weighed to the nearest gram and then broken out on a flat surface. The height of the thick albumen is measured with a tripod micrometer as described by Haugh (1937). The interior quality calculator developed by Brant, Otte, and Norris (1951) is used to determine the Haugh Units. It is important to measure the albumen height immediately after breaking. A delay of a few minutes can make a difference in the Haugh Unit reading. Eggs with very high albumen will not have a flat surface and in such cases a point about halfway between the yolk and the edge of the widest expanse of thick white should be selected.

In 1953, Sauter, Harns, Stadelman and McLaren compared the relationship of candle quality of eggs to other quality measurements. The result was that highly significant correlations were obtained between candled quality and albumen index, yolk index, yolk color, albumen score and pH. Besides these, the higher the quality of the egg as determined by candling, the better the cooked product.

In 1958, Wesley and Stadelman completed a "Measurements of Interior Egg Quality" study. They used 13 different methods of determining interior quality including: Haugh Units, Thick Albumen Diameter, Thin Albumen Diameter, Yolk Index, Chalazae Size, Yolk Mottling, Yolk Centering, Shape of Thin Albumen, Shape of Thick Albumen, Percent Outer Thin Albumen, Percent Inner Thin Albumen, Percent Thick Albumen, and Total Percent Thin Albumen. The result was that Haugh Unit values are closely related to thin albumen diameter, yolk centering, shape of thin albumen, shape of thick albumen, percent outer thin albumen, percent thick albumen, and total percent thin albumen. Yolk index, though it is significantly correlated to several interior quality measurements, does not give as complete a picture of overall egg quality as do Haugh Unit values. These findings are in agreement with Sharp and Powell (1930),

who found that the height of the thick albumen decreases with the age of the egg much more rapidly than yolk index, and was a more critical means of quality evaluation. Thick albumen diameter is not significantly correlated with the yolk index, but is significantly correlated with Haugh Unit value. It is not a practical interior quality measurement and is also time consuming. While measurement of the thin albumen is time consuming, it is felt that this measurement reflects the appearance of the broken out egg as the housewife sees it to a greater degree than any other measurement studied. Because of this possibility it is an important interior quality measurement. Percent thick albumen is significantly correlated with fewer of the other measurements than any of the measurements taken with the exception of chalazae size and yolk mottling. From a practical standpoint, percent thick albumen is not a good indicator of quality as normally defined. Yolk mottling, yolk centering, chalazae size, and percent inner thin albumen have no significant correlation with any of the methods used in this study. Since these factors were not significantly correlated with other measurements and yet play an important role in consumer acceptance of broken-out egg quality, the next step might be to make a consumer survey to determine which factors the housewife considers most important. It was concluded on the basis of this work that Haugh Unit values, yolk index, and thin albumen diameter are the most practical interior quality measurements to use to get a relatively complete quality description of a normal egg. Haugh Unit values are significantly correlated to more quality measurements than any other measurement studied. Haugh Unit values are significantly correlated with 8 of the 13 methods studied.

Methods of Measurement of Exterior Quality

Shell quality is an important factor in egg quality particularly in

relation to the handling and transportation of eggs. The thickness and porosity of egg shells are important factors in maintaining egg quality. Shell thickness influences breaking strength and porosity influences the passage of gases and microorganism. Shell quality can be measured in several ways.

I. Porosity. Attempts have been made to determine egg permeability with water (Thunberg, 1902), with air (Haines and Moran, 1939, and Romanoff, 1940), and dyes (Weston and Halnan, 1927, and Almquist and Holst, 1931). The various methods known for determining egg shell permeability are either too time consuming, require a great deal of equipment, or are largely dependent upon subjective evaluation of results. Recently, Fromm (1959) employed spectrophotometric studies to determine shell permeability. This technique involves the use of a colorimetric method to determine shell permeability by quantitatively determining the degree of dye penetration into or through the shell of the egg. The eggs are held in a 0.1% methylene blue solution in absolute methyl alcohol for 60 seconds. The dye on the surface of the eggs is then washed off by immersing them in successive containers of methyl alcohol. The eggs are air dried, the contents removed and the shells of two eggs selected at random and placed in a mortar. The shells are then comminuted with a pestle, and the dye lodged within the shells or between the shell membranes is extracted by thoroughly mixing with 50 ml. of methyl alcohol. The alcoholic dye solution is then decanted into a centrifuge tube and centrifuged at 1900 r.p.m. for 5 minutes. The optical density of the supernatant liquid in the centrifuge tube is determined with a spectrophotometer. This technique has been shown to be effective with both white and brown shell eggs. The limitation is that changes of egg or dye solution temperatures affected the degree of dye penetration into the eggs and the procedure is

extremely time consuming.

II. Shell thickness. At least two devices, a convex anvil micrometer and a thickness measure gauge are generally used for measuring shell thickness. Both instruments are calibrated to 0.001 inch. Thickness measurements are preferably made on the equatorial region of the egg. Olsson (1936) indicated that the shell thickness coefficient of variability is least in the equatorial region. Welch et. al. (1960) in their studies on the comparison of the two devices, have found that the thickness gauge produces an approximately 0.002 inch higher reading than the micrometer. However, the thickness gauge is commonly used in measuring shell thickness. For measuring the thickness of an egg shell an Ames No. 25 paper thickness gauge is probably the most accurate method for determining shell thickness.

Shells thinner than 0.013 of an inch are poor risks in market channels (Brant and Shrader, 1952).

III. Specific Gravity Method (Olsson, 1934). This method provides a measure of shell quality without injury to the intact egg, whether it be used for hatching or goes into market channels. The specific gravity method is a simple floatation procedure. Eggs are dipped into brine solutions having a range of specific gravity such as 1.062 to 1.102 in intervals of 0.004, the end point being the lowest specific gravity in which the egg floats. The higher the specific gravity in which an egg floats, the better is its shell quality.

The use of specific gravity as an index of egg shell quality is found to have some advantages and some disadvantages. Measurement of shell quality by specific gravity leaves the egg intact for further use. To measure shell thickness or shell weight the egg must be opened. However, it is questionable whether specific gravity is as accurate a measurement

as is shell weight or shell thickness. A change in temperature of several degrees in either the egg or the salt solution will change the specific gravity reading for a particular egg. The shape of the egg also has some influence on specific gravity.

When eggs are transferred from one salt solution to another, even though they are rinsed before they are dipped in the second solution, water on the shell dilutes the next solution. A large number of eggs dipped in a small volume of salt solution could change the specific gravity of the solution appreciably.

IV. Shell strength. Several devices have been designed and various methods adapted to measure egg shell quality. In the majority of cases the methods have been too cumbersome and complex for practical use and have shown far greater variation than warrants their general application. When the methods require breaking of the shell, they obviously have practical limitations.

Romanoff (1929), Swenson and James (1932), Almquist and Burmester (1934), Stewart (1936), Stuart and Hart (1938) applied either a downward or a sideways force or pressure as a means of measuring shell strength and corrected their results with shell thickness. Lund et al. (1938) devised an apparatus for measuring the resistance of an egg to crushing and its shell to puncturing. Tully and Franke (1932) introduced a puncturing method which had the advantage over other methods that an egg could be tested repeatedly. Cheney and MacIntyre (1947) used a modified puncturing method involving a penetrometer with which a correlation in most samples of approximately 0.80 was obtained between shell thickness and puncture resistance.

Kennard (1945) applied a shock test to duplicate conditions encountered in handling and transportation as a measure of shell quality. Novikoff

and Gutteridge (1949) used a direct dropping means of measuring shell strength. A device described by Mehring (1949) seems to have given satisfactory results for measuring the strength of egg shells. The apparatus is simple, constructed of wood and has a device for applying pressure on the shells of eggs until they are fractured. Required pressure is read on a kilogram capacity spring scale.

V. Shell weight. The determination of the shell weight of an egg is, like specific gravity, an indirect measurement of shell thickness. Its determination requires that the egg be opened, dried and weighed twice to an accuracy of at least one-tenth of a gram. This procedure is tedious and time-consuming. If the albumen is not wiped from the shell, it will influence the weight of the shell. Therefore, because of the work required to measure this index of shell thickness and because the egg is destroyed in the process, percent shell is not too widely used as a measurement.

According to a report of Frank et. al. (1962) specific gravity is the most reliable single measurement for determining shell strength. Mounthey and Vandergant (1957) found the correlation coefficient between the specific gravity and shell thickness, and between specific gravity and shell weight were statistically significant. Steele et. al. (1962) have revealed correlation coefficients between specific gravity and percent shell to be 0.904, between shell thickness and percent shell to be 0.842 and between specific gravity and shell thickness to be 0.802.

FACTORS AFFECTING INITIAL EGG QUALITY

Disease

Most outbreaks of disease or any major flock disturbance will influence egg quality. The most common diseases affecting egg quality are Newcastle

disease and infectious bronchitis.

Newcastle disease is an infectious, highly contagious malady which attacks chiefly chickens and turkeys. Newcastle disease causes high mortality in the case of chicks. In laying birds the disease causes little death loss, but egg production as well as egg quality and shell quality are lowered.

Beach (1943) showed that Newcastle caused a sudden and drastic drop in egg production and a mortality of about 5%. Lorenz and Newlon (1944) reported that eggs laid up to 45 days after an outbreak of Newcastle disease revealed these abnormal conditions: (1) up to 10% of the eggs had abnormal air cells, many of which contained free floating bubbles, (2) a high percent of the hens produced eggs with abnormal shells, and (3) albumen quality was decreased in nearly all eggs laid. Berg et. al. (1947) reported that albumen and shell quality were lower after a Newcastle disease attack than prior to infection, but that not all birds affected with the disease produced poorer quality eggs following a return to normal egg production. The decrease in albumen quality and the increase in roughness of shells following a disease attack tended to be permanent.

Patt (1948) reported that hens drop from about 75% production to zero production in 8 days after being vaccinated for Newcastle disease and that some pens resumed normal egg production within six weeks. Parnell (1950) also reported that loss or inedible eggs appeared earlier in the eggs from the birds that had experienced a Newcastle disease and the percentage of loss eggs was much higher than for the non-Newcastle disease groups at all periods of storage. Most of the inedible eggs resulted from stuck yolks, a condition that is common in lots of eggs containing much watery albumen. Yolk quality as measured by yolk index, color, and general table quality

was no different in the Newcastle affected eggs than in those not so affected. Quinn (1950) found candling grades and albumen scores of day-old and week-old eggs from the recovered Newcastle pullets were significantly lower than those of normal pullets from June to November. In eggs held at 77° F. and 100° F. for 7 days, thick white of eggs from the recovered Newcastle pullets declined 20% more than from normal pullets. In eggs held at 100° F. for 14 days, percent loss in thick white was 33.5 in eggs of Newcastle pullets and 20.7 in eggs of normal pullets. However, eggs from Newcastle pullets lost less weight than eggs from normal ones. Eggs from Newcastle pullets averaged 22.7 ounces; eggs from normal pullets averaged 24.0 ounces. Later, Quinn *et. al.* (1956) pointed out that approximately 26% of the Newcastle disease recovered pullets' eggs were candled as U.S. AA Quality and 36% were U.S. A Quality whereas the control pullets' eggs candled about 59% AA and 37% A. Of the eggs laid by the Newcastle disease recovered pullets 38% were graded as B and C Quality as compared to 4% for the control group. Many of the C Quality eggs contained "bubbles", loose air cells, or both.

Infectious bronchitis which is a highly infectious, contagious disease commonly causes a drastic and usually sudden decrease in egg production. Mortality is slight, seldom amounting to more than 5% of the laying flock. The most damaging effect is the failure to return, after several weeks pause, to what is considered a profitable rate of lay. In addition, abnormality of egg shape, shell strength and texture and poor interior quality, further reduce the profitability of a recovered flock. These conditions following the occurrence of the disease in a mature flock make infectious bronchitis one of the most costly of the poultry industry.

