FACTORS AFFECTING THE QUALITY AND GRADE OF MANITOBA EGGS.

by

August S. Johnson.

A THESIS

Submitted to the Graduate School of

T h e   U n i v e r s i t y   o f   M a n i t o b a

in Partial Fulfilment of the Requirements for the

Degree of Master of Science.

M a y   1 9 4 6.

Contents

Contents (continued)

ACKNOWLEDGMENTS

The author wishes to express his sincere appreciation to Professor J. R. Cavers, in charge of Poultry Husbandry at the University of Manitoba, for suggestion of the problem, advice throughout the project and helpful criticism during the writing of this thesis.

The invaluable advice given by Dr. C. H. Goulden, Senior Agricultural Scientist, of the Dominion Laboratory of Cereal Breeding, Winnipeg, regarding statistical analysis of the data, is gratefully acknowledged.

The author is indebted to the Dominion Department of Agriculture for the payment of expenses incurred during the field work. The cooperation of members of the staff of the Poultry Division in the local branch of the Dominion Department of Agriculture and of the Manitoba Cooperative Poultry Marketing Association was appreciated.

Thanks is also expressed to Dr. H. F. Batho, formerly of the Physics Department, University of Manitoba, for assistance in testing the yolk shadow scale, and to Mr. W. E. Clark, of the Dominion Rust Research Laboratory, Winnipeg, for the photographic work.

Contents of Tables

Contents of Tables (continued)

Contents of Tables (continued)

Contents of Figures

Contents of Figures (continued)

INTRODUCTION

The perishable nature of eggs means that the maintenance of their quality is of importance to producers and consumers alike. Considerable experimentation has been done in the laboratory with regard to the factors involved in production and maintenance of quality as well as the bearing that these factors have on the candling grade. Yet, in spite of this, a considerable proportion of the eggs which are marketed in Manitoba are of inferior grades. Therefore, one must conclude that, either the knowledge gained is not being used to improve egg quality, or that it does not apply to Manitoba conditions.

The poultry industry in Manitoba is generally a farm flock proposition, secondary in importance to grain and livestock production. Yet the income from poultry products forms about seven per cent of Manitoba's agricultural revenue. About two-thirds of this results from the sale of eggs. Because poultry is kept as a side-line by most flock owners, conditions of care and management vary greatly between farms and are, in many cases, haphazard. It is difficult to simulate these conditions in the laboratory in order to determine the reasons for the large proportion of low grade eggs which appear on the market, particularly during certain seasons of the year.

Egg quality is primarily a summer problem in Manitoba. This is shown clearly in Figure 1 where the seasonal trend of the percentage of A grade eggs, at a representative grading station, is charted. It indicates a level of about 92 per cent A grade eggs during the winter months of 1944, compared with only 45 per cent during August and September. Yet records of shipments for a few individual flocks have been observed where the percentage of A grade eggs remained at the winter level throughout the year. A preliminary investigation by the Dominion Department of Agriculture and the University of Manitoba in 1944 indicated the need for a study of the different factors of management in order to establish whether the variations in quality between farms were due entirely to environmental conditions of the eggs after laying or whether they were due partly to management and feeding of the flock.

The relationship between different factors of quality in eggs and the candling appearance, as seen in commercial grading, is one which has never been definitely determined. Correlations have been observed between some of these factors, such as yolk shadow and yolk color, but the independent effect of each in determining the candling grade has never been ascertained.

The purpose of this study was, therefore, to determine, through field observations, the relative importance of various production and handling factors affecting the grade of Manitoba eggs and also to find the relation between grade and actual quality, as revealed by routine methods of measurement.

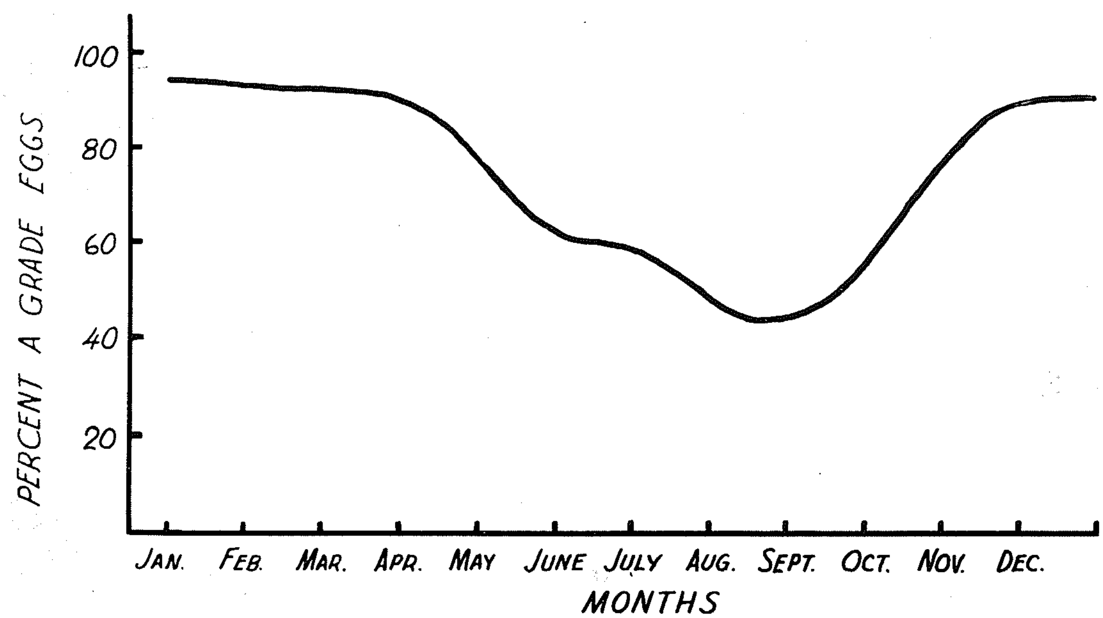


Figure 1. Trend of egg quality, during 1944, in the district surveyed.

REVIEW OF LITERATURE

Almquist (2) stated in his review of work done on the "Relation of Candling Appearance of Eggs to their Quality" that although the present method of grading eggs by candling is not accurate enough to make fine distinctions in quality, it is probable that no other method will be devised by means of which eggs can be graded commercially with the same versatility, accuracy and speed.

Coles (10) stressed the two main factors which are used as criteria of egg quality, namely the condition of yolk and of albumen. The two are related in candling since "attention to the yolk" implies a reliance upon the amount of thick white encasing the yolk, as the criterion of egg quality. He stated:

> "the method of candling adopted with regard to the grading of yolks is only about 60% accurate. But on the other hand it must be realized that the majority of eggs that have been regarded as 'seconds' on candling (although presumably fresh) prove to be abnormalities on breaking out, i.e., they have fractured whites or unequal chalazae. Nevertheless it is probable that quite a number of eggs are affected by these peculiarities and that candlers are apparently rejecting them as 'seconds'."

He further showed that shipping eggs for a distance of 250 miles caused a deterioration in quality of about 20 percent.

Almquist, Givens and Klose (4) found that the transmission of light by egg albumen is correlated with its percentage of mucin content. The physical condition of the mucin is affected by temperature and pH variations which cause differences in transmission of light. Thus changes in the candling appearance of eggs may result which are not caused by changes in interior quality.

Lorenz and Newlon (28) observed that, under ranch conditions, the greatest loss in albumen quality of eggs occurs during the first 24 hours after laying, although important influences on albumen quality occur also before they are laid and during the remainder of the time on the ranch. They observed a significant seasonal loss in albumen quality. They maintained that actual interior quality deteriorates more than the estimate of quality by candling. Perry (39) claimed exactly the opposite: that the candling appearance seems to indicate a greater deterioration than has actually taken place. Paulhus and Gwin (36) concluded that the candled appearance of eggs was not as reliable a measure of interior quality as broken-out appearance. Botsford (7) found that yolk color could vary considerably without influencing the candler's grade. He decided that the visibility of yolk shadow and the movement of yolk consistent with the type of light used, were the best means of determining interior quality, other factors being auxiliary. It was found by Macdonald and Krishnan (31) that the loss in quality in the first 18 to 24 hours at room temperature is slightly more than the loss in quality from storage for a week at 55°F. Powell and Sharp (40) and Pennington <u>et al</u> (38) indicated the value of measurement of deterioration of the yolk as a criterion of internal quality. The method commonly proposed is the yolk index, which is the height divided by the width. As deterioration progresses the yolk flattens, resulting in a smaller index. However, Holst and Almquist (21), Heiman and Wilhelm (17), Wilhelm (54), and Heiman and Carver (15) indicated that the yolk index had certain limitations as an accurate measure of quality and that it was surpassed in accuracy, as a physical measurement, by the albumen index and albumen height. Holst and Almquist (21) suggested that judgment of quality by determination of the percentage of thick white would be superior to the yolk index. Although the percentage of thick white was used as a measure of quality by Lorenz and Almquist (27), Holst and Almquist (21), Macdonald and Krishnan (31) and Knox and Godfrey (25), this method was not found satisfactory by Krishnan (26) or by Heiman and Wilhelm (17), who decided that it bore little relationship to the observed grade. The latter found the same to be true in case of the yolk index. Heiman and Carver (15) proposed the use of the albumen index, involving the surface area of the egg, as a more accurate measure of interior quality. This method was used, also, by Heiman and Wilhelm (17) and by Jeffrey (23).