Broadfoot and Smith (1954) found a rapid drop in egg production beginning

2 or 3 days after onset of respiratory symptoms from perhaps 60 to 85% to a level of 5 to 20% in about 5 days. There was also a slow return to production, with only a few flocks having returned to former levels after 8 to 10 weeks. Most flocks never reached former production levels. The disease in laying flocks resulted in a significant decrease in egg production and an increase in percentage of shell abnormalities.

It is generally agreed that infectious bronchitis virus acts similarly to that of Newcastle disease with respect to the production of eggs with thin and malformed shells and weak, watery albumen. In brown eggs, the color of the shell is frequently lighter; similar effects also have been noted with Newcastle disease. "Bubbly" air cells have not been reported following infectious bronchitis.

The report of Lerner, Taylor and Beach (1950) has implicated a typical infectious coryza as a factor in producing unsatisfactory egg quality, although the adverse effects of this disease upon egg production and visibility are generally recognized. The effects upon shell and albumen quality following the outbreak are quite similar to those produced by Newcastle disease or bronchitis infection. In the outbreak described in this report, the disease seemed to produce a lasting disability. "Bubbly" air cells were not formed, although floating or displaced air cells were observed. The presence of white coagulation in the albumen of the egg was frequently observed. Reports have been made that infectious laryngotracheitis have influenced the egg production and egg quality. Raggi et. al. (1961) reported that a controlled experiment on the effects of infectious laryngotracheitis virus (ILT) on egg production and egg quality showed that a temporary but highly significant drop in egg production and some reduction in shell thickness in 22 layers infected intratracheally with a commercial available ILT vaccine.

These diseases not only cause lower egg production, as well as egg quality, but also these effects can have an important economic loss upon the poultry industry. Fortunately, these diseases can be controlled or minimized by proper vaccination of the pullets.

Strain

The initial quality of fresh shell eggs varies among breeds and strains. As early as 1943 Knox and Godfrey noted that eggs from White Leghorn hens had a significantly greater percentage of thick white than eggs from Rhode Island Red hens. Grimes (1953) observed that standard-bred strains tended to produce eggs of superior albumen quality when compared with eggs laid by crossbred and incrossbred strains although the quality of eggs from the standard-bred strains was less uniform. The fact that breeds and strains do lay eggs of significantly different albumen quality has been supported by many other workers including Dawson *et. al.* (1953), Cotterill and Winter (1954), Johnson and Gowe (1956), King and Hall (1955) and Proudfoot (1962).

Strain and Johnson (1957) reported that there were significant differences between strains when internal quality of fresh eggs was measured in three seasons—October, February and June. These results supported earlier work reported in the literature by King and Hall (1955) and Johnson and Gowe (1956).

Reports are controversial on the effect of storage at different temperatures on the decline of egg quality among different strains of egg production fowl. May, Schmidt and Stadelman (1957), working with 186 different strains, reported differences in rate of egg quality decline in eggs from different strains when the eggs were stored 7 days at 55° to 60° F. The difference in rate of albumen quality loss and the initial albumen quality

were found to differ at the 0.01 level of probability. Mueller (1959) studied interior quality loss at a storage temperature of 82° F. over a 7-day period and he concluded that eggs of high initial quality among strains had a more rapid decline than eggs of lower initial quality although eggs which ranked high in initial quality still ranked high in Haugh unit score at the end of the storage period. McClary and Bearse (1956) reported that heredity had no measurable effect on the rate of loss of albumen quality of eggs from hens used in their study.

Reports have been made that show that other initial qualities of eggs such as egg weight, shell quality, blood and meat spots, and prominence of chalazae also vary among breeds and strains. Baker and Curtiss (1957) found that there was a highly significant difference among strains in egg shell mottling, specific gravity, shell thickness and interior quality. Baker and Stadelman (1958) reported that the prominence of chalazae varied among strains. There was no correlation between prominence of the chalazae and internal egg quality. The prominence of chalazae was a heritable characteristic. May and Stadelman (1960) found that strains significantly influenced percentage moisture, protein of fresh egg and protein of dry egg.

Van Wagnen, Hill and Wilgus (1937) reported that the frequency of meat spots varies with breeds. Jeffrey (1945) found a difference between Leghorn and heavy breeds with respect to meat and blood spots. Amer (1961) also reported there was a highly significant difference between breeds with respect to blood spots and meat spots. Fayoumi eggs contained the highest percentage of both meat and blood spots, followed by Rhode Island Reds and Leghorns. Dawson et. al. (1945) reported that heredity was an important factor in the production of eggs containing blood spots.

Among all the traits of egg quality affected by strains, albumen quality

in different strains is more easily detected according to King and Hall (1955). Most of the traits of egg quality are heritable. Therefore it is possible to develop these heritable traits by selective breeding.

Drugs

Presently several medications can be added to the laying rations in order to prevent or eliminate diseases. These include such products as nicarbazin, piperazine, sulfanilamide, arasan, and others. Some of these medications have affected the quality of eggs. Nicarbazin is one of those having serious effects on egg quality.

Nicarbazin, a coccidiostat, has been reported to cause several effects on egg quality. These are shell depigmentation (McClary, 1955; Ott et. al., 1955, 1956a & b; Sherwood et. al., 1956a), yolk mottling (Baker et. al., 1956, 1957; Polin and Porter, 1956; Polin et. al., 1957; Weiss, 1957) and a decreased egg size (Sherwood et. al., 1956b; Weiss, 1957; Baker et. al., 1957).

Shell depigmentation was reported to occur at a minimum effective level of 0.003 to 0.005 percent by Sherwood et. al. (1956a) and Ott et. al. (1957). Baker et. al. (1957) reported the effect at 0.009 percent but not at the 0.003 percent level.

Yolk mottling was reported in fresh eggs from Leghorns fed 0.0015 percent and a marked increase in the incidence at 0.003 percent in fresh eggs from both heavy and light breeds (Baker et. al., 1957). This is contrary to the data reported by Polin (1957) who found that yolk mottling in fresh eggs was within normal incidence and degree even at the 0.0125 percent level. Also Weiss (1957) and McLoughlin et. al. (1957) found that yolk mottling in fresh eggs at 0.0125 percent levels was not noticeable enough to attract any particular attention. In heavy breeds yolk mottling was significantly increased

above control values in eggs held in storage when the nicarbazin level was at least 0.005 percent (Polin et. al., 1957; Polin, 1957). In agreement with these results, Baker et. al. (1957) reported yolk mottling to increase significantly during storage of eggs of heavy breed hens fed nicarbazin at a level above 0.003 percent, whereas eggs from White Leghorns showed the effect at the 0.003 percent level of nicarbazin. Polin et. al. (1957) showed that nicarbazin caused a significant increase in yolk mottling above the normal incidence in eggs stored 7-10 days and from hens fed at least 0.005 percent and no direct effect on albumen quality at the highest level fed (0.010%). They also found the effect on yolk quality, caused by the active moiety of nicarbazin, 4,4'-dinitrocarbanilide, was on the permeability of yolk membrane.

Sherwood et. al. (1956b) reported that White Rock hens lay a slightly smaller egg when fed nicarbazin at 0.005-0.007 percent; yet Weiss (1957) did not detect any effect on egg weight at 0.0125 percent fed to hybrid hens. He did not find a significant effect on eggs laid by White Rocks and Leghorns at this level. Baker et. al. (1957) reported that egg size was reduced by feeding nicarbazin at 0.006 percent or more to Leghorns with no effect on heavies at 0.003 and an effect at 0.009 percent. Polin et. al. (1958) found nicarbazin to cause a decreased egg size by reducing yolk size at a minimum level of 0.007 percent. Weiss et. al. (1960) reported that when fed nicarbazin at the level of 0.04% 5 month-old White Leghorn pullets delayed attainment of full egg production for 8-10 weeks. By one month after withdrawal of the drug, production and egg weight were essentially normal.

It is very important to use this drug at recommended levels and it should not be used in the ration of laying hens; otherwise the eggs will be abnormal.

Other drugs such as arasan, sulfanilamide, reserpine, piperazine and others have been reported to affect the egg quality. Swanson et. al. (1955) reported that arasan, a fungicidal product used in seed treatments and containing tetramethylthiuran disulfide as the active ingredient, in levels as low as 22 p.p.m. would decrease the shell thickness. At levels of 22 p.p.m. and 50 p.p.m. arasan the eggs were misshapen. At 200 p.p.m. of arasan no hard-shelled eggs were laid after 36 hours on the experimental diet.

Scott et. al. (1945) reported that the average thickness of the egg shell was reduced when sulfanilamide was added to a laying hen's diet. Becker and Bearse (1962) reported that feeding White Leghorn hens 0.003% sulfanilamide in their ration significantly reduced egg production, egg weight, Haugh unit values, and the specific gravity of their eggs.

Van Matre et. al. (1957) reported that reserpine afforded protection against decreased egg production and shell quality following heat stress under laboratory conditions. Gilbreath et. al. (1959) showed that a low level of reserpine (2.0 mg. per kg. of diet) added to a suitable diet would support egg weight and shell quality during periods of relatively high temperatures. The drug did not affect albumen quality under the conditions of their study. Eoff et. al. (1961) reported reserpine at a high level (1.0 mg. per pound of feed) caused a significant decrease in egg weight. Reserpine (0.25 and 0.5 mg. per pound of feed) produced significant increase in egg weight.

Piperazine and phenothiozine have been reported to cause yolk mottling or yolk discoloration. Nitrofurazone, Aureomycin, Terramycin, Penicillin, arsanilic acid, Malathion and Furazolidone have been reported to have no effect on egg quality.

Management

Management is very important in poultry production. If it is not done in the proper way it not only will affect the quality of eggs, but also a great economic loss will be encountered. Management includes many things such as feeding systems, housing systems, ventilation, etc. In this paper only the factors which will influence the initial quality of an egg will be discussed.

Stevenson and Bryant (1944) found no significant difference in annual egg production and egg size between birds reared on range and those reared in confinement. Winter and Schlamb (1948) reported that egg size was slightly larger for the range reared group. Ott et. al. (1957) measured the egg quality and egg weight of pullets and found that the eggs produced by the range reared birds were higher in Haugh unit value and lower in weight than those from confinement reared birds. Barley et. al. (1959) found the average egg weight was 56.10 and 55.05 respectively, for the range reared and confinement reared birds. This difference was highly significant. Pepper (1959) reported that there was little or no difference in quality between eggs produced by confinement or range reared birds or between birds reared on high or low energy diets.

Gowe (1955) reported no significant differences in egg weight of caged and floor layers. Lower egg production was observed in the caged layers than in the birds on the floor. Bailey et. al. (1959) and Lowry et. al. (1956) found that the average egg weight of cage housed birds was significantly heavier than for the floor housed birds. Froning and Funk (1957) reported that egg weight was significantly higher for the caged birds throughout the study. Egg quality as measured by Haugh units was

approximately the same for both groups. Percent of thick albumen and height of thick albumen were consistently higher in eggs from caged layers. Shupe and Quisenberry (1961) found that birds housed in floor pens had significantly lower body weight and laid smaller eggs than birds housed in colony and individual cages.

Jeffrey and Pino (1943) compared blood spot incidence of caged and floor birds. Their work showed caged birds to have a lower incidence of blood spots than did the birds on the floor. Jeffrey (1945) reported results contrary to his earlier work when Rhode Island Reds in cages produced eggs with a higher percentage of blood spots than did the floor birds. Lowry et. al. (1956) found higher production in caged birds. The birds had significantly lower mortality, larger eggs and higher incidence of blood spots. Grotts (1956) reported higher egg weight and increased incidence of blood spots in eggs from caged birds. No differences were observed in albumen quality and shell thickness. Froning and Funk (1957) and McDowell (1958) also reported that eggs from caged birds had more blood spots than eggs from floor birds.

Yao (1959) showed the chickens on the slatted floor had a higher mortality, more non-layers and poor layers, fewer eggs with blood spots, and a higher egg albumen quality than those on the litter floor. Osborn et. al. (1959) found there was no difference in egg weight and initial interior quality between the systems but the incidence of blood spots appeared to be lower on slats than litter. Magruder et. al. (1962) showed no differences between the two systems regarding blood spots, shell thickness, shell strength and Haugh units. More large eggs were produced by the layers housed on slatted floors than those housed on litter (shavings).