Van Wagenen and Wilgus (50) outlined a method of scoring broken-out eggs (according to a set of standard pictures) as to their physical appearance. They obtained significant correlations between the observed condition of the albumen and the visibility and mobility of the yolk shadow. They suggested the height of the thick albumen as a suitable physical measurement of its condition and therefore as a measure of the interior quality of the egg. Subsequently they described this method in more detail (Wilgus and Van Wagenen (52)) and devised an index by means of which the albumen height of any egg could be interpreted in terms of a two ounce egg. Considered by them as an accurate and rapid aid in determining interior quality, this method was used, also, by Lorenz and Newlon (28).

As stated by Pennington (37) and supported by Heiman and Wilhelm (18) and Henderson and Wilcke (19), the color of the yolk is due primarily to the pigment-producing xanthophyllic compounds; these occur in green feed, yellow corn etc., in the hens' diet. Yolk color and other egg quality factors, according to Munro (32), are a function of the individuality of the hen but much of the variation is due to feed. According to Schaible et al (43) the spotting of yolks occurs, not because of deep yolk color, but because the egg yolk is composed of concentric layers of dark and light yolk surrounding a central core of light yolk; thus, when a dark layer protrudes through an imperfect external layer of light colored yolk, spots occur. Results obtained by Stewart, Gans and Sharp (48) indicate that, with increasing yolk color, there is a slight but regular change in the condition of the white causing a lowering of the quality score. The percentage of thin albumen remains fairly constant up to a yolk color of 3.5 (in a range of 1 to 5) after which it increases rapidly. They indicated that an increase in size of air cell seemed to be associated with increased yolk color.

Correlation coefficients between yolk color and yolk shadow varying from .44 to .71 were obtained by Parker, Gossman and Lippincott (34). They concluded from this that there was a strong trend of yolk shadow with yolk color and their contention was that it would be possible to estimate yolk color in fresh eggs fairly accurately by candling.

Ringrose and Morgan (41) showed that green feed as a supplement did not affect the quality of eggs as measured by the determination of albumen height, percentage firm albumen and yolk index. This evidence was substantiated by Denton and Titus (12).

In previous work done by Ringrose and Morgan (42), it was shown that different levels of protein supplements have no material effect on interior physical quality of the egg. Card and Sloan (9), in testing different rations, found that in no case did the percentage of thick white drop enough to result in eggs of distinctly inferior quality, but that there was some indication that the percentage of firm white could be influenced by the ration.

Knox and Godfrey (25) and Hunter et al (22) found a definite seasonal trend toward lower interior quality as evidenced by the percentage of thick albumen from spring to summer.

Holst and Almquist (21), Lorenz et al (30), Van Wagenen and Hall (49), Lorenz and Taylor (29), and Macdonald and Krishnan (31), all gave supporting evidence of the inheritance of albumen quality to the extent that strains of poultry can be developed with higher albumen quality than others.

Experimental evidence was given by Skoglund and Tomhave (45) to show that the frequency of gathering eggs has a marked effect on interior egg quality as shown by quality of the white. Wilhelm and Heiman (55) found that eggs maintain their quality during storage in proportion to their original quality; that is, about the same percentage loss occurred in all cases. Almquist and Lorenz (6) obtained a high positive correlation between the percentage of firm white of stored eggs with that of fresh eggs from the same hens. They claimed that eggs with a higher initial percentage of firm white had a lower percentage liquefaction.

MATERIALS AND METHODS

I. Apparatus used and methods of measuring quality.

The project was of a nature demanding that any measurements or tests of egg quality be as simple as possible. With limited facilities available in the field and the necessity of securing a maximum amount of information at any one time, this was important. However, it would have been pointless to sacrifice accuracy for speed and volume of data.

Determinations were made according to five criteria which were used in the work throughout:

1. yolk shadow
2. candling grade
3. yolk color
4. albumen score
5. albumen height

1. Yolk shadow

Although it is not in itself a direct criterion of egg quality, yolk shadow is considered an important factor in estimating interior quality. Because of its importance in the commercial grading of eggs, due to this attributed association with interior quality factors, as found by other workers (7,34), it was important to obtain a measure of yolk shadow before the eggs were broken.

A yolk shadow scale was devised (Figure 2) consisting of a 4 x 16 inch metal plate, with 1/2 inch holes in two rows 1/4 inch apart. There were fifteen holes, 1/2 inch apart, in each row. Over one row of holes were placed a series of colored filters, which were combinations of different shades of gelatin paper, resulting in a range from light straw color to dark reddish amber. The other row of holes was left open.

The use of colored filters was necessary since, in candling, the passage of light through the egg, resulting in yolk shadow, also involves a certain amount of color, due to the effect of the shell. This color increases with greater depth of yolk shadow, which results from a lower degree of light transmission. Arranged as shown in Table I, the filters gave an even gradation of color, as well as a gradual reduction in the transmission of light, from Filters 1 to 15.

To obtain the desired effect of color and light transmission the following colors of gelatin paper were used:

light straw - #2
lemon - #6
light amber - #10
amber - #12
dark amber - #13

The colors of paper were obtained commercially by the name and number given.

TABLE I

Composition of filters of yolk shadow scale.

Filter No.	Color Combination	Filter No.	Color Combination
1	1 light straw	10	1 light straw 1 lemon 2 light amber 2 amber
2	1 lemon		
3	1 light straw 1 lemon	11	1 lemon 3 light amber 3 amber
4	1 light straw 2 lemon		
5	3 light straw 1 lemon	12	2 light amber 4 amber
6	1 light straw 1 lemon 1 light amber	13	5 light amber 2 amber 1 dark amber
7	1 light straw 1 lemon 2 light amber	14	3 light straw 1 light amber 1 dark amber
8	1 light straw 2 lemon 2 light amber	15	2 light straw 1 lemon 1 light amber 2 amber 2 dark amber
9	1 light straw 1 lemon 2 light amber 1 amber		

In order to approach as nearly as possible an even gradation of light transmission, in association with increasing depth of color, it was necessary to test the filters by means of a photoelectric cell, using a constant source of light. When satisfactory combinations were obtained by this method, they were checked more accurately by means of a flickermeter. Readings were obtained on the flickermeter with light passing through the different filters. Thus the percentage transmission of light through each filter was calculated and the relative transmission of the filters was obtained. Four readings were taken for each of the 15 filters. The averages of these are shown in Table II.

TABLE II

Relative light transmission of yolk shadow scale filters.

Filter Number	Average Flicker Reading
1	.796
2	.788
3	.728
4	.654
5	.602
6	.588
7	.508
8	.371
9	.423
10	.368
11	.298
12	.251
13	.242
14	.216
15	.185

A gradual decrease in light transmission was obtained in all cases except with filter number 8, the reading here being too low. It was found impossible to avoid this drop and still maintain an even gradation of color. This did not prove to be a serious defect when the scale was in use. It was attributed to a sharp drop in the light transmission in that particular portion of the spectrum.

In using the yolk shadow scale each egg was held before the candling lamp in the normal manner for candling and was rotated slightly in order to make certain that the deepest yolk shadow was showing through the upper portion of the shell. The scale was placed over the egg so that the yolk shadow showed through one of the open holes. The corresponding filter was then in such a position that the light that came through it passed through the albumen and shell only, and no yolk shadow was included. By comparing with different filters, the depth of yolk shadow was obtained.