Mueller et. al. (1951) reported that the effects of light on egg

quality and blood spot incidence were inconsistent. Stiles and Dawson (1961) found continuous light and short intermittent light periods increased blood spot incidence, albumen height, egg weight and Haugh unit score over the normal 14 hours of light followed by 10 hours of darkness. But according to earlier reports, lighting system does not influence the egg quality.

Stiles and Dawson (1961) found that physically disturbing hens by shaking and frightening them several times a day had no significant effect on blood and meat spot incidence. Frightening birds significantly decreased egg shell thickness by 0.31 thousandths of an inch, but did not affect other egg quality factors. Eggs from birds subjected to abnormal sounds had increased blood spot incidence, but the sounds had no significant effect on other quality characteristics.

Hanson et. al. (1948) used such nesting litters as straw, excelsior, wood fiber, wood shavings, rice hulls, almond shells and diatomaceous silica. They found that straw, excelsior and wood fiber were preferred by the birds to other materials. Their observations on the effect of nesting materials on egg soilage did not yield conclusive results. They concluded that factors other than nesting materials contributed to variation in egg soilage. Dawson and Watts (1952) studied the effect of nest litter on cleanliness of eggs. They found that nesting materials did have some effect on cleanliness of eggs, but they felt that the condition of the floor litter affected the number of dirty eggs more than did the nest litters. Siegel and Howes (1959) reported that the type of nesting material had little effect on the percentage of clean, cracked, or broken eggs, if the nesting material is maintained properly. Baker (1962) showed both perlite ore and calcined clay were responsible for significantly more clean eggs than either shavings or peanut shucks. The number of clean eggs was

significantly higher in the pen where calcined clay was used than was the case where perlite ore was used.

Season

It has been known that egg quality is influenced by seasons, especially in summer temperature. High environmental temperatures reduce the thickness of the chicken's egg shell, thereby lowering its breaking strength. The usual pattern followed is a gradual thinning of the shell, which is initiated during the spring months and becomes progressively worse as the temperature increases. When the atmosphere cools, there is a return toward normal thickness.

That egg size is influenced by season has been shown by many investigators. Jull (1924) observed that egg weight increased from December to February and decreased from February to April. Bennion and Warren (1933) reported the components of the egg decreased in weight when hens were exposed to high environmental temperature. The shell and albumen decreased considerably more than the yolk in proportion to their weight. Funk and Kempster (1934) reported that eggs of maximum size were produced during the spring months of February and March. Lorenz and Almquist (1936) showed that egg weight was decreased by increased air temperature during the formation of the egg, but the percentage of firm white and shell weight were not affected by the air temperature during this time. Warren et. al. (1950) observed that the size of eggs increased throughout the laying year if the birds were not subjected to high summer temperatures. Rosenberg and Tanaka (1951) reported that in Hawaii, where the maximum temperature averaged approximately 80° F., New Hampshire pullets produced eggs which increased in size continually for the first 11 months of lay. Cunningham et. al. (1960) also reported that

egg weight tended to be greater in the spring and smaller during periods of high temperature. Campos et. al. (1960) reported a sudden severe drop in egg production in some strains of layers upon exposure to 100° F. for a 24 hour period; egg weight and shell thickness were likewise adversely affected by exposure to the high ambient temperature. Huston and Carmon (1961) found the birds in variable temperature environment laid eggs which had a higher specific gravity than eggs laid by birds held at a high constant temperature (90° F.). The decline in specific gravity was related to environmental temperature and age of the hen. Mueller (1961) reported a constant temperature of 90° F. depressed egg weight and shell quality as compared with a constant temperature of 55° F. It is known that as temperature climbs up from 70° to 90° F., blood calcium level drops and shell becomes thinner almost immediately. Since feed consumption drops in hot weather particularly, the calcium intake is or may be a limiting factor.

The interior quality of the egg has been studied extensively and from many different points of view. Knox and Godfrey (1934) found a definite seasonal variation in egg quality. They reported that interior quality was poorest in June. Lorenz and Newlon (1944) in a survey of ranches in California, reported that a significant seasonal trend existed in egg quality and they attributed this in part to the advancing age of the flock and in part to changes in environmental conditions.

Warren et. al. (1950) also observed a marked decrease in albumen quality as the season progressed. They observed a decline in albumen quality of eggs produced by hens in both controlled and uncontrolled environments and concluded that the cause was due to factors within the birds and not to external environmental factors. Sauter et. al. (1954b) considered both season and aging of the hen as seasonal variation. They

produce better albumen quality than hens (Yao, 1958; Lorenz and Newlon, 1944; Cunningham et. al., 1960).

Although shell weight increases with larger eggs, the percentage of shell and its thickness decline (Halloran and Maxwell, 1955; Lorenz and Almquist, 1936; Fronda and de la Cruz, 1939) and defects of the shell tend to increase (Halloran and Maxwell, 1955). Hen egg shells are more porous than those of pullets (Bolton, 1957). Shell quality of eggs stored over a period of time from birds of one to one and a half years of age showed definite increases in the measurable porosity which is responsible for a lower quality egg, whereas in pullet eggs no increase in average porosity was observed (Kraft, McNally and Erant, 1957). Flavor of the egg, however, shows no consistent variation with increasing age of the hen (Harns et. al., 1954).

Age of birds and season of the year are the two correlative factors which influence the quality of eggs. But age of the birds has a greater influence on egg weight, albumen volume, Haugh units and solids in albumen than does the season of the year. As birds grow older their shells become thinner with the exception of birds that are forced into a molt. Upon resumption of egg laying the shells of eggs from force molted hens are found to have regained their full thickness which is a good indication that the shell mechanism of the hen is tired and needs a rest to restore its efficiency (Wallace, 1961).

Ration

There are numerous ingredients in the ration which will influence the quality of eggs. In this paper discussion will consist only of the commonly used ingredients in the ration which affect egg quality.

Calcium is a very important mineral in the ration of laying hens. The

level of calcium in the diet affects egg shell quality. Thin shelled eggs result from a low level of calcium and this causes considerable financial loss to poultrymen because of increased number of cracked and broken eggs and because of down grading of the eggs due to thinness of shells. It is estimated that as high as 5% of all eggs produced in the U.S.A. are lost, either in production or handling, because of weak thin shells. Therefore, thin shelled eggs is one of the major problems in poultry operations.

In recent years, both research studies and field experience have pointed to the need for higher levels of calcium than the 2.25% calcium recommended by the National Research Council. Higher egg shell quality can be obtained. The reason is that high production levels, larger eggs and smaller birds require higher calcium levels in the ration. Though the calcium requirements of laying hens has been studied to some extent, the problem of the optimum amount of calcium required has not yet been completely solved.

Evans and Carver (1942) reported that levels of calcium of 2.5% or higher prevented any decrease in shell thickness if the level of phosphorus was satisfactory. Levels of 2.5% calcium and 0.8% phosphorus were generally considered to be merely optimum for the laying hen. The 3.5% calcium and 1.0% phosphorus level produced the greatest increase in egg shell thickness. Evans, Carver and Brant (1944) found hens receiving 3.0% calcium in the diet gave better results than those receiving higher or lower levels when egg shell thickness was used as the criterion. However, a level of 2.5% calcium allowed as satisfactory production as the one of 3.0%. Tyler (1946) showed no difference in egg production or shell thickness in 6.0% or 3.0% calcium diets. Soft shelled eggs as well as other egg abnormalities were observed in the birds given the high calcium diet. Thus, it would appear that calcium levels in excess of the amount required could be deleterious.

Peterson et. al. (1959) reported that egg shell quality was significantly improved by dietary calcium levels which were considerably higher than the previously estimated requirement. A level of 3.75% significantly increased the specific gravity of eggs as compared to that with 2.25%. Calcium levels of 4.5% and 5.25% resulted in further increases but of less magnitude. Reddy (1962) suggested that about 3.0% to 3.8% calcium in the diet appeared to be necessary for optimum shell weight, percent shell, interior quality and percent egg production. However, the National Research Council recommended levels of 2.25% calcium in the diet as being adequate for maximum egg weight.

It has been common knowledge for years that eggs laid during the hot summer months generally have thinner more fragile shells than have those laid during cool months. As temperature climbs up from 70° to 90° F., blood calcium levels drop and shells become thinner. Since feed consumption drops in hot weather the calcium intake suffers. Many workers have tried to increase the level of vitamin C or D in order to increase the thickness of the shell during the summer months but their effect on improving the egg shell quality is questionable.

Berg, Barse and Miller (1951) found that increasing the level of calcium in the ration from 2.25% to 2.625% to 3.0% when the vitamin D content of the ration was maintained at 450 A.O.A.C. units per pound of feed did not prevent the normal seasonal decline in egg production, shell thickness or shell smoothness. Likewise, increasing the level of vitamin D from 450 to 900 A.O.A.C. units when calcium was maintained at a level of 2.25% of the ration did not alter the seasonal decline in performance. When both the calcium and vitamin D were simultaneously increasing in amounts, no improvement in performance of the birds was recorded. Berg et. al. (1947) and Couch and coworkers (1947) found the National Research Council recommended levels

of calcium (2.25%) and vitamin D (450 A.O.A.C. units) when maintained in the ration continuously would promote as satisfactory shell quality as could be obtained by feeding higher levels of these feed components. However, the N.R.C. recommended levels have not been able to prevent the seasonal decline in shell quality.

Heywang and Kemmerer (1955) found no difference in egg weight or shell thickness when hens maintained at high environmental temperature were fed supplementary ascorbic acid as compared with birds not receiving the added vitamin. Thornton and Moreng (1958,1959) reported the addition of ascorbic acid to the hen's diet would maintain or improve shell quality during heat stress. Further studies by Thornton (1960) and Thornton and Deeb (1961) suggested that the response to ascorbic acid might be influenced by factors other than heat stress, namely dietary protein level, calcium level and the bird's metabolic rate. Hunt (1960) showed egg specific gravity to be not influenced by ascorbic acid in hens fed practical diets under conditions of high or normal environmental temperature. Pepper et. al. (1961) and Harms and Waldron (1961) reported that supplemental ascorbic acid did not significantly alter egg production nor shell thickness. Recently Hunt and Aitken (1962) and Arscott et. al. (1962) also have reported that ascorbic acid did not improve egg shell quality

The levels of vitamin A in the ration may affect the egg quality. Bearnse (1955) stated that suboptimal levels of vitamin A caused more blood spots and above optimal levels caused less blood spots in eggs than the N.R.C. recommendation for this vitamin. Later, Bearnse (1960) reported that one of the abnormalities associated with vitamin A deficiency in hens was the production of eggs with a high incidence of blood spotting of the yolk. Donovan et. al. (1961) showed the percent of eggs containing meat and blood

spots was significantly greater and yolk color was significantly lighter for the groups on the highest vitamin A level (110,000 I.U.) compared to the groups on the lower levels (0, 10,000). Pope et. al. (1961) also had similar results to those of Donovan et. al.

Cottonseed and its by-products used in laying rations are implicated in the discoloration of eggs in two ways: (1) gossypol produces olive or chocolate-brown yolks described by Schaible, Moore and Moore (1934) and Swensen, Fieger and Upp (1942), and (2) salmon colored yolks and pink whites are associated with cottonseed meal feeding as reported by Sherwood (1928, 1931).

Discoloration of egg albumen with the feeding of cottonseed meal to hens has been thought to be due to the passage of iron from the yolk into the white, followed by a reaction with conalbumin causing a pink discoloration of the albumen. Passage of conalbumin into the yolk also appears to cause the salmon yolk color (Schaible and Bandemer, 1946a & b). Evans et. al. (1957) reported on the occurrence of pink whites and salmon yolks with the feeding of crude cottonseed oil or cottonseed meal and found the pink white factor to be heat labile. Masson et. al. (1957) showed that the feeding of sterculic acid caused pink whites and salmon yolks in the stored eggs. The dark discolorations caused by gossypol and appearing in the yolks of stored eggs from layers fed cottonseed meal accompanies an increase in the pH of the yolks. This increase in pH is enhanced by another component of cottonseed meal, Halphenic acid, which also causes pink white and salmon colored yolks (Kemmerer et. al., 1960; Frampton et. al., 1961). Heywang et. al. (1962) found that oil dipping apparently prevented the formation of dark yolk discolorations when the dietary level of free gossypol was less than 0.008%. Oil spraying was effective at the 0.001 and 0.002% level of free gossypol when the storage temperature was 35° F. but not when it was 50-55° F.

There is a further reason for hesitation about feeding cottonseed meal to laying hens because it is not always clear whether the discolorations of eggs are due to gossypol. There is the possibility that minor constituents other than gossypol may be involved in some effects currently attributed to gossypol. The level of gossypol content in the cottonseed meal should be less than 0.004%. Eggs from cottonseed meal fed hens should be marketed as quickly as possible.

It has long been known that the color intensity of egg yolks can be rapidly changed when the hens consume graded levels of different pigments. This is of value due to the variations in the color of the yolk required by consumers or for other purposes. Alfalfa meal and corn are rich in xanthophyll which will affect the intensity of yolk color. Additional interest by egg breakers in more intensely pigmented yolks has stimulated research with other pigments in the ration such as xanthophyll and synthetic carotenoid.

Tarver (1961) found xanthophyll oil in various levels increased yolk color. Farr et. al. (1962) compared alfalfa meal, algae meal, B-apo-8'-carotenal and canthaxanthin. They found that when B-apo-8'-carotenal was used as a pigmenting agent, a pleasing yellow yolk color was produced. This is substantiated by earlier workers (Bunnell and Bauernfeind, 1958; Marusich et. al., 1960).

Flavor is one of the important factors that should be used as a criterion by the consumer for evaluating quality of eggs. Normal flavor of eggs may vary somewhat, probably because of individual differences between hens or dissimilarity of diets which the flocks receive. Therefore, when formulating a ration one should be careful about the ingredients which are used as to whether or not they will cause off flavors.

FACTORS AFFECTING QUALITY OF STORED EGGS

The interior of an egg is at its maximum at the time it is laid. This quality can not be improved, as deterioration begins immediately. It is necessary to maintain the egg's quality during storage as near as possible the level it was when first laid. There are many factors affecting the quality of stored eggs. Temperature, time, and humidity are the most important of these.

Temperature and Time

It is a general observation that the interior quality of eggs deteriorates when the eggs are stored in unsuitable temperature and extended periods of time. The higher the temperature and the longer the storage period, the greater is the decrease in egg quality. Higher temperature increases evaporation; thus, the higher temperature results in lower candled quality and lower albumen quality. Low temperature aids in the retention of quality.

Wilhelm and Heiman (1938) studied the effect of temperatures of 30°, 50°, 70°, and 90° F. on eggs stored at from 3 hours to 192 days using the change in albumen index as a criterion. They found the quality losses for some of the longer storage periods closely approached each other, but there was decided difference in initial quality which was still apparent upon breaking. The storage temperature of 30° F. retarded albumen index loss markedly after a 30% loss had occurred. The higher temperatures were increasingly less desirable for holding eggs. Van Wagenen, Hall and Altman (1939) reported quality changes which occurred in eggs held at 35°, 45°, 55°, 65°, and 80° F. They concluded that 45° F. was the most desirable

temperature for holding eggs on the farm. Evans and Carver (1942) found that a low temperature of 40° F. gave better results than one of 56° F. for holding eggs under farm conditions. Bennion and Price (1940) also reported that a temperature between 40° and 65° F. was desirable for holding eggs.

Funk (1944) showed that thick albumen was converted to thin albumen very slowly at temperatures of 30° and 50° F., but quite rapidly at temperatures of 80° and 100° F. Jensen and Stadelman (1951) found that eggs refrigerated at 30° to 38° F. for more than a week had essentially the same quality as when they were placed in storage. They also found that there was a rapid decline in quality during the normal marketing procedure with this decline being closely associated with the temperature of egg holding rooms. Dawson and Hall (1954) reported quality of albumen held at 75° F. continued to decline rapidly through 14 days of holding. Differences were small in quality of eggs held at 32° and 45° F. The albumen quality score of newly laid eggs averaged 2.5 (U.S.D.A. Score). During holding, the quality declined to an average Grade A (Score of 5.0) in 7 days at 75° F., in 14 days at 60° F., or 21 days at 45° F. Eggs held at 32° F. still had an albumen score of 4.0 after 21 days. They found temperature of 60° F. or lower to be practical for normal farm holding of eggs.

Fry and Newell (1957) found that eggs stored at 60° F. for one day were lower in quality than those stored for 7 days at 30° F. and eggs stored at 90° F. for one day were lower in quality than those stored at 60° F. for 7 days. After an initial loss of three Haugh units the first two days of storage, eggs stored at 30° F. maintained approximately the same quality throughout the test. The initial drop in quality was the greatest regardless of the temperature. At all three temperatures the decrease in Haugh units for the first 48 hours of storage was significantly greater than the

decrease for any succeeding 48 hour period. They concluded eggs stored at a temperature below 60° F. to be desirable for farm holding of eggs. Longer storage required maintenance of temperatures at 30° F. for high egg quality. Meehan et. al. (1960) reported storage of eggs at 34° and 55° F. for 8 to 21 months had only slight effects on egg white performance quality (as measured by foaming power and angel food cake quality, but storage at 75° to 95° F. resulted in markedly decreased angel food cake volumes while storage at 95° F. also adversely affected the foaming power of the white.

A temperature not over 60° F. for normal farm holding of eggs is agreed upon by all workers. Holding conditions under 60° F. are necessary to retard the loss of egg quality. The lower the temperature, the higher egg quality will be maintained. The 55° F. temperature is commonly used in commercial storage of eggs and farm holding of eggs as short-time storage. The 30° F. temperature is used only for long-time storage. However, such storage is not common now except in times of surpluses of eggs.

Humidity

The effect of humidity on eggs is dependent on the accompanying temperature. High temperatures cause more rapid evaporation than low temperatures. Humidity is also a factor in preventing evaporation of moisture from eggs. It prevents loss of weight of the egg and also prevents loss in grade. Therefore, proper humidity in the egg-holding room is desirable to prevent loss of moisture which causes increased air cell size.

Investigations show conclusively that low temperatures are necessary for maintaining the interior quality of stored eggs (Romanoff and Romanoff, 1949; Van Wagenen, Hall and Altman, 1939; Henderson and Lorenz, 1951; Dawson and Hall, 1954; Fry and Newell, 1957). Investigations also show that

high humidities are necessary for minimizing evaporation (Van Wageningen, Hall and Altman, 1939; Jeffrey and Darago, 1940; Evans and Carver, 1942). Korslund et. al. (1957) found that the quality of eggs stored at 30% relative humidity was significantly lower than that of eggs held at 90% relative humidity. Vondell (1961) reported that holding eggs for 7 days at 50% and 80% relative humidity at 55° F. showed no grade loss in air cell depth or Haugh units, but the loss in weight was 2.5 to 3 ounces per case of 30 dozen eggs at 55% relative humidity. Schwall et. al. (1961) showed low relative humidity increased the weight loss in untreated eggs but did not significantly affect eggs that were oil treated.

It is generally agreed that humidity does not affect albumen quality. Jeffrey and Darago (1940) reported the interior egg quality expressed by height of thick albumen was not affected by relative humidity of the holding room. Funk (1944) showed humidity to have but little influence on the deterioration of the albumen or yolk. Evans and Carver (1942) also found that the humidity appeared to have little or no effect on the albumen index at temperatures of 40° or 56° F. Korslund et. al. (1957) agreed with other workers that the relative humidity of the storage area had no economically significant effect on albumen quality as expressed in Haugh units. Mueller (1956) reported that storage at 12° and 37.5° C. and a relative humidity ranging from 0% to 100% had, except for 100% relative humidity, no effect on Haugh unit score, yolk height and carbon dioxide content of the albumen. Eggs which were kept at 100% relative humidity had moist shells and their Haugh unit scores as well as the carbon dioxide content of their albumen were significantly higher (0.01 level) than the respective measurements of eggs kept at lower humidities. It seemed probable that the negative correlation between water-loss and Haugh unit score was due to the

positive correlation between carbon dioxide-loss and water-loss. The limited solubility of carbon dioxide in water was proposed as an explanation for higher Haugh unit score and higher carbon dioxide content of eggs at 100% relative humidity.

High humidity in the egg holding room is desirable to prevent loss of moisture which causes increased air cell size. If temperatures are below 50° F. a relative humidity of 60% appears satisfactory. With a temperature of 50° to 60° F., the humidity should be about 70%. At a temperature of 60° to 70° F., the humidity should be about 80%. A low temperature is probably more important than high humidity. However, temperatures from 50° to 60° F. and relative humidity from 70 to 80% are commonly used in holding eggs in farm and market channel storage.

Atmosphere

It has been reported by Atwood and Weakley (1924) as well as by Smith (1931) that infertile chicken eggs lose CO₂ during storage. According to Smith (1931) the CO₂ loss of individual eggs may begin at a rate of 9.0 mg. per day and gradually drop to 0.1 to 0.2 mg. per day, at which level it may continue for 100 days or more. He also found that the rate of CO₂ loss depends on the temperature.

The CO₂ content of fresh eggs has been determined by Mathien and Urbain (1908) and Straub and Donak (1934). These investigators found that the albumen of fresh eggs contained approximately 55 mg. CO₂ and that there was no CO₂ in the yolk.

The relationship between the rise in pH of the albumen and albumen liquifaction was reported by Sharp (1929). This rise is caused by release of CO₂ from the egg. He found that this could be prevented by holding eggs

in an atmosphere containing higher than normal concentrations of CO_2 by placing freshly laid eggs in a CO_2 tight container in which the CO_2 content of the eggs quickly reaches equilibrium with that of the surrounding atmosphere.

Sharp and Stewart (1931) recommended adding CO_2 to the air in cold storage rooms to aid in preserving the albumen quality by keeping a low pH. Wilhelm (1940) reported improved albumen indexes of eggs stored in sealed mason jars with a vacuum CO_2 atmosphere. Swanson (1953) found that the thinning of thick white was retarded by maintaining a CO_2 atmosphere around the eggs. Cotterill (1955) showed that the natural thinning as indicated by Haugh units was not a function of temperature if the pH was maintained near its initial value. The subsequent thinning of white under normal atmospheric conditions was retarded after the eggs were exposed to a CO_2 treatment. Cotterill and Gardner (1957) reported benefit to albumen quality by pretreating with CO_2 and by storage in sealed containers whereby the low concentrations of CO_2 would maintain the albumen quality of eggs stored at room temperature (75° to 80° F.) as effectively as refrigeration at 50° F. under normal atmospheric conditions. Holding shell eggs at temperatures higher than 80° F. required much higher levels of CO_2 to produce the same effects.

Swanson (1953) first suggested plastic overwrapping of retail egg cartons as a means of preserving egg quality. He reported that eggs packaged with overwraps within 24 hours of laying did not require the addition of CO_2 to the package to preserve albumen quality. Later, Fletcher et. al. (1959) found that the addition of CO_2 to Cryovac packaged eggs resulted in lower scores for flavor and odor.

However, the addition of CO_2 in the storage room or in the package is very seldom commercially used. Oiling and plastic overwraps replace it.

Shell Treatment

Oiling is the most widely used process for shell treatment. The purpose of oiling is to retain the original CO₂ within the shell which helps to keep the albumen firm, prevents the absorption of odors and flavors, and slows down the evaporation from the egg during storage or other holding that would cause enlargement of the air cell.