2. Candling grade

To prevent bias on the part of the author, grading of all the eggs was done by an inspector from the Department of Agriculture who was not aware of the source of the eggs or the type of care to which they had been

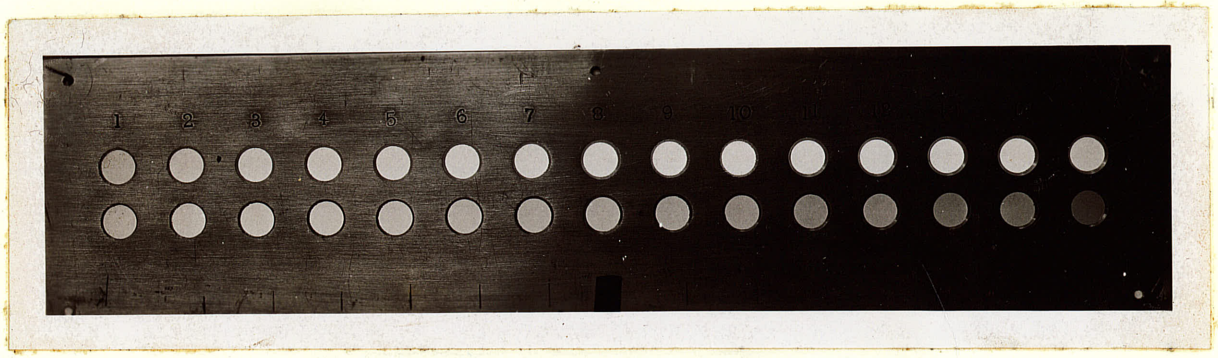


Figure 2. Yolk shadow scale.

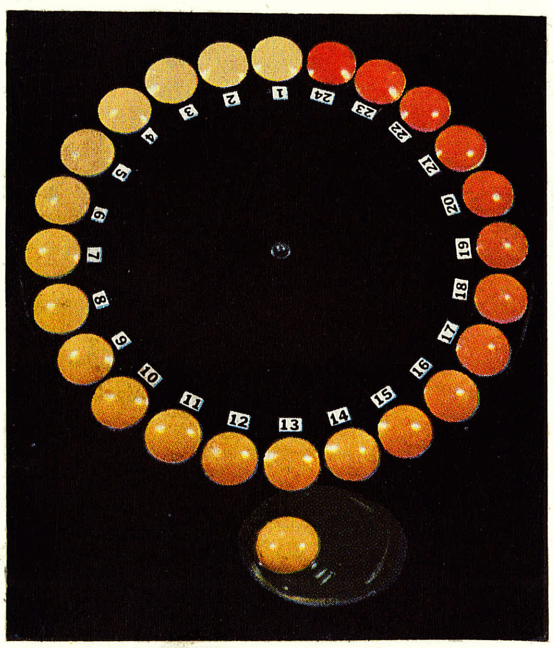


Figure 3. Yolk color rotor and method of matching colors.[1]

[1]Photo courtesy Professor E. S. Snyder, Ontario Agricultural College.

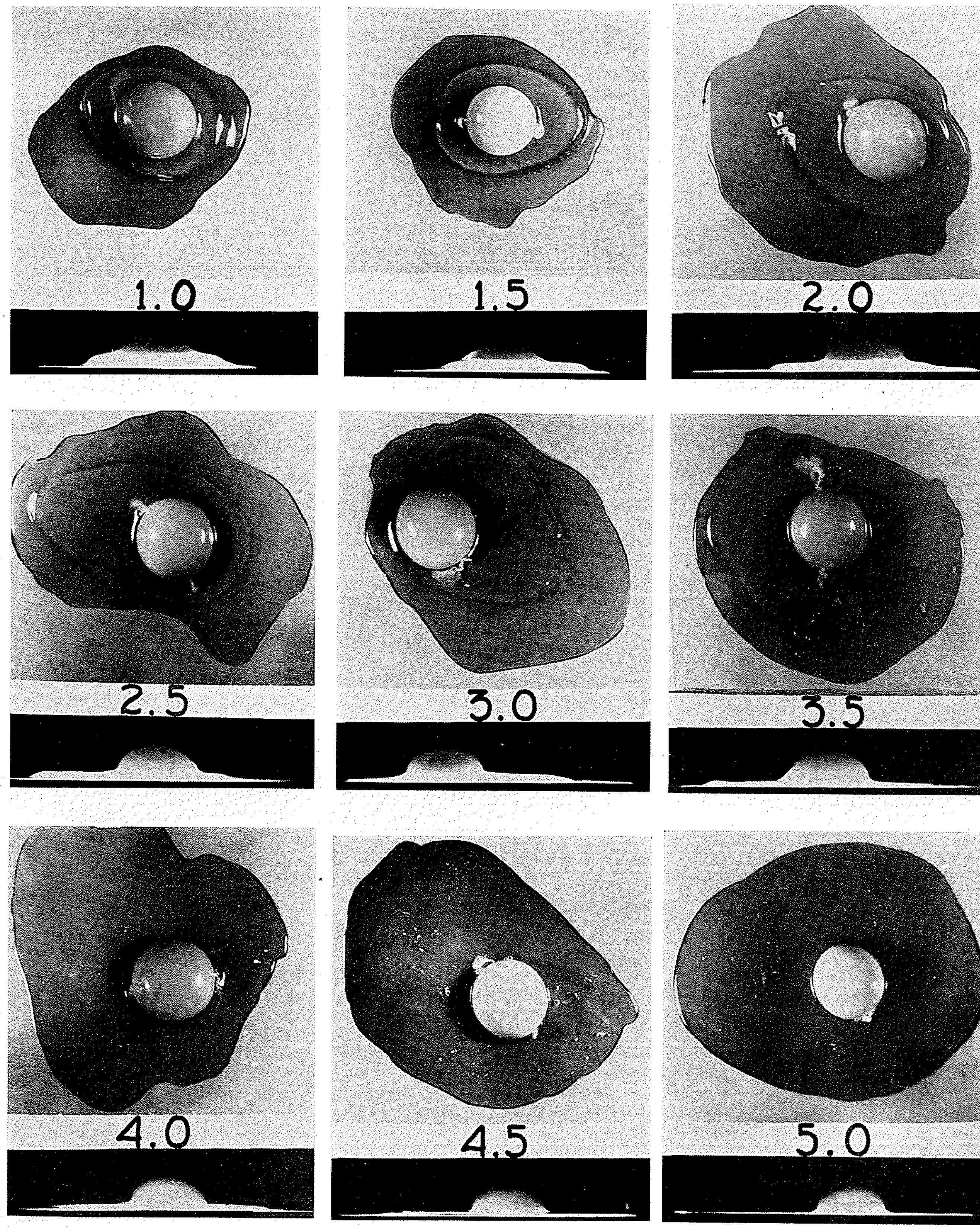
subjected. The eggs were graded for interior quality only, no attention being paid to slight stains on the shell. In selecting the eggs, cracks, off shapes and very poor shells were avoided. Small meat and blood spots were disregarded in grading but if an egg was found to contain so much blood as to make estimation of its quality difficult, it was discarded.

3. Yolk color.

A measure of yolk color was necessary in order to determine its relation to yolk shadow and general quality. This was done by matching the yolk in the broken-out egg with the nearest number on a yolk color rotor as illustrated in Figure 3. In determining the yolk color it was necessary to have adequate lighting to ensure a correct match. This was provided by a 200 watt daylight bulb suspended about 4 feet above the table where the determinations were being carried out.

4. Albumen score

Conclusions of several workers show that the most accurate measures of interior egg quality are measurements of the condition of the firm albumen. The method devised by Van Wagenen and Wilgus (50), of scoring broken-out eggs by comparing them with a set of standard pictures (Figure 4), was used as one measure of albumen quality.



Photos Courtesy Dr. Alfred Van Wagenen, Cornell University

Figure 4. Standard pictures for determination of albumen score.

5. <u>Albumen height</u>

It was felt that a visual judgment as a test of albumen quality might not be accurate enough since there was a possibility of human error entering into the determinations. It was, therefore, decided to use the direct measure of the albumen height, devised by Wilgus and Van Wagenen (52), as an additional indication of quality.

A thick glass plate was supported by four metal bases with screw-tops, which could be adjusted so that the glass was perfectly level. The egg was broken by giving it a short, quick tap on the sharp edge of a table. Proper manipulation in this way caused a complete break around the circumference of the shell. It was sometimes necessary to cut the shell membrane slightly with a small pair of scissors to help in opening the egg. Considerable care was necessary at this point to avoid rupturing of the thick albumen and release of the inner thin albumen. If this occurred a true measure of the physical condition of the albumen could not be obtained and the egg was discarded.

Indication of the albumen height was obtained by taking the average of two measurements, directly opposite each other, on the "plateau" or level area on the surface of the thick albumen. These measurements were taken with a tripod micrometer half-way between the edge of the yolk and the outer edge of the plateau, avoiding the chalazae, as shown in Figure 5.

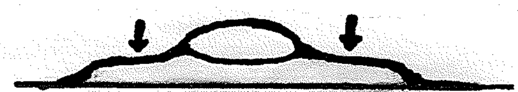


Figure 5. Points of measurement of albumen height.

Figure 6 shows the tripod micrometer in position for measuring the albumen height. The two readings seldom differed more than .010 inches. In eggs of exceptionally good quality, albumen was quite high around the edge of the yolk and there was no definite break in it. In such cases the readings were taken at the point where this break would ordinarily occur. Readings were taken to .01 inches.