As early as 1807, Dutch farmers used linseed oil to preserve eggs (Spamer, 1931). Evans and Carver (1942) found that the oiling of stored eggs held quality better and prolonged the keeping quality of eggs for all the storage periods tested. This has been substantiated by many workers (Lorenz, 1949; Korsland et. al., 1957; Swanson, 1958). Schwall et. al. (1961) found that untreated eggs lost significantly more interior quality and weight than eggs treated by oiling. Oil treating maintained Fresh Fancy or Grade AA interior quality for 21 days or longer under the refrigerated conditions of this study while the majority of the untreated eggs dropped to Grade A after three days of storage. Goodwin et. al. (1962) also reported untreated eggs lost significantly more Haugh units than the oil treated eggs. Oiling retarded the loss of CO₂ and maintained albumen condition longer than untreated eggs.

Grant (1948) stated that eggs should have an internal temperature of 50° to 70° F. at the time of oiling. Koonz and Kauffman (1950) reported that oil penetration was greater when the eggs were warm and least when the temperature of the egg was below 50° F. regardless of the oil temperature. Meyer (1953) found that the pour point of egg processing oil should be several degrees above the average storage temperature to form the best seal during storage. This is disagreed with by Winter and Cotterill (1949). They found the

temperature of the oil did not have any special effect on the keeping quality.

Recently oil spraying is the most widely used process for shell treatment. It has replaced the dipping method and has been used with variable success. Swanson (1958) in reviewing oiling procedures, pointed out that the dipping in oil was found to have some shortcomings. The oil constantly needed sterilization, otherwise it developed a bad odor, sanitation could not be maintained properly, and a little negligence caused much trouble. Therefore, the recent method of oil spraying replaces oil dipping for it does not produce any such problem and is very convenient for application. Though the oil-dipped eggs hold quality better than the sprayed eggs, the difference is not significant.

Stadelman and Wilson (1958) found that oil-dipped eggs had better Haugh units and less weight loss than spray-oiled eggs. Sauter et. al. (1961) reported that oil dipping produced the best results in maintaining candled grade, Haugh unit values, reducing weight loss and maintaining a low pH in the albumen. The oil spraying methods produced results intermediate between oil dipping and untreated controls, but were almost as effective as oil dipping when eggs with good quality shells were used. Schwall et. al. (1961) observed no statistical difference between spray or dip methods of oil treating shell eggs as a means of avoiding weight loss and maintaining high albumen condition.

In a comparison of several methods of oiling Stadelman and Wilson (1958) observed that an aerosol oil spray containing a small amount of silicone gave the best results with respect to quality preservation, ease of application and oil shine. Howler and Stadelman (1961) also found aerosol treatment containing $\frac{1}{2}\%$ silicone maintained albumen conditions more effectively than aerosol alone. Greater loss in weight and Haugh units were shown with decreased

silicone content of the aerosol sprays used.

Time of oiling is still a problem. When eggs are oil treated shortly after laying, problems of cloudy whites, excessive increases in outer thin white, and difficulty of peeling hard cooked eggs are sometimes encountered. A series of experiments have been conducted to determine the most desirable time to oil eggs with respect to oviposition and to study the effects of holding temperature before or after oiling on these problems.

Evans and Carver (1942) found that eggs oiled within five to seven hours of the time they were laid had the albumen index best preserved when they were stored for three months at 32° F. Eggs oiled the morning after they were laid were intermediate in albumen index loss. Eggs oiled as soon as gathered had the greatest increase of outer liquid albumen and decrease of firm albumen. Eggs oiled the day after gathering were superior to the other two when all criteria were considered. They recommended that oiling of eggs be done 5 to 7 hours after laying time. These recommendations were confirmed by such workers as Gibbons (1950), Grant (1948), Swenson (1939), Carlin and Foth (1952) and Sauter *et. al.* (1954), all of whom observed similar results with the same oil or with other kinds of oil. Stadlerman and Wilson (1958) found that oiling of shell eggs on the day following the day of production significantly improved keeping quality during a two week storage period as measured by weight loss or albumen quality expressed as Haugh units. Goodwin *et. al.* (1962) reported time of oiling following lay significantly affected the interior appearance. Oiling one hour following lay was statistically better than all oiling times tested, except the six hour treatment. The one hour oiling produced higher average Haugh units for all storage times than did the six hour oiling treatment. Oiling resulted in lower pH values with one and six hours oiling treatments having the lowest pH values. Froning

and Swanson (1961) found when oil dipping process was used that delaying the treatment 8 to 12 hours proved beneficial. At a storage temperature of 32° F. cloudiness scores and increases in percent outer thin white were high for all oiling treatments. Delaying the treatment had no effect. At this lower temperature even the uncoiled controls had a high incidence of cloudy whites and an increase in outer thin white equivalent to that of the oil treated groups.

The desirable time of oiling thus may be 5 to 7 hours or later after oviposition dependent upon the method of oil application.

Overwrapping

Another method of maintaining a low pH and preventing the escape of moisture is that of overwrapping eggs. Oil processing has been successful in reducing albumen liquefaction, but undesirable side effects have been found. Fletcher *et. al.* (1959) reported that oil treated eggs picked up foreign flavors readily and that the process tends to lower quality. Swanson (1959) found that these oil treated eggs did not peel well after hard cooking.

The use of overwrapping material to overwrap cartons of eggs to maintain quality has been under study for years. The plastic films on egg containers effectively maintain albumen quality and reduce weight loss. There are many plastic films on the market such as cellophane, cryovac, visten, polyethylene and others. Among them, cellophane and polyethylene are widely used. Cryovac which has a low permeability to gases and water vapor, has proven to be the best for overwrapping the eggs but is quite expensive. It almost completely prevents evaporation and escape of CO₂ and it provides the best results. Polyethylene which has a relatively high permeability to gases but low permeability to water vapor, is equally effective in preventing evapor-

ation but allows escape of CO_2 to the extent that the pH will rise.

Packing shell eggs in air tight containers as per Wilhelm (1940) or the use of a plastic film overwrap on egg cartons, according to Pyke (1945) and Swanson (1953), was reported to retard thinning of the thick white for a period of 7 to 10 days at temperatures of 60° to 80° F. by maintaining a CO_2 atmosphere around the eggs. Orr and Snyder (1959) reported that eggs stored in cryovac bags maintained consistently higher Haugh unit values than oiled eggs as was found also in the study reported by Fletcher et. al. (1959). Davis and Brunson (1961) found oiled eggs were superior to all others with one exception, i.e., wrapped eggs held at 55° F. compared with oiled eggs.

Davis (1959) and Gardner et. al. (1961) found the overwrapped eggs were significantly superior to unwrapped eggs. Cryovac was superior to polyethylene. The unwrapped eggs made a rapid ascent in pH and remained at a relatively high level. The cryovac wrapped eggs increased slowly in pH and at a rather constant rate. The polyethylene wrapped eggs were intermediate. Davis and Beekler (1960, 1962) reported that cryovac wrapped eggs were significantly superior to polyethylene. Cryovac, having the least permeability to moisture and CO_2 , was preventing evaporation and maintaining low albumen pH and high albumen scores.

RELATIONSHIP OF QUALITY TO CONSUMER PREFERENCES AND PER CAPITA CONSUMPTION LEVELS OF EGGS

Consumers' tastes and preferences of eggs are influenced by many forces. Individual differences, traditions and personal experiences of the consumers themselves may result in considerable variation in preferences. For years researchers have studied consumer differences with respect to the attributes

they use to evaluate eggs. According to the report of Banks and Voss (1962) they found that Grade A eggs were preferred over Grade B, but Grade B eggs were completely satisfactory to more than 50% of the respondents. All socio-economic groups preferred Grade A eggs over Grade B. Classifying households on the basis of comments about the stand-up characteristics of the eggs indicated that 73% of the respondents did not differentiate between Grade A and Grade B eggs. This indicates that consumers had similar preferences for albumen quality of eggs.

Eggs with medium orange colored yolks were preferred over eggs with light lemon colored yolks. Approximately 45% of the respondents preferred medium orange colored yolks. The other 55% were divided equally between those who preferred darker and those who preferred lighter yolk colors. Yolk preference and grade preference had approximately the same influence on consumers' evaluation of eggs. The results indicate that these consumers had opposing preferences for egg yolk colors. This report shows that albumen quality and yolk color are both more important than uniformity of the attribute itself, and other attributes. However, uniformity within a dozen eggs is an important consideration.

Over the past decade, per capita egg consumption in the U.S.A. has declined 17% despite a significant rise in consumer purchasing power and sharp decreases in the real price consumers paid. In 1961, there were only 326 eggs consumed per capita compared with 392 eggs in 1951. The number of shell eggs consumed per person dropped to 295 in 1961 from 365 in 1951. Most of the loss in per capita consumption has occurred as a result of a drop in the use of eggs in consumers' breakfasts (U.S.D.A., 1962). People are eating smaller breakfasts that include fewer eggs or exclude eggs entirely according to a 1958 survey conducted by U.S.D.A. The other reason is that of health

reasons. Eggs contain more cholesterol than other foods in the human diet. Reports have shown that high levels of cholesterol in the body may cause heart diseases; however, there is little evidence that the cholesterol level of the diet has any appreciable effect on blood cholesterol. Besides these reasons, egg quality and the consumer's preferences are important. Consumers do not like low quality eggs nor defects such as blood and meat spots, large chalazae, mottled yolks, and off flavored eggs. Therefore, maintaining a high quality egg which satisfies the consumers' preferences may be a means of increasing or maintaining egg consumption.

SUMMARY

A hen's egg is one of the most perfect nutritive foods, containing all the essentials necessary for the growth and development of the body. Eggs, which are liked by most people, have long held an important place in human diets but they are also among the most delicate and perishable food products and are subject to rapid deterioration and are easily affected by unfavorable surroundings.

The quality of an egg is very unstable and it changes as it proceeds from the finest when first laid, toward an inedible condition, under the influence of various factors of which temperature, humidity and time are the most important. Other factors contributing to the rate of quality deterioration include management and handling practices. The initial quality of the egg is also influenced by many factors, but these initial factors can be controlled or improved by good management, good breeding and good nutrition of the fowl.

To maintain a high quality egg is a very essential part of marketing. The demand for high quality eggs is growing and is likely to continue to

grow for some time to come. Because consumers are discriminating against poor quality eggs and are willing to pay well for the assurance of being able to secure a particular grade or quality of eggs it is, therefore, important that the eggs are handled so as to reach the consumer with the least possible loss of their original quality.

To meet the requirements of consumers, recommended practices for the production and care of high quality market eggs should be as follows:

1. Good breeding: High egg quality starts with good breeding.
2. Good nutrition: A balanced ration is essential for high production of eggs of good quality.
3. Good management: Keep litter dry, nests clean, and provide an abundant supply of water.
4. Frequent gathering of eggs: Eggs should be gathered at least three or four times per day.
5. Proper cleaning: Dirty eggs should be properly cleaned. Eggs must be quickly dried after cleaning to best conserve quality.
6. Rapid cooling: Eggs should be cooled as soon as they are laid. The best temperature for holding market eggs on the farm is from 50° to 60° F. with a holding room relative humidity of 70 to 80%.
7. Frequent marketing: Twice a week marketing or oftener is essential to shorten the period between production and consumption.

ACKNOWLEDGMENT

The author wishes to express his most grateful thanks to his major instructor, Dr. Jack L. Fry, Assistant Professor of Poultry Science and Poultry Products Technology, for his valuable advice and guidance.

The author wholeheartedly offers his sincere thanks to Professor T. B. Avery, Professor and Head of the Department of Poultry Science, and to all other faculty members of the Department for the encouragement and support given throughout the course of this work.