To avoid the necessity of converting the albumen height reading into terms of a two ounce egg (Wilgus and Van Wagenen (52), eggs of an even size were selected, just large enough to weigh 24 ounces to the dozen.

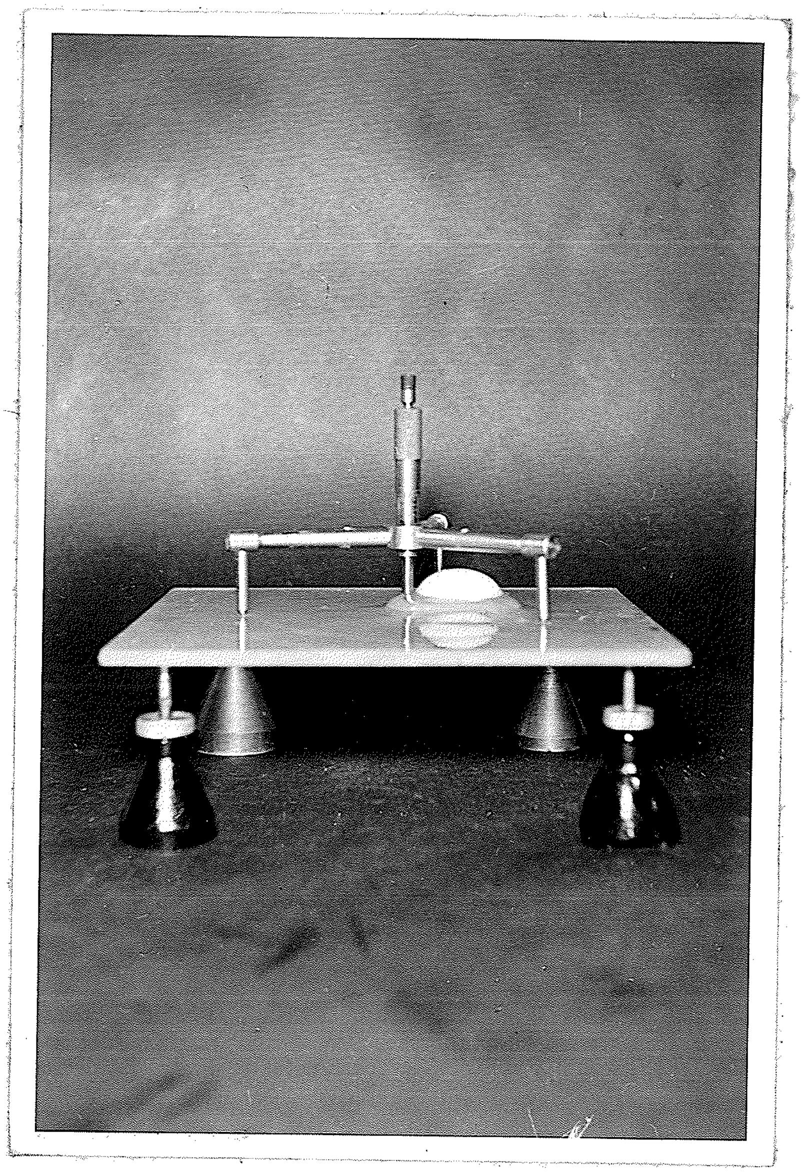


Figure 6. Method of measuring albumen height.

II. Experimental procedure.

The project constituted a survey of farm egg quality in Manitoba and the analysis of the data obtained therefrom. The purpose being to obtain a picture of egg quality which would be fairly representative of Manitoba, a rural district was selected which would most closely conform to this as well as to other requirements. This district contained a fairly large proportion of small flocks of from 100 to 250 birds, which was felt to be a desirable feature, since about 60% of Manitoba's egg production comes from such flocks. Another point in favor of selection of this district was that it was a central point for a fairly large number of shippers who could be reached quite easily. A government egg inspector stationed in the district was on hand to grade the eggs that were brought in from the farm. With the assistance of the Manitoba Cooperative Poultry Marketing Association, facilities were arranged in the local grading station for the breaking of eggs and measuring of egg quality.

During the summer of 1946 two trips were made to the district chosen. One week was spent each time in gathering data. The first trip was made during the first week of June. At this time numerous farms were visited of which 29 were selected as being suitable for study. The second trip was made in the first week of September when 28 farms were included in the survey.

Criteria which decided whether or not farms were suitable to include in the survey were:

1. Size and productivity of the flock.
2. Age and number of eggs on hand at the time of visit.
3. Apparent reliability of flock owner as to information regarding age of the eggs and feeding and general care of the flock.
4. Degree of interest and cooperation shown by the flock owner.

It was felt desirable to make repeat visits in September to farms visited in June but this was not always possible since some small flocks that were laying well in June were not in production in September. Information regarding care of flock and eggs was recorded in a questionnaire as shown in Figure 7.

In order to get a representative sample of the egg quality on a farm at the time of survey it was attempted to obtain three lots of eggs:

1. one dozen fresh from the nest.
2. one dozen day-old eggs.
3. one dozen eggs three days old.

It was sometimes difficult to adhere strictly to this system since occasionally, at the time of visiting a farm, there were not enough eggs of one age on hand. In such cases, of which there were four in June and three in

Figure 7.

Chart used for recording information on care of flock and eggs.

Farm No.________________ Date____________________

Name____________________ Address________________

Section__________ Township__________Range_________

No. Hens: Pullet_______ No. Roosters_____ Breed____

Yearling______

Egg Production: Winter___Spring____Summer____Fall__
(high,medium,low)

Temperature: Outside______Humidity: Outside_______

Egg Room_____ Egg Room_______

Feed: Mash______________________________________

Concentrate________________________________

Grain______________________________________

Shell, grit________________________________

Green feed_________________________________

Pasture____________________________________

Egg Collection:

Nests______________________________________

Time_______________________________________

Containers_________________________________

Holding____________________________________

Cleaning___________________________________

Delivery:

Frequency__________________________________

Method_____________________________________

Destination________________________________

Remarks:

____

September, if it was still felt desirable to secure some information from these farms, two lots of eggs were obtained.

The eggs were placed in dozen-size cartons which were marked as to number of farm and age of eggs. The cartons were then placed in an egg case the bottom of which was lined with shock absorbing material. The egg case was transported by car to the egg station.

The itinerary for each day was planned in such a way that a number of farms in one small area could be visited; thus the eggs could be brought back to the station in a minimum of time. These farms were first selected at the egg station by consultation with the operator and examination of records of previous egg receipts. The list for each day was made complete enough to include a variety of conditions of management and sizes of flocks. Allowance was made for the fact that some of the farms selected at the station would not be found suitable for study when visited.

Considerable attention was paid to securing data from flocks that were kept indoors. These were somewhat difficult to find and, of the 29 flocks visited in June, only 6 were kept indoors or on restricted pasture, while in September 11 of the 28 flocks were in this category. It was felt that these would serve as a means of comparison between unlimited and restricted pasture as to their effect on egg quality.

Since the major part of the work constituted the actual quality measurements of the eggs there was a limit to the amount that could be collected during each day. Therefore not more than five or six farms were surveyed per day.

Immediately upon arrival at the station the external measurements, that is, yolk shadow and grade, were made. The eggs were then broken out so that records of the yolk color, albumen score and albumen height could be recorded. Recordings of all the quality measurements were made for each individual egg on a chart such as is shown in Figure 8.

Figure 8.

Table used for recording data on egg quality.

Farm No.____________________ Date____________________

1.	Eggs (age)													
	1	2	3	4	5	6	7	8	9	10	11	12	Total	Average
Yolk Shadow														
Candle (A,B,C)														
Shell Color (W,L,M,D)														
Yolk Color														
Albumen Score														
Albumen Height														
Remarks:														

In the case of 17 farms duplicate lots of eggs of the different ages were obtained for the purpose of determining the extent of quality loss during shipment. At the egg station, recordings were made of the depth of yolk shadow and candling grade of each egg. The eggs were then marked as to number, age, and farm. These eggs were gathered in the latter part of the week and were stored in a crate in the egg station. At the end of the week they were shipped by railroad to Winnipeg among a carload of eggs. In June the temperature of the car, on unloading in Winnipeg, was 58°F. The temperature reading was not taken in September. Recordings were again made of yolk shadow and grade, after which the eggs were broken immediately and the usual interior quality determinations were made.

The time that elapsed between loading at the point of origin and unloading in Winnipeg was in each case three days. It was felt that in the case of these 17 farms, the eggs broken at the station would give a sample of the quality before shipment, and thus an estimate of the drop in quality of eggs from different farms could be obtained.

In recognition of the need for a check on the survey data, a more accurate type of experiment was set up at the University poultry plant. The object of this part of the project was chiefly to determine the effect, if any, of unlimited green feed on the candling grade and interior egg quality over a storage period of about a week.

Three pens each, of Barred Rock and White Leghorn hens, containing 30 birds per pen, were selected for this experiment. The two breeds were placed in alternate pens. All birds received the same basic ration, the only difference being in the amount of green feed consumed. Two pens, one of each breed, were given free access to plots of oat and rye pasture. Two similar pens were fed soaked, cut alfalfa at the rate of 3 pounds per 100 birds per day. The two remaining pens received no green feed.

The four pens receiving green feed were kept on this system for two weeks before any determinations were made, in order to allow the yolk color to become established.

The birds in these six pens were trapnested and the eggs were marked as to bird and pen number. The eggs were placed in empty nests at each trapping and were gathered twice a day and brought to the place of storage.

Recordings were made immediately of yolk shadow and grade. The eggs were stored, when cooled, in dozen-size cartons which were marked as to the date of gathering. The temperature of storage was 59.7 ± 2.0°F. The above procedure was followed for eight consecutive days at the end of which time the usual quality measurements were taken. The grading was done by an inspector from the Department of Agriculture.

Thus indications of the influence of green feed on egg quality could be obtained under uniform conditions of storage.

III. Statistical Methods.

Statistical treatment of the data required the use of several types of analysis. Methods of determining variance, x^2 square, linear regression and the significance of differences by the t-test were carried out as outlined by Goulden (13).

The analysis of the discriminant function, as described by Cox and Martin (11), was used in determining the relative importance of the quality factors in grading. This method lent itself particularly well to this type of data where it was desired to determine the independent effect of each quality factor. It was used in the same manner as outlined by the authors for differentiating between two types of soil. A description will be given later in more detail.

There were unequal frequencies of variates in the sub-classes in some of the data. This made the analysis of variance more complicated. A three-fold classification of variates was necessary in order to obtain a maximum amount of information. The method of "expected sub-class frequencies," described by Snedecor and Cox (47), was used. By this method, expected sub-class frequencies, corresponding to the actual frequencies, were calculated and used for the analysis. The suitability of the application of the method to the type of data concerned was tested by determining the goodness of fit of the theoretical to the actual data by means of the x^2 test. In all cases it was found satisfactory. The sum of squares for error was derived from the actual frequencies.

In determining the type of curve to fit to the data resulting from the study of the effect of green feed on egg quality, use was made of the "orthogonal polynomials" as given by Goulden (14). The heterogeneity of regressions was tested by analysis of variance.

RESULTS.

I. Individual importance of quality factors in grading.

The method of determination of the Discriminant Function as outlined by Cox and Martin (11) was used in the study of the relationship of yolk shadow, yolk color, albumen score and albumen height to candling grade. It was necessary to obtain a weighted value which would indicate the maximum amount of differentiation obtainable between grades, when only A and B grade eggs were considered. This value, D, was the difference between the means of a weighted compound, X, calculated for the two grades. The bases for obtaining this compound were the mean differences between grades for the four factors (Table III), in relation to their standard deviations shown in Table IV and also the coefficients of correlation between the different factors, listed in Table V.

Using the correlation coefficients in Table V, solutions to a set of normal equations were obtained, resulting in the derivation of the coefficients L_1, L_2, L_3 and L_4, shown in Table VI, each of which was a measure of the discriminating power of yolk shadow, yolk color, albumen score and albumen height respectively.

TABLE III

Mean values of four quality factors, by grade, and mean differences between grades, for June and September

Variate	June values			September values		
	A grade	B grade	Mean diff	A grade	B grade	Mean diff
Yolk shadow#	7.64	10.03	2.39	7.57	9.83	2.26
Yolk color#	15.01	16.72	1.71	13.56	15.48	1.92
Albumen score#	2.17	2.59	.42	2.27	2.73	.46
Albumen height##	.262	.221	.041	.247	.202	.045

#arbitrary units
##inches

TABLE IV

Standard deviations of values of four quality factors for June and September.

Variate	Standard deviations	
	June	September
Yolk shadow	1.5864	1.3098
Yolk color	2.6588	2.3179
Albumen score	.4508	.5186
Albumen height	.0491	.0484

TABLE V

Coefficients of correlation between four quality factors for June and September.

Variates		Correlation coefficients June	September
Yolk shadow	x Yolk color	.4899	.4245
	x Albumen score	-.0573	.2465
	x Albumen height	-.1951	-.2799
Yolk color	x Albumen score	-.1224	-.1387
	x Albumen height	.1113	.1253
Albumen score	x Albumen height	-.7982	-.8769

1% level of significance = .0810

TABLE VI

Relative values, L, of four quality factors, in differentiating between grades.

Variate	Discriminating values June	September
Yolk shadow	.117228	.063549
Yolk color	-.037017	-.002460
Albumen score	.202033	.218183
Albumen height	.213890	.236919

The results in Table VI show that the order of importance of the quality factors in differentiating between grade is: albumen height, albumen score, yolk shadow and yolk color. The negative values obtained in the case of yolk color do not indicate a negative effect of yolk color in maximizing the value of D, but can be considered to be the same as a positive value. This is true because the calculations resulting in the L values involved the use of several negative correlation coefficients.

The sum of the products of the coefficient L for each factor, multiplied by the result of the division of the corresponding mean difference by the standard deviation, was the value D which was the difference between the means of the compound X. D was found to be .015981 for the June data and .015191 for September.

Analyses of variance, the results of which are shown in Tables VII and VIII, were carried out to test, in each case, the significance of the difference D, and the validity of using the above factors in determining egg quality. The sums of squares for between grades were obtained by the formula (11):

$$\frac{N_1 N_2}{N_1 + N_2} \times D^2$$

where N_1 and N_2 were the numbers of variates in grades A and B respectively. The sums of squares within grades were the values of D. In the case of the June data (Table VII) and also for the September data (Table VIII), a highly significant F value was obtained for the variance between the means of the compound X, calculated for each of the two grades.

TABLE VII

Results of analysis of variance of the compound X, between and within grades, for June data.

Source of variation	D.F.	Mean Square	F value
Between grades	3	.017257	1165.23##
Within grades	1079	.0000148	
Total	1082		

##Exceeds the 1% point

TABLE VIII

Results of analysis of variance of the compound X, between and within grades, for September data.

Source of variation	D.F.	Mean Square	F value
Between grades	3	.019460	1526.27##
Within grades	1191	.00001275	
Total	1194		

##Exceeds the 1% point

II. Relation between spring and fall egg quality.

The flocks which were included in the survey in June were, for the most part, in full production. None had dropped in production sufficiently to cause any changes in the regular system of holding and marketing the eggs. Although the average egg quality had probably dropped. slightly following the usual seasonal trend (Figure 1), the daily temperatures up till the first day of the survey had been quite low.

The flocks selected in September as suitable for study were nearing the end of their production period, although most of them were still laying quite well. It was desirable to compare the results from June and September to determine the extent of the drop in quality in September attributed by some workers (22, 23, 25) to the longer period of laying. Some decrease in quality could possibly be expected as a result of less care being taken by the flock owners as production went down and other work became more pressing.

The method of "expected sub-class numbers" given by Snedecor and Cox (47) was used in the analysis of variance of yolk shadow, yolk color, albumen score and albumen height between June and September. The use of this method was necessary due to the unequal frequencies in the sub-classes. It allowed for a three-fold classification of variates according to grades, ages and months.

Yolk shadow

The average yolk shadow of the June eggs was 8.24 as compared with 8.02 in September. The difference between these, although rather small, was found to be significant, as shown in Table IX. Here differences due to grade and age of the eggs were also found to be significant. Differences in grade, however, were responsible for the greater proportion of the variance.

Yolk color

Birds which were allowed on pasture in the month of September were not able to find fresh, green grass as they were in June. As a result, the yolk color was not quite so deep in September. The mean yolk color of eggs from outdoor flocks was 15.1 in June and 13.6 in September. The analysis of variance, results of which are given in Table X, indicated this difference as highly significant. A marked difference was also observed between grades and ages.

A noteworthy point was the consistent manner in which the yolk color became lighter with age, accounting for the significant F value for ages. The decrease in color

TABLE IX

Results of analysis of variance of yolk shadow, in arbitrary units, of grade A and B eggs of three ages in June and September.

Variance due to	D.F.	Mean Square	F value
Months	1	11.99	5.67#
Grades	1	1899.78	898.07##
Ages	2	11.65	5.51#
Months x Grades	1	.37	.17
Months x Ages	2	1.12	.53
Grades x Ages	2	4.71	2.22
Months x Grades x Ages	2	7.48	3.54#
Error	1889	2.12	
Total	1900		

#Exceeds the 5% point
##Exceeds the 1% point

TABLE X

Results of analysis of variance of yolk color, in arbitrary units, of grade A and B eggs of three ages in June and September.