REFERENCES

- 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. Burmester, 1934.
Characteristics of an abnormal type of egg shell. *Poultry Science* 13:116-122.
- Amer, M. F., 1961.
Incidence of meat and blood spots in eggs of Fayoumi and some standard breeds. *Poultry Sci.* 40:1341-1344.
- Arscott, G. H., P. Rachapattayakom and P. E. Bernier and F. W. Adams, 1962.
Influence of ascorbic acid, calcium and phosphorus on specific gravity of eggs. *Poultry Sci.* 41:485-488.
- Atwood, H., and C. E. Weakley, 1924.
Amount of carbon dioxide given off by eggs during incubation. *West Virginia Agr. Exp. Sta. Bul.* 185:1-15.
- Baker, R. C., F. W. Hill, A. Van Tienhoven and J. H. Bruckner, 1956.
Effect of nicarbazin on egg quality. *Poultry Sci.* 35:1132.
- Baker, R. C., and R. Curtiss, 1957.
Strain differences and seasonal changes in egg shell mottling, shell thickness and specific gravity and the interrelationships between these factors. *Poultry Sci.* 36:1103.
- Baker, R. C., F. W. Hill, A. Van Tienhoven and J. H. Bruckner, 1957.
The effect of nicarbazin on egg production. *Poultry Sci.* 36:718-726.
- Baker, R. C., and W. J. Stadelman, 1958.
Chicken egg chalazae-strain and individual hen variations and their relation to internal quality. *Poultry Sci.* 37:558-564.
- Baker, R. C., 1962.
The effect of type of nesting material on cleanliness of eggs. *Poultry Sci.* 41:870-873.
- Bailey, B. B., J. H. Quisenberry and J. Taylor, 1959.
A comparison of performance of layers in cage and floor housing. *Poultry Sci.* 38:565-568.
- Banks, C. D., and L. A. Voss, 1962.
Consumer preferences and their application to egg grading standards and marketing procedures. *University of Missouri, Agr. Expt. Bul.* 813.
- Beach, J. R., 1943.
Avian pneumoencephalitis, *Proc. 46th An. Meet. U. S. Livestock Sanitary Ass'n.*, pp. 203-223.

- Bearse, G. E., 1955.
Effect of alfalfa, vitamins on egg blood spot incidence. Flour and feed 56:26-27.
- Bearse, G. E., C. F. McClary and H. C. Saxena, 1960.
Blood spot incidence in chicken eggs and vitamin A level of the diet. Poultry Sci. 39:860-865.
- Becker, W. A., and G. E. Bearse, 1962.
Sulfanilamide, specific gravity of eggs and an interaction. Poultry Sci. 41:198-200.
- Bennion, N. 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, 1940.
Factors affecting egg quality. Oregon State College Cir. No. 138.
- Berg, L. R., G. E. Bearse and V. L. Miller, 1947.
The effect of the pre-laying level of calcium on the performance of White Leghorn pullets. Poultry Sci. 26:463-468.
- Berg, L. R., G. E. Bearse and C. M. Hamilton, 1947.
The effect of Newcastle disease on egg production and egg quality. Poultry Sci. 26:614-622.
- Berg, L. R., G. E. Bearse and V. L. Miller, 1951.
The effect water-soluble vitamins and energy level of calcium and/or vitamin D on the performance of laying pullets. Poultry Sci. 30:799-804.
- Bolton, W., 1957.
The effect of the age of the hen on the porosity of the egg. J. Agr. Sci. 49:384-386.
- Brant, A. W., A. W. Ott and K. H. Norris, 1951.
Recommended standards for scoring and measuring opened egg quality. Food Technol. 5:356.
- Brant, A. W., and H. L. Shrader, 1952.
Equipment and methods for measuring egg quality. U.S.D.A. AMS No. 246.
- Broadfoot, D. I. and W. M. Smith, Jr., 1954.
Effects of infectious bronchitis in laying hens on egg production, percent unsettable eggs and hatchability. Poultry Sci. 33:653-654.
- Bunnell, R. H., and J. E. Bauernfeind, 1958.
Paper presented at XI World's poultry Congress at Mexico City, Sept. 21-30.
- Campos, A. C., F. H. Wilcox and C. S. Shaffner, 1960.
The influence of fast and slow rises in ambient temperature on production traits and mortality of laying pullets. Poultry Sci. 39:119-129.

- Carlin, F. A., and J. Foth, 1952.
Interior quality and functional properties of oiled and thermostabilized eggs before and after commercial storage. Food Tech. 6:443.
- Cheney, B. and T. M. MacIntyre, 1947.
Quoted by Novikoff and Gutteridge (1949).
- Clark, T. B., 1940.
The relation of production and egg weight to age in White Leghorn fowls. Poultry Sci. 19:61-66.
- Cotterill, O. J. and A. R. Winter, 1954.
Egg white lysozyme. I. Relative lysozyme activity in fresh eggs having low and high interior quality. Poultry Sci. 33:607-611.
- Cotterill, O. J. and F. A. Gardner, 1957. Retarding thick white deterioration by holding shell eggs in sealed containers. Poultry Sci. 36:196-206.
- Cunningham, F. E., O. J. Cotterill and E. M. Funk, 1960.
The effect of season and age of bird on egg size, quality and yield. Poultry Sci. 39:289-299.
- Davis, G. T., 1959.
Plastic overwraps for maintenance of egg quality. Poultry Sci. 38:1197.
- Davis, B. H. and C. C. Brunson, 1961.
Relative effectiveness of oil and cellophane in protecting eggs. Poultry Sci. 40:1393.
- Davis, G. T. and A. F. Beeckler, 1962.
Plastic packing of eggs. I. Methods of packaging. Poultry Sci. 41:391-397.
- Dawson, L. E. and J. P. Watts, 1952.
Effect of nest litter on cleanliness of eggs. Poultry Sci. 31:913.
- Dawson, L. E., L. R. Champich, J. A. Davidson and H. C. Zindel, 1953.
Improving egg quality through R.O.P. breeders-A progress report. Poultry Sci. 32:896.
- Dawson, L. E., and C. W. Hall, 1954.
Relationship between rate of cooling, holding container and egg albumen quality. Poultry Sci. 33:624-628.
- Donovan, G. A., D. C. Henderson and R. N. Luneau, 1961.
Influence of high level vitamin A feeding on laying hens. Poultry Sci. 40:1395-1396.
- Eoff, H. J., R. E. Davies, T. M. Ferguson and J. R. Couch, 1961.
The effect of tranquilizers on egg production and egg shell quality in caged layers. Poultry Sci. 40:1315-1321.

- Erasmus, J. E., 1954.
Relations of yolk, albumen and egg weight in inbred lines of Brown Leghorns. *J. Agr. Sci.* 45:32-35.
- Evans, R. J. and J. S. Carver, 1942. Shell treatment of eggs by oiling.
1. Effect of time between production and oiling on interior quality of stored eggs. *U. S. Egg & Poultry Mag.* 48:546-549.
- Evans, R. J., J. S. Carver and A. W. Brant, 1944.
The influence of dietary factors on egg shell quality. *Poultry Sci.* 23:36-42.
- Evans, R. J., S. L. Bandemer, J. A. Davidson and P. J. Schaible, 1957.
Studies on the occurrence of pink whites and salmon colored yolks in stored eggs from hens fed crude cottonseed oil or cottonseed meal. *Poultry Sci.* 36:798-807.
- Farr, F. M., C. R. Creger and J. R. Couch, 1962.
Egg yolk pigmentation. *Poultry Sci.* 41:1643.
- Fletcher, D. A., H. L. Orr, E. S. Snyder and A. O. Nicholson, 1959.
Effect of oiling, packaging materials and addition of CO₂ on quality of shell eggs held in storage. *Poultry Sci.* 38:106-111.
- Frampton, V. L., B. Piccolo and B. Heywang, 1961. Discolorations in stored shell eggs produced by hens fed cottonseed meal. *J. Agr. & Food Chem.* 9:59-63.
- Frank, F. R., M. H. Swanson and R. E. Burger, 1962.
The relationship between shell strength and certain physical-chemical properties of egg shells. *Poultry Sci.* 41:1644.
- Fronza, F. M., and A. M. de la Cruz, 1939. Studies on the physical qualities of the hen's egg. VII. Variability of the physical qualities of new-laid eggs produced in different laying periods. *Philippine Agr.* 28:523-542.
- Fromm, D., 1959.
A rapid method for the determination of egg shell permeability. *Poultry Sci.* 38:171-173.
- Froning, G. and E. M. Funk, 1957.
Seasonal variations in quality of eggs laid by caged layers and their sisters on the floor. *Poultry Sci.* 36:1118-1119.
- Froning, G. W., and M. H. Swanson, 1961.
Effect of time of oiling and holding temperature on cloudy whites and percent outer thin white of shell eggs. *Poultry Sci.* 40:1405.
- Fry, J. L., and G. W. Newell, 1957.
Management and holding conditions as they affect the interior quality of eggs. *Poultry Sci.* 36:240-246.

- Funk, E. M., and H. L. Kempster, 1934.
Egg weight in the domestic fowl. Missouri Agr. Expt. Sta. Bul. 332.
- Funk, E. M., 1944.
Effects of temperature and humidity on the keeping quality of shell eggs. Missouri Agr. Expt. Sta. Res. Bul. 382.
- Funk, E. M., 1948.
The relation of the yolk index determined in natural position to the yolk index as determined after separating the yolk from the albumen. Poultry Sci. 27:367.
- Gardner, F. A., M. M. Miller and H. V. Courtenay, 1961.
The effect of overwrapping on interior egg quality. Poultry Sci. 40: 1406.
- Gibbons, M. R., 1950.
Preservation of eggs. Canadian J. of Res. 26:118-127.
- Gilbreath, J. C., L. F. Garvin and Q. B. Welch, 1959. Effect of orally administered reserpine on egg production and quality. Poultry Sci. 38:535-538.
- Goodwin, T. L., M. L. Wilson and W. J. Stadelman, 1962.
Effects of oiling time, storage position and storage time on the condition of shell eggs. Poultry Sci. 41:840-844.
- Gowe, R. S., 1955.
A comparison of the egg production of seven White Leghorn strains housed in two environments - floor pens and a laying battery. Poultry Sci. 34: 1198.
- Grant, J. H., 1948.
The secret of oiling eggs successfully. U. S. Egg & Poultry Mag. 54: 10-11.
- Grimes, J. F., 1953.
Influence of breeding method on albumen quality. Poultry Sci. 32:902.
- Grotts, R. F., 1956.
Seasonal variations in egg quality. M.S. Thesis. University of Missouri, pp. 66.
- Hafez, E. S., E., A. L. Badreldin and G. A. R. Kamar, 1955.
Egg components in the Fayomi fowl during the first laying year. Poultry Sci. 34:400-410.
- Haines, R. B., and T. Moran, 1940.
Porosity of, and bacterial invasion through, the shell of the hen's egg. J. Hygiene 40:453-461.
- Halloran, H. R. and B. T. Maxwell, 1955.
Effect of hen's age on egg quality. Nulaid News33(3):15-16.

- Hansen, R. S., G. E. Bearse and L. R. Berg, 1948.
Bird preference for and comparative egg soilage on various nesting materials. Poultry Sci. 27:666.
- Harms, R. H. and P. W. Waldroup, 1961.
The effect of composition of diet upon weight of eggs. Poultry Sci. 40:564-567.
- Harns, J. V., E. A. Sauter, B. A. McLaren and W. J. Stadelman, 1954.
The effect of season, age, and storage conditions on the flavor of eggs and products made using eggs. Poultry Sci. 33:992-997.
- Haugh, R. R., 1937.
The Haugh unit for measuring egg quality. U. S. Egg Poultry Mag. 43: 552-555.
- Heiman, V. and J. S. Carver, 1935. The yolk color index. U. S. Egg Poultry Mag. 41(8):40-41.
- Henderson, S. M., and F. W. Lorenz, 1951.
Cooling and holding eggs on the ranch. Calif. Agr. Exp. Sta. Cir. No. 405.
- Heywang, B. W. and A. R. Kemmerer, 1955.
The effect of procaine penicillin and ascorbic acid on egg weight and shell thickness during hot weather. Poultry Sci. 34:1032-1036.
- Heywang, B. W., A. R. Kemmerer and R. W. Lowe, 1962.
Yolk discolorations from cottonseed meal when eggs were oiled before storage. Poultry Sci. 41:131-133.
- Holst, W. F., and H. J. Almquist, 1931.
Measurement of deterioration of stored hen's eggs. Hilgardia 6:49-60.
- Homler, B. E. and W. J. Stadelman, 1961.
Effect of shell treating and cleaning methods upon albumen condition. Poultry Sci. 40:1415.
- Hunt, J. R., 1960.
The effects of adding ascorbic acid and acidic salts to the diet of laying pullets. Synopses of Addresses, The Poultry Industry School, Ont. Agr. College.
- Hunt, J. R. and J. R. Aitken, 1962.
Studies on the influence on ascorbic acid on shell quality. poultry Sci. 41:219-226.
- Jeffrey, F. P. and V. Darago, 1940.
Effect of high humidity on egg quality during shortholding periods. New Jersey Agr. Exp. Sta. Bul. 682.
- Jeffrey, F. P., 1941.
Changes in pullet year albumen index as affected by age of bird. Poultry Sci. 20:298-301.