Variance due to	D.F.	Mean Square	F value
Months	1	1214.73	222.77##
Grades	1	1125.06	202.52##
Ages	2	173.28	31.14##
Months x Grades	1	5.18	.58
Months x Ages	2	12.06	1.97
Grades x Ages	2	9.78	1.62
Months x Grades x Ages	2	2.74	.65
Error	1889	5.62	
Total	1900		

##Exceeds the 1% point

was slight and with a smaller number of variates might have appeared insignificant, but the large number of determinations in this case ruled out the possibility that the difference might have occurred by chance. Illustrated graphically in Figure 9, the decrease was slight up to one day of age but was more marked between the one day and three day old eggs. This finding is in disagreement with the results of other workers who claim that a darkening of the yolk color occurs with age.

Albumen score and Albumen height

Because these factors are measures of the same physical character, and because they are closely correlated in the data, they are best discussed together. The results of the analyses of variance are presented in Tables XI and XII.

Significant F values were obtained due to the differences in the main effects: months, ages and grades. The interaction between months and grades, in the case of albumen height, indicates a significant difference in the drop in albumen quality from A to B grade, in June as compared with September. This difference was not obtained in the case of albumen score. It was not considered very important since, in the type of analysis used, the differences between actual and expected numbers for grades were considerably larger than they were for months or ages; thus any interactions involving grades tended to become slightly inflated.

The mean values of albumen score were 2.25 and 2.31 for June and September respectively. The values for albumen height were .254 and .243 inches. Although these differences between months for the two factors were found to be significant, they were not reflected in the percentages of B grade eggs which amounted to 24.2 per cent in June and 23.59 per cent in September. The difference in quality as measured by albumen condition, was, therefore, not great enough to be observed in candling.

TABLE XI

Results of analysis of variance of albumen score, in arbitrary units, of grade A and B eggs of three ages in June and September.

Variance due to	D.F.	Mean Square	F value
Months	1	139.03	6.59##
Grades	1	4533.57	215.04##
Ages	2	1979.02	93.87##
Months x Grades	1	.19	.01
Months x Ages	2	3.11	.15
Grades x Ages	2	11.35	.54
Months x Grades x Ages	2	57.72	2.74
Error	1889		
Total	1900		

##Exceeds the 1% point

TABLE XII

Results of analysis of variance of albumen height, in inches, of grade A and B eggs of three ages in June and September.

Variance due to	D.F.	Mean Square	F value
Months	1	570.80	25.80##
Grades	1	3370.74	152.38##
Ages	2	2239.34	101.24##
Months x Grades	1	100.04	4.52#
Months x Ages	2	40.23	1.82
Grades x Ages	2	30.80	1.39
Months x Grades x Ages	2	14.23	.64
Error	1889	22.12	
Total	1900		

#Exceeds the 5% point
##Exceeds the 1% point

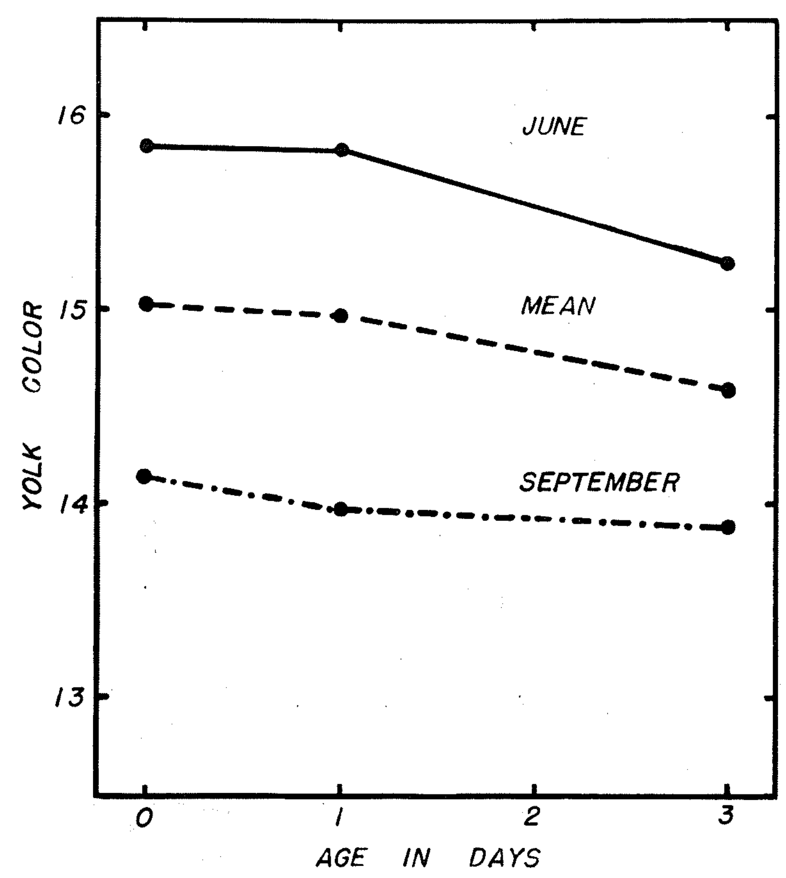


Figure 9. Effect of age of eggs on yolk color.

III. Effect of pasture on egg quality.

The investigation of the possibility that large amounts of green feed are directly responsible for a lowering of egg quality, involved the necessity of a re-grouping of the data for June and September. Flocks were classified as being on restricted or unrestricted pasture. The group on restricted pasture included all flocks which were kept indoors entirely, and others which were indoors at least until 1:00 p.m., thus receiving the required rations before they were let out. Many of the latter flocks were actually kept in until 4.00 or 5.00 p.m. This grouping was felt to be satisfactory since, in the type of survey done, it was impossible to make a clear-cut distinction as to whether or not the birds received any green feed.

The "expected sub-class" analysis (11) was again used. For this purpose the effect of months was not considered to be important. The data were grouped according to age and grade of eggs, and also diet. The latter classification was in two groups, restricted and unrestricted, with respect to pasture. Analyses were made of the variance of yolk shadow, yolk color, albumen score and albumen height.

Grade

An inspection of the grading results revealed that the percentage of B grade eggs increased more rapidly with age in the eggs from unrestricted flocks, compared with those having restricted pasture. This comparison is set out in Table XIII.

TABLE XIII

Comparison of percentage of B grade eggs, by days, from flocks with restricted and unrestricted pasture.

Age	Percentage B grade	
	Restricted pasture	Unrestricted pasture
Nest	8.1	7.6
One Day	12.2	26.1
Three Days	27.0	47.2
Average	15.9	27.1

Yolk shadow

The mean yolk shadow of eggs from flocks on restricted pasture was 7.08 as compared with 8.48 for unrestricted. Table XIV shows the difference between these two values as being highly significant. The effects of age and grade were highly significant, as before (Table IX). The interaction between ages and diets is illustrated graphically in Figure 10. The yolk shadow of the eggs from restricted flocks increased .90 units during the first day, compared with .63 for unrestricted. Darkening of shadow was less rapid thereafter, but was relatively more pronounced in eggs from unrestricted flocks.

TABLE XIV

Results of analysis of variance of the yolk shadow, in arbitrary units, of grade A and B eggs of three ages, classified according to diet.

Variance due to	D.F.	Mean Square	F value
Ages	2	29.71	11.02##
Grades	1	1838.60	682.33##
Diets	1	470.12	174.47##
Ages x Grades	2	1.11	.41
Ages x Diets	2	8.51	3.16#
Grades x Diets	1	.00	.00
Ages x Grades x Diets	2	5.64	2.09
Error	1877	2.70	
Total	1888		

#Exceeds the 5% point
##Exceeds the 1% point

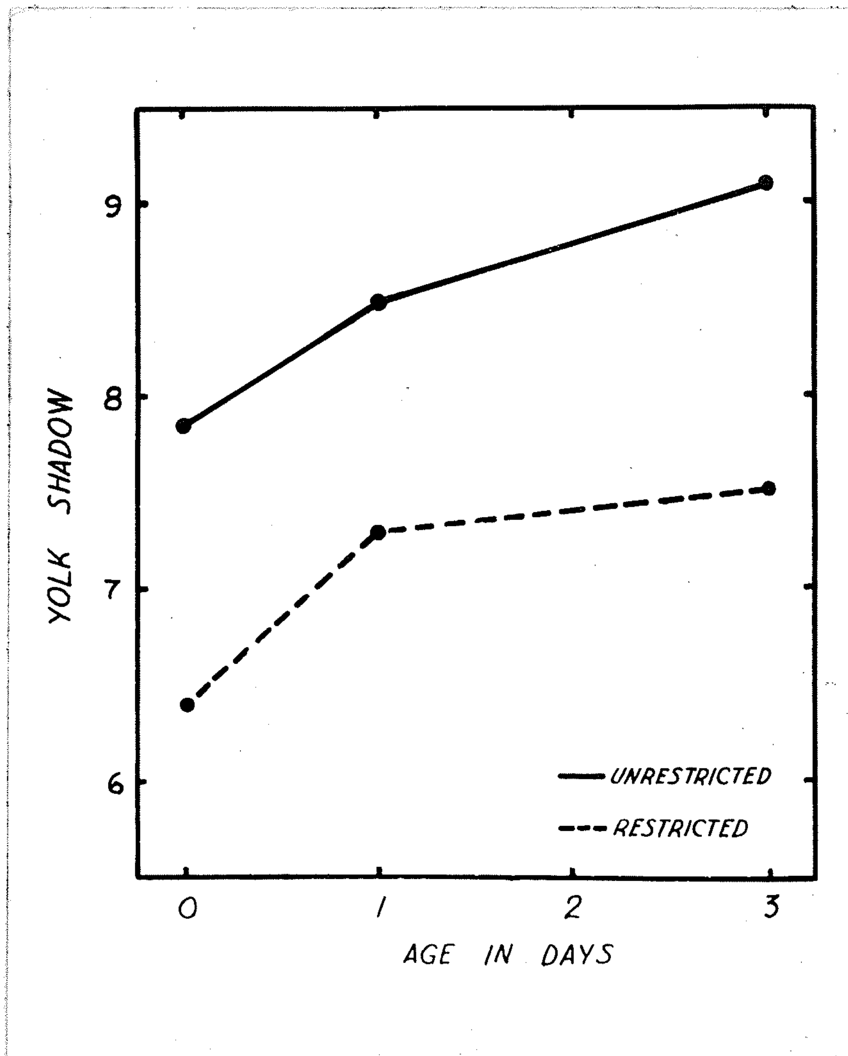


Figure 10. Interaction of yolk shadow between ages of eggs and diets of birds, with reference to amount of green feed.

Yolk color

Table XV shows a highly significant difference between the yolk color of eggs from restricted and unrestricted flocks. These values were 12.77 and 15.63 respectively. In the case of the restricted flocks, the B grade eggs were 2.57 units darker in yolk color than the A grade eggs. For the unrestricted flocks, this difference was .83 units. Thus the interaction between grades and diets was highly significant.

TABLE XV

Results of analysis of variance of yolk color, in arbitrary units, of grade A and B eggs of three ages, classified according to diet.

Variance due to	D.F.	Mean Square	F value
Ages	2	130.58	24.03##
Grades	1	845.69	155.64##
Diets	1	2562.42	471.57##
Ages x Grades	2	4.64	.85
Ages x Diets	2	13.97	2.57
Grades x Diets	1	150.39	27.68##
Ages x Grades x Diets	2	1.78	.33
Error	1877	5.43	
Total	1888		

##Exceeds the 1% point

Albumen score and Albumen height

Comparison of the albumen quality of eggs from restricted birds and from flocks on free range, revealed no significant difference in general effect of diet. The mean squares for albumen score and albumen height, shown in Tables XVI and XVII, were both non-significant.

In the case of albumen score, an interaction between grades and diets was found. This would seem to indicate a difference in albumen score, between grades, depending on the amount of pasture. Thus the average albumen score of A grade eggs from restricted flocks was slightly higher, indicating poorer quality than that of A grade eggs from birds on unlimited pasture. The situation was reversed in the case of the B grade eggs. These differences, however, were slight and were not shown in the data for albumen height.

TABLE XVI

Results of analysis of variance of albumen score, in arbitrary units, of grade A and B eggs of three ages, classified according to diet.

Variance due to	D.F.	Mean Square	F value
Ages	2	1964.11	84.48##
Grades	1	3561.76	153.19##
Diets	1	5.82	.25
Ages x Grades	2	43.27	1.86
Ages x Diets	2	27.32	1.17
Grades x Diets	1	148.95	6.41#
Ages x Grades x Diets	2	129.85	5.58##
Error	1877	23.26	
Total	1888		

#Exceeds the 5% point
##Exceeds the 1% point

TABLE XVII

Results of analysis of variance of albumen height, in inches, of grade A and B eggs of three ages, classified according to diet.

Variance due to	D.F.	Mean Square	F value
Ages	2	2149.34	95.41##
Grades	1	3384.63	150.24##
Diets	1	69.62	3.09
Ages x Grades	2	28.36	1.26
Ages x Diets	2	24.42	1.17
Grades x Diets	1	.06	.00
Ages x Grades x Diets	2	26.31	1.17
Error	1877	22.53	
Total	1888		

##Exceeds the 1% point

IV. The effect of shipping on egg quality.

The study of the decline in quality of eggs from the time they left the farm until they had been shipped 250 miles to Winnipeg, involved the taking of duplicate samples on seventeen farms. Six of these duplicate lots were taken in June and eleven in September. Since the procedure necessitated a comparison of the quality of one sample of eggs on the farm with that of a similar sample after shipping, it was essential that the two be alike originally. The percentages of B grade eggs in each lot, when graded at the egg station, were calculated. Applying the chi square test for goodness of fit, as shown in Table XVIII, it was found that there was a high probability of the difference between the two samples having occurred by chance; therefore, they could be considered as similar samples.

TABLE XVIII

Comparison of original and duplicate lots of eggs, as to percentages of B grade eggs.

Age	Original lot (theoretical) % B grade	Duplicate lot (actual) % B grade	$(A-t)^2/t$
Nest	9.7	6.9	.808
1 Day	24.0	22.5	.094
3 Day	40.2	35.8	.526
			X^2 = 1.428 P = .30 to .50

In the analysis of variance of the different quality factors comparisons were made between farms, ages of eggs, as well as between the samples before and after shipping. In the case of five of the farms, no nest eggs were available. To avoid complications of calculation due to unequal sub-class frequencies, separate analyses were made between the nest eggs and the corresponding day-old eggs for twelve farms and also between the day-old and the three day eggs for seventeen farms.

Direct comparisons were made of the yolk shadow and candling grade of the duplicate lot, before and after shipping. The comparisons for yolk shadow, albumen score and albumen height were made between the original lot at the egg station and the duplicate lot after shipping.

The effect attributed to the result of shipping actually included the deterioration which occurred due to storage in the egg station prior to shipping. This time was about two to three days.

Comparison of the percentages of B grade eggs in the three age lots, before and after shipping, yielded an X^2 value which was highly significant, indicating that it was quite improbable that such a difference occurred by chance (Table XIX).

TABLE XIX

Comparison of percentages of B grade eggs, before and after shipping.

Age	Total No. of eggs.	% B grade before shipping	% B grade after shipping
Nest	144	6.9	30.6
1 Day	204	22.5	46.1
3 Day	204	35.8	54.4

$X^2 = 10.53$
$P = .01$

Yolk shadow

The yolk shadow showed progressive darkening from 7.52 units for the nest eggs before shipping to 8.55 units for the same eggs after shipping. This was .33 units darker than the mean drop in quality on the farm from nest eggs to those three days old. The results of the analysis of variance are shown in Table XX. Significant differences in yolk shadow were obtained due to variations between farms, ages, and as the result of transportation. The highly significant interaction between farms and ages indicates a varying ability of eggs from different farms to maintain their original quality, as measured by depth of yolk shadow.

TABLE XX

Results of analysis of variance of depth of yolk shadow, in arbitrary units, between nest and one day old eggs and between one day and three day old eggs.

Variance due to	Nest and One Day		One Day and Three Day	
	D.F.	M.S.	D.F.	M.S.
Farms	11	28.24##	16	31.47##
Shipping	1	141.02##	1	167.77##
Ages	1	10.29#	1	22.01##
Farms x Shipping	11	2.11	16	2.59
Farms x Ages	11	5.48##	16	4.77##
Shipping x Ages	1	.21	1	2.37
Farms x Shipping x Ages	11	1.21	16	1.54
Error	528	1.56	748	1.94
Total	575		815	

#Exceeds the 5% point
##Exceeds the 1% point

Albumen score and albumen height

The mean values for albumen score and albumen height are shown in Table XXI. The results of the analyses of variance are presented in Tables XXII and XXIII. A considerably greater drop in albumen quality occurred in the nest eggs during shipments than in the day-old eggs. In fact, the albumen quality of the nest eggs was very slightly lower after shipping than for the day-old eggs. This does not appear reasonable and cannot be definitely accounted for. The only possible explanation of the discrepancy would be that the nest eggs in some cases were not cooled as rapidly as were the others. This was not an important factor as far as the original lot of eggs was concerned, since they were broken immediately. In the case of the duplicate samples, however, the slightly delayed cooling caused more rapid deterioration during subsequent holding. Thus, in the comparison between nest and one day old eggs, the significant interaction obtained between shipping and ages for both albumen score and height is explained. It is probable that had it not occurred there would have been a significant difference between ages.