- Jeffrey, F. P. and J. Pino, 1943.
The effects of heredity and of certain environmental factors on the incidence of blood spots in chicken eggs. Poultry Sci. 22:230-234.
- Jeffrey, F. P. 1945. Blood and meat spots in chicken eggs. Poultry Sci. 24:363-374.
- Jensen, L. S. and W. J. Stadelman, 1951.
The effect of frequent variations in temperature on egg quality loss during short holding periods. Poultry Sci. 30:788-789.
- Johnson, A. S. and R. S. Gowe, 1956.
The performance of eight strains of white leghorns at three locations with respect to egg quality traits. Poultry Sci. 35:1149.
- Jull, M. A., 1924.
Egg weight in relation to production. Part 11. The nature and causes of changes in egg weight in relation to annual production in pullets. Poultry Sci. 3:153-172.
- Kemmerer, A. R., B. W. Heywang and M. G. Vavich, 1960.
Effect of *sterculia foetida* oil on gossypol discoloration in cold storage eggs. Poultry Sci. 39:1264.
- King, S. C. and G. O. Hall, 1955.
Egg quality studies at the New York Random Sample Test. Poultry Sci. 34:799-809.
- Knox, C. W. and A. B. Godfrey, 1934.
Variability of thick albumen in fresh-laid eggs. Poultry Sci. 13:18-22.
- Koonz, C. H. and F. L. Kauffman, 1950.
Study of factors that influence penetration of oil into shells of eggs. Poultry Sci. 29:767.
- Korslund, H. J., W. W. Marion and W. J. Stadelman, 1957.
Some factors affecting quality loss in shell eggs. Poultry Sci. 36:338-341.
- Kraft, A. A., E. H. McNally and A. W. Brant, 1958.
Shell quality and Bacterial infection of shell eggs, Poultry Sci. 37:638-644.
- Lerner, I. L., L. W. Taylor and J. R. Beach, 1950.
Evidence for genetic variation in resistance to a respiratory infection in chickens. Poultry Sci. 29:862-869.
- Lorenz, F. W. and H. J. Almquist, 1936.
Seasonal variations in egg quality. Poultry Sci. 15:14-18.
- Lorenz, F. W. and W. E. Newlon, 1944.
A field survey of ranch egg quality. Poultry Sci. 23:418-430.
- Lorenz, F. W. and W. E. Newlon, 1944.
Influence of avian pneumoencephalitis on subsequent egg quality. Poultry Sci. 23:193-198.

- Lorenz, F. W., 1949.
On the efficiency of egg processing oils. Poultry Sci. 28:119-127.
- Lorenz, F. W., 1953.
Personal communication. Univ. of Calif., Davis, Calif.
- Lowry, D. C., I. M. Lerner and L. W. Taylor, 1956.
Intra-flock genetic merit under floor and cage managements. Poultry Sci. 35:1034-1043.
- Lund, W. A., V. Heiman and L. A. Wilhelm, 1938.
The relationship between egg shell thickness and strength. Poultry Sci. 17:372-376.
- Marusich, W., E. De Ritter and J. C. Bauernfeind, 1960.
Evaluation of carotenoid pigments for coloring egg yolks. Poultry Sci. 39:1338-1345.
- Masson, J. C., M. G. Vavich, B. W. Heywang and A. R. Kemmerer, 1957.
Pink discoloration in eggs caused by sterculic acid. Science 126:751.
- Mathison and Urbain, 1908.
Cited by Romanoff, A. L., and A. J. Romanoff, 1949. The Avian Egg. John Wiley and Sons, Inc. New York. p.422.
- May, K. N., F. J. Schmidt and W. J. Stadelman, 1957.
Strain variation in albumen quality decline of hen's eggs. Poultry Sci. 36:1376-1379.
- May, K. N., and W. J. Stadelman, 1960.
Some factors affecting components of eggs from adult hens. Poultry Sci. 39:560-565.
- McClary, C. F., 1955.
The restriction of ooporphyrin deposition on egg shells by drug feeding. Poultry Sci. 34:1164-1165.
- McDowell, K., 1958.
What about blood spots? American Poultry J., July-August.
- McLoughlin, D. K., E. E. Wehr and R. Rubin, 1957.
Egg shell color and egg production in New Hampshire laying hens as affected by nicarbazin medication. Poultry Sci. 36:880-884.
- Meehan, J. J., T. F. Sugihara, E. D. Ducay and Leo Kline, 1960.
Some performance and composition changes in egg white, whole egg, and yolk liquids as related to holding temperatures and other factors in parent shell egg breaking stock. Poultry Sci. 39:1274-1275.
- Mehring, A. L., Jr., 1949.
A device for measuring the strength of shells of eggs. Poultry Sci. 28:621-622.

- Meyer, E., 1953.
Mineral oil protects egg quality. Poultry Processing and Marketing. 59(5):12,24.
- Mountney, G. J. and C. Vanderzant, 1957.
Relationship of selected egg quality measurements. Poultry Sci. 36: 908-913.
- Mueller, C. D., T. B. Avery, H. D. Smith and R. E. Clegg, 1951.
Effects of controlled light and temperature for laying hens. Poultry Sci. 30:679-686.
- Mueller, W. J., 1961.
The effect of constant and fluctuating environmental temperatures on the biological performance of laying pullets. Poultry Sci. 40:1434.
- Novikoff, M. and H. S. Gutteridge, 1949.
A comparison of certain methods of estimating shell strength. Poultry Sci. 28:339-343.
- Olsson, N., 1934.
Studies on specific gravity of hen's eggs. Otto Harrassowitz, Leipzig.
- Olsson, N., 1936.
Studies on some physical and physiological characters in hen's eggs. Sixth World's Poultry Congress, Sec. II:310-320.
- Orr, H. L. and E. S. Snyder, 1959. A further study on the use of plastic film bags for egg storage. Poultry Sci. 38:736-737.
- Osborn, D. L., T. S. Yao and J. L. Adams, 1959.
Slat floors vs. floor pens for laying hens. Poultry Sci. 38:1234-1235.
- Ott, W. H., S. Kuna, C. C. Porter, A. C. Cuckler and D. E. Fogg, 1955.
Biological studies on nicarbazin, a new anticoccidial agent. Poultry Sci. 34:1215.
- Ott, W. H., A. M. Dickinson and A. C. Peterson, 1956a. Studies on the effect of nicarbazin on reproduction in chickens. Poultry Sci. 35:1163.
- Ott, W. H., S. Kuna, C. C. Porter, A. C. Cuckler and D. E. Fogg, 1956b.
Biological studies on nicarbazin, a new anticoccidial agent. Poultry Sci. 35:1355-1367.
- Parnell, E. D., 1950.
The keeping quality of shell eggs in storage as affected by Newcastle disease. Poultry Sci. 29:153-155.
- Parnell, E. D., 1957.
Profitable Poultry Production. John Wiley and Sons, Inc. New York.
- Pepper, W. F., S. J. Slinger, H. L. Orr and E. S. Snyder, 1959.
Effect of high and low energy diets and range versus confinement rearing on egg production and quality of fresh and held eggs. Poultry Sci. 38: 379-385.

- Petersen, C. F., and C. E. Lampman, 1949.
Relationship of egg size during first year production to percentage increase in second year. Poultry Sci. 28:302-305.
- Petersen, C. F., E. A. Sauter, A. C. Wiese and D. J. Lumijarvi, 1959.
Influence of calcium and other nutrients upon shell quality of high producing White Leghorn hens. Poultry Sci. 38:1236.
- Philpott, D., 1933.
The nature of variations in the egg weights of the domestic fowl.
Proc. 5th World's Poultry Cong. 2:479-490.
- Platt, C. S., 1948.
Some observations on the effect of Newcastle disease upon laying fowl.
Poultry Sci. 27:201-206.
- Podhradsky, J., 1936.
Andert sich die chemische Zusammensetzung des Eiklers, Eidotters und der Eischale während der Legeleistung und des Lebens der Legehennen?
Proc. 6th World's Poultry Cong. 1:321-323.
- Polin, D. and C. C. Porter, 1956.
The effect of nicarbazin on porphyrin and yolk formation. Poultry Sci. 35:1165.
- Polin, D., W. H. Ott and O. H. Siegmund, 1957.
The incidence and degree of yolk mottling in eggs from hens fed diets with and without nicarbazin. Poultry Sci. 36:524-528.
- Polin, D., 1957.
Biochemical and weight changes of mottled yolks in eggs from hens fed nicarbazin. Poultry Sci. 36:831-835.
- Polin, D., W. H. Ott and A. Zeissig, 1958.
Field studies on the effect of nicarbazin on egg quality. Poultry Sci. 37:898-909.
- Pope, C. W., P. J. Schaible and L. E. Dawson, 1961.
Effects of certain nutrients upon blood spots in chicken eggs. Poultry Sci. 40:377-382.
- Proudfoot, F. G., 1962.
The decline of internal egg quality during storage at 30° F. and 70° F. among six strains of Leghorns reared in confinement and on range. Poultry Sci. 41:98-103.
- Pyke, W. E., 1945.
Packaging is means of preserving eggs; treatment within egg cartons are helpful. Colorado Farm Bul. 7(3):9-13.
- Quinn, J. P., 1950.
Effect of Newcastle disease on egg quality. Poultry Sci. 29:776.

- Quinn, J. P., A. W. Brant and C. H. Thompson, Jr., 1956.
Effect of a naturally occurring outbreak of Newcastle disease on egg quality and production. *Poultry Sci.* 35:3-10.
- Reddy, C. V., 1962.
Influence of calcium in the laying rations on shell quality and interior quality of eggs. Kansas State University, Poultry Seminar, Presentation.
- Romanoff, A. L., 1929.
Study of the physical properties of the hen's egg in relation to the function of the shell secretory glands. *Biol. Bull.* 56:351-356.
- Romanoff, A. L., 1940.
Physicochemical changes in unfertilized incubated eggs of *Gallus domesticus*. *Food Research* 5:291-306.
- Romanoff, A. L., and A. J. Romanoff, 1949.
The Avian Egg. John Wiley and Sons, Inc. New York.
- Rosenberg, M. M., and T. Tanaka, 1951.
Effect of temperature on egg weight in Hawaii. *Poultry Sci.* 30:745-747.
- Sauter, E. A., W. J. Stadelman, Vivian Harns and B. A. McLaren, 1951.
Methods for measuring yolk index. *Poultry Sci.* 30:629-630.
- Sauter, E. A., J. V. Harns, W. J. Stadelman and B. A. McLaren, 1953.
Relationship of candled quality of eggs to other quality measurements. *Poultry Sci.* 32:850-854.
- Sauter, E. A., V. Harns, W. J. Stadelman, and B. McLaren, 1954a.
Effect of oil treating shell eggs on their functional properties after storage. *Food Tech.* 8:82-85.
- Sauter, E. A., J. V. Harns, W. J. Stadelman, and B. A. McLaren, 1954b.
Seasonal variations in quality of eggs as measured by physical and functional properties. *Poultry Sci.* 33:519-524.
- Sauter, E. A., C. F. Petersen and C. E. Lampman, 1961.
A comparison of various shell treatments in maintaining the quality of washed eggs. *Poultry Sci.* 40:1502-1507.
- Schaible, P. J., L. A. Moore and J. M. Moore, 1934.
Gossypol, a cause of discoloration in egg yolks. *Science* 79:372.
- Schaible, P. J., and S. L. Bandemer, 1946a.
Composition of fresh and storage eggs from hens fed cottonseed and non-cottonseed rations. III. Iron content. *Poultry Sci.* 25:451-452.
- Schaible, P. J., and S. L. Bandemer, 1946b.
Composition of fresh and storage eggs from hens fed cottonseed and non-cottonseed rations. V. Cause of discoloration. *Poultry Sci.* 25:456-459.

- Schwall, D. V., F. A. Gardner and E. D. Parnell, 1961.
Effects of oil treating on shell egg quality during short term refrigerated storage. Poultry Sci. 40:583-588.
- Scott, H. K., E. Jungherr and L. D. Matterson, 1944.
The effect of feeding sulfanilamide to the laying fowl. Poultry Sci. 23:446-453.
- Sharp, P. F., 1929.
The pH of the white as an important factor influencing the keeping qualities of hen's eggs. Science 69:278-280.
- Sharp, P. F., and C. K. Powell, 1930.
Decrease in the interior quality of hen's eggs during storage as indicated by the yolk. Ind. Eng. Chem 22:908-910.
- Sharp, P. F., and G. F. Stewart, 1931. Carbon dioxide and the keeping quality of eggs. U. S. Egg and Poultry Mag. 37:30.
- Sherwood, R. M., 1928.
The effect of various rations on the storage quality of eggs. Texas Agr. Exp. Sta. Bul. 376:5-12.
- Sherwood, R. M., 1931.
The effect of cottonseed meal and other feeds on the storage quality of eggs. Texas Agr. Exp. Sta. Bul. 429:5-19.
- Sherwood, D. H., T. T. Milby and W. A. Higgins 1956.
The effect of nicarbazin on reproduction in White Rock breeder hens. Poultry Sci. 35:1014-1019.
- Sherwood, D. H., T. T. Milby and H. L. Witz, 1956.
Further studies on effect of nicarbazin on reproduction of chickens. Poultry Sci. 35:1171.
- Shupe, W. D., and J. H. Quisenberry, 1961.
Effect of certain rearing and laying house environments on performance of incross egg production type pullets. Poultry Sci. 40:1165-1171.
- Siegel, P. B., and C. E. Howes, 1959.
A comparison of various poultry nesting materials. Poultry Sci. 38:1247.
- Smith, A. J. M., 1931.
Rate of carbon-dioxide output by eggs. Dept. Sci. Ind. Research (Brit.) Report of the Food Investigation Board for 1930, p. 95-97.
- Snyder, E. S., 1961.
Eggs, Publication 446, Ontario Dept. of Agr.
- Spamer, C. O., 1931.
Historic methods and present practice of preserving eggs in Holland. U. S. Egg and Poultry Mag. 37(2):48-51.

- Stadelman, W. J., and M. L. Wilson, 1958.
An oil dispensing aerosol for quality preservation of shell eggs. Poultry Sci. 37:731-733.
- Stephenson, A. B., and R. L. Bryant, 1944.
The value of a sod range for starting chicks, growing pullets and laying hens. Virginia Agr. Exp. Sta. Bul., 362:1-18.
- Stewart, G. F., 1936.
Shell characteristics and their relationship to the breaking strength. Poultry Sci. 15:119-124.
- Stiles, P. G., and L. E. Dawson, 1961.
The effect of physical disturbance, sound and light on the incidence of blood spots and other egg quality factors. Poultry Sci. 40:189-195.
- Strain, J. H., and A. S. Johnson, 1957.
Seasonal, strain and hatch effects on egg quality traits. Poultry Sci. 36:539-546.
- Straub, J. and C. M. Donck, 1934.
Cited by A. L. Romanoff and A. J. Romanoff, 1949. The Avian Egg. John Wiley and Sons, Inc., New York, p. 42.
- Stuart, H. O., and C. P. Hart, 1938.
The effect of different calcium intake levels on egg production, shell strength, and hatchability. Poultry Sci. 17:3-7.
- Swanson, M. H. 1953.
A proposal for the use of carbon dioxide in retail egg cartons. Poultry Sci. 32:369-371.
- Swanson, M. H., P. E. Waibel, N. V. Helbacka and E. L. Johnson, 1955.
The effects of arasan on shell egg quality. Poultry Sci. 34:1223-1224.
- Swanson, M. H., 1959.
Some observations on the peeling problem of fresh and shell-treated eggs when hard cooked. Poultry Sci. 38:1253-1254.
- Swenson, T. L., and L. H. James, 1932.
Oiling does not make shell eggs more brittle. U.S. Egg and Poultry Mag. 38(11):14-16.
- Swenson, T. L., 1939.
A summary of studies on the oiling of eggs. USDA MC-58:1-27.
- Swensen, A. D., E. A. Fieger and C. W. Upp, 1942.
The nature of egg yolk discoloration produced by cottonseed meal. Poultry Sci. 21:374-378.
- Tarver, F. R., Jr., 1961.
The influence of yolk color intensity upon yolk shadow values, albumen quality and yolk color index—deposition and color intensity of abdominal fat of pullet carcasses. Poultry Sci. 40:987-991.

- Thornton, P. A., and R. E. Moreng, 1958.
The effect of ascorbic acid on egg quality factors. Poultry Sci. 37:691-698.
- Thornton, P. A., and R. E. Moreng, 1959.
Further evidence on the value of ascorbic acid for maintenance of shell quality in warm environmental temperature. Poultry Sci. 38:594-599.
- Thornton, P. A., 1960.
The effect of dietary calcium level on the efficiency of ascorbic acid in maintenance of egg shell thickness at increased environmental temperatures. Poultry Sci. 39:1401-1406.
- Thornton, P. A., and S. S. Deeb, 1961.
The influence of thyroid regulators on blood ascorbic acid levels in the chicken. Poultry Sci. 40:1063-1067.
- Thurnberg, T., 1902.
Quoted by Romanoff, A. L., and A. J. Romanoff, 1949. The Avian Egg, John Wiley and Sons, Inc. New York.
- Tyler, C., 1946.
The influence of different levels of dietary calcium upon egg shell thickness, with a study of the relationship between egg-shell thickness and porosity. J. Agr. Sci. 36:111-116.
- U.S.D.A., 1960.
Regulations governing the grading and inspection of shell eggs and United States standards, grades, and weight classes for shell eggs. (As amended effective August 1, 1963). U.S.D.A., AMS., Poultry Div. Regulations Effective July 1, 1960.
- U.S.D.A., 1961.
Egg Grading Manual. U.S.D.A., Agr. Handbook No. 75.
- U.S.D.A., 1962.
Poultry and egg situation. U.S.D.A. Economic Research Service Bul. No. 218.
- Van Matre, N. S., R. E. Burger and F. W. Lorenz, 1957.
Resistance to heat stress following administration of tranquilizing drugs. Poultry Sci. 36:1165.
- Van Wagenen, A., G. O. Hall and H. S. Wilgus, Jr., 1937.
Variation in egg quality characteristics in certain breeds, varieties and strains in chickens. J. Agr. Res. 54:767-777.
- Vondell, J. H., 1961.
The effects of humidity on eggs and cases. Poultry Sci. 40:698-701.
- Wallace, H. B., 1961.
What to do for egg shell problems. Hy-Line Service Bull.

- Warren, D. C., R. Conard, A. E. Schumacher and T. B. Avery, 1950.
Effects of fluctuating environment on laying hens. Kansas Agr. Exp.
Sta. Bul. 68.
- Weiss, H. S., 1957.
Further comments on the effect of nicarbazin on the egg. Poultry Sci.
36:589-591.
- Weiss, H. S., H. Fisher and P. Griminger, 1960.
Chemical control of onset of egg production. Poultry Sci. 39:1221-
1223.
- Welch, Q. B., R. E. Waggoner and J. C. Gilbreath, 1960.
A comparison of two devices for measuring egg shell thickness. Poultry
Sci. 39:907-909.
- Wesley, R. L., and W. J. Stadelman, 1959.
Measurements of interior egg quality. Poultry Sci. 38:474-481.
- Weston, W. A. R. D., and E. T. Halnan, 1927.
"Black spot" of eggs. Poultry Sci. 6:251-258.
- Wilhelm, L. A. 1939.
Factors affecting interior egg quality. Proc. 7th World's Poultry Cong.
p. 521-524.
- Wilhelm, L. A., 1939.
Egg quality—a literature review. U. S. Egg and Poultry Mag. 45(9,10,11):
565-573, 588-594, 619-624, 675-679, 687-694.
- Wilhelm, L. A., 1940.
Methods of improving interior egg quality. Poultry Sci. 19:3-8.
- Winter, A. R. and K. F. Schlamb, 1948.
Influence of range versus confinement rearing on growth, feed consumption,
egg production and liveability. Poultry Sci. 27:571-578.
- Yao, K. T. S., 1958.
Egg interior quality of purebred, inbred, incross and incrossbred chickens.
Poultry Sci. 37:1254-1255.
- Yao, T. S., 1959.
The influence of slatted floor and litter floor on the genetic variations
in chickens. Poultry Sci. 38:1472-1473.

FACTORS AFFECTING QUALITY OF MARKET EGGS

by

KUM-SEONG LEONG

B.S., National Taiwan University, Taipei, Free China, 1960

AN ABSTRACT OF A MASTER'S REPORT

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Poultry Science

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1963

A hen's egg is one of the most perfect nutritive foods, containing all the essentials necessary for the growth and development of the body. Nature has so completely balanced the food nutrients in the egg that it is an almost perfect and an economical food for man.

The quality of eggs is unstable. They are among the most delicate and perishable food products, are subject to rapid deterioration and are easily affected by unfavorable surroundings if not handled properly.

Factors affecting the initial quality of an egg are:

1. Breeds: High egg quality starts with good breeding. Important egg quality factors such as egg weight, shell texture, shell thickness, shell color and albumen height are inherited.

2. Ration: Unbalanced rations or unfavorable ingredients will affect egg quality. With a lack of calcium in the diet, soft or thin shelled eggs are obtained. Feeding a high level of cottonseed meal to laying hens will cause discolorations of eggs because of gossypol. Alfalfa meal and corn will affect the intensity of yolk color for they are rich in xanthophyll.

3. Disease: Most outbreaks of disease or any major flock disturbance will influence egg quality. The most common diseases affecting egg quality are Newcastle disease and infectious bronchitis.

4. Drugs: Presently several medications can be added to the laying hen rations in order to prevent or eliminate diseases. These include such products as nicarbazin, piperazine, sulfanilamide and others. Some of these have affected egg quality. Nicarbazin is one of the most serious. It causes shell depigmentation, yolk mottling and decreased egg size if included in the diet of laying hens.

5. Seasons: Egg quality is affected by seasons and especially by

summer temperature. High environmental temperatures reduce the thickness of the chicken's egg shell. Egg weight, egg size and albumen quality are also influenced by seasons.

6. Age: As birds grow older they lay larger eggs, their shells become thinner, and albumen quality declines.

7. Management: Management is very important in poultry production. If it is not done in the proper way, it not only will affect the quality of eggs but also a great loss will be encountered from the standpoint of low-ered production.

The factors affecting quality of stored eggs are:

1. Temperature and time: The higher the temperature and the longer the storage period, the greater is the decrease in egg quality because higher temperature increases evaporation and gaseous losses. The 55° F. temperature is commonly used in short-time commercial egg storage or farm holding of eggs.

2. Humidity: Humidity is an important factor in preventing evaporation of moisture from eggs. Thus, it prevents loss of egg weight and it also prevents reduction in grade.

3. Atmosphere: Addition of CO₂ in the storage room or in the package is done or could be done in order to preserve the albumen quality by keeping a low pH. It is seldom used commercially.

4. Shell treatment: The purpose of oiling is to retain the original CO₂ within the shell which helps to keep the albumen firm and to slow down the evaporation from the egg during storage.

5. Overwrapping: Another method of maintaining a low pH and preventing the escape of moisture is that of overwrapping eggs with cellophane or plastic films. Shell treatment is, however, more practical from a labor-cost standpoint.