There is close agreement between the results obtained for albumen score and albumen height. The interaction between farms and shipping for the one and three day comparisons indicates a significant difference in the ability of eggs from different sources to maintain their quality during shipping. This difference was less noticeable in the relatively fresh eggs. Therefore it was not due to initial variations between flocks, such as hereditary factors, but was due to conditions of gathering and holding. The average drop in albumen height during shipping of one and three day old eggs was .031 inches, yet it varied from .008 to .117 inches between farms.

The mean albumen height of the three day old eggs, after shipping, was .198 inches, actually lower than the mean albumen height of all the 3 day old B grade eggs in the June and September data, which was .210 inches. When the difference between these two was tested by the "t" test for the significance of differences between means, a "t" value of .214 was obtained which was not significant. Therefore, judging by the mean value for albumen height these should have been B grade eggs. However, the probable reason that they did not grade any more than 54.4 per cent B grade was that the albumen height of eggs that were originally B grade before shipping had deteriorated quite far and thus made the mean value still lower.

TABLE XXI

Mean values of albumen score, in arbitrary units, and of albumen height, in inches, for different ages before and after shipping.

Age	Albumen score		Albumen height	
	Before	After	Before	After
Nest	2.08	2.68	.264	.211
1 Day	2.28	2.60	.248	.215
3 Day	2.50	2.75	.225	.198

TABLE XXII

Results of analysis of variance of albumen score, in arbitrary units, between nest and one day old eggs and between one day and three day old eggs.

Variance due to	Nest and One Day		One Day and Three Day	
	D.F.	M.S.	D.F.	M.S.
Farms	11	258.85##	16	199.76##
Shipping	1	3047.96##	1	1750.03##
Ages	1	59.42	1	854.44##
Farms x Shipping	11	26.75	16	43.78
Farms x Ages	11	29.12	16	43.64
Shipping x Ages	1	257.34##	1	33.36
Farms x Shipping x Ages	11	19.263	16	17.61
Error	528	27.54	748	26.91
Total	575		815	

##Exceeds the 1% point

TABLE XXIII

Results of analysis of variance of albumen height, in inches, between nest and one day old eggs and between one day and three day old eggs.

Variance due to	Nest and One Day D.F.	Nest and One Day M.S.	One Day and Three Day D.F.	One Day and Three Day M.S.
Farms	11	233.54##	16	203.53##
Shipping	1	2643.67##	1	1927.10##
Ages	1	51.36	1	949.02##
Farms x Shipping	11	25.23	16	25.41#
Farms x Ages	11	21.27	16	23.57
Shipping x Ages	1	156.25##	1	28.31
Farms x Shipping x Ages	11	22.27	16	24.88
Error	528	20.27	748	15.01
Total	575		815	

#Exceeds the 5% point
##Exceeds the 1% point

In an attempt to establish the cause of the variation in quality between farms, the data for 12 farms were regrouped, according to whether the flocks were on unlimited range, or on restricted pasture. In this case it was possible to compare the three age groups in one analysis. This analysis was made for yolk shadow and for albumen height, using it as the measure of albumen quality, as shown in Tables XXIV and XXV.

The differences in yolk shadow for shipping and ages were obviously significant as found before in Table XX. A significant difference was obtained due to diets.

This was due chiefly to the greater depth of yolk color as a result of unlimited green feed.

In the case of albumen height this difference did not occur. Examination of the data regarding albumen height revealed, however, that although the main effect of diets was not significant, the interaction of diets with ages was significant. There was, according to this data, a noticeable difference in the ability of eggs from birds on unrestricted pasture to maintain their quality as compared with eggs from birds on restricted pasture. This difference was due to the greater albumen height of eggs from unrestricted birds dropping to about the same level as the restricted in the three day period. Thus the unrestricted dropped in albumen height from .244 to .207 inches, while the restricted dropped from .232 to .210 inches.

The distribution of the percentages of B grade eggs, shown in Table XXVI, where the percentage of B grade increased more rapidly in eggs from unrestricted flocks, seems to bear out the importance of the interaction between ages and diets. However, re-examination of the results of the yolk shadow analysis in Table XXIV indicates a greater degree of significance attributed there to the same interaction. It seems, therefore, that the rapid increase in the percentage of B's from the unrestricted flocks was due as well to other factors, such as yolk color, which, being deeper for the unrestricted flocks, showed up more freely in the yolk shadow of the older eggs after the albumen height had dropped considerably. Thus, with age, the importance of yolk color increased as a factor in deciding grade.

The interaction which occurred between shipping and ages was again obviously the result of the greater proportional drop in quality exhibited by the nest eggs as compared with the older ones.

TABLE XXIV

Results of analysis of variance of yolk shadow, in arbitrary units, of eggs of three ages, sorted as to diet and shipping.

Variance due to	D.F.	M.S.	F value
Shipping	1	186.11	79.84##
Ages	2	25.16	10.79##
Diets	1	126.81	54.40##
Shipping x Ages	2	.92	.39
Shipping x Diets	1	.61	.26
Ages x Diets	2	12.95	5.56##
Shipping x Ages x Diets	2	1.20	.51
Error	852	2.33	
Total	863		

Exceeds the 1% point

TABLE XXV

Results of analysis of variance of albumen height, in inches, of eggs of three ages, sorted as to diet and shipping.

Variance due to	D.F.	M.S.	F value
Shipping	1	2893.01	134.00##
Ages	2	673.26	31.18##
Diets	1	29.26	1.36
Shipping x Ages	2	162.49	7.54##
Shipping x Diets	1	40.47	1.87
Ages x Diets	2	86.47	4.00#
Shipping x Ages x Diets	2	15.14	.70
Error	852	21.59	
Total	863		

#Exceeds the 5% point
##Exceeds the 1% point

TABLE XXVI

Comparison of percentages of B grade eggs in three age groups between flocks on unlimited and restricted pasture.

Age	Restricted pasture	Unrestricted pasture
Nest	22.2	18.1
1 Day	30.6	38.9
3 Day	40.3	53.9

V. The Seasonal Trend of Egg Quality on Individual Farms.

The best measure of the relation between flock management and quality of eggs is a record of the weekly grading reports from individual flocks throughout the year. It is an indication of the flockowner's ability to produce good quality eggs in the winter and to maintain that quality during the summer when conditions are less favorable.

During the time of survey, the author selected several farms which would well illustrate the variation which occurs in egg quality between farms. Records of the weekly grading reports during 1945 for five of these farms were obtained from the Manitoba Cooperative Poultry Marketing Association. The percentages of A grade eggs per week were calculated for each farm. The average trends of quality are charted in Figures 11 to 15.

The flocks were rated A, B, and C with respect to the way in which different management practices were carried out. These factors and the bases on which the ratings were made are listed in Table XXVII. These ratings were made according to conditions found at the time of visit and were qualitative in all cases except with regard to green feed. Here the rating was intended

TABLE XXVII

Criteria of management for rating flocks and bases for making the ratings.

Factors	Rating	Basis for Rating
General care of flock	A	Interest of flockowner; approved methods of feeding; cleanliness of laying house, nests and surroundings.
	B	Average care of flock. Average conditions of house and nests.
	C	Lack of interest of flockowner; unclean house and indications of careless feeding.
Green feed	A	None - birds entirely indoors.
	B	Restricted pasture.
	C	Unlimited pasture.
Gathering of eggs	A	3-4 times per day.
	B	twice per day.
	C	once per day.
Holding of eggs	A	temperature 50°-60°F.
	B	temperature 60°-70°F.
	C	temperature 70°F. and over.
Delivery of eggs	A	Three times per week.
	B	twice per week.
	C	once per week.

as an indication of the relative amounts consumed by the birds. Table XXVIII gives the ratings of each individual flock.

Frequency of gathering and temperature of holding seemed to be the most important factors as far as maintaining high quality. It is interesting to note that dark yolk color resulting from unlimited pasture did not affect the grading of eggs produced by Flock 2. In Flocks 3, 4 and 5, when combined with poor conditions of care, it was a factor in influencing the grade.

TABLE XXVIII

Ratings of five individual flocks according to different management factors.

Factor	Ratings				
	Flock 1	Flock 2	Flock 3	Flock 4	Flock 5
General care	A	A	A-B	B	C
Green feed	A	C	C	C	B
Gathering	A	A	B	B	C
Holding	B	A	B	B	C
Delivery	B	B	A	C	C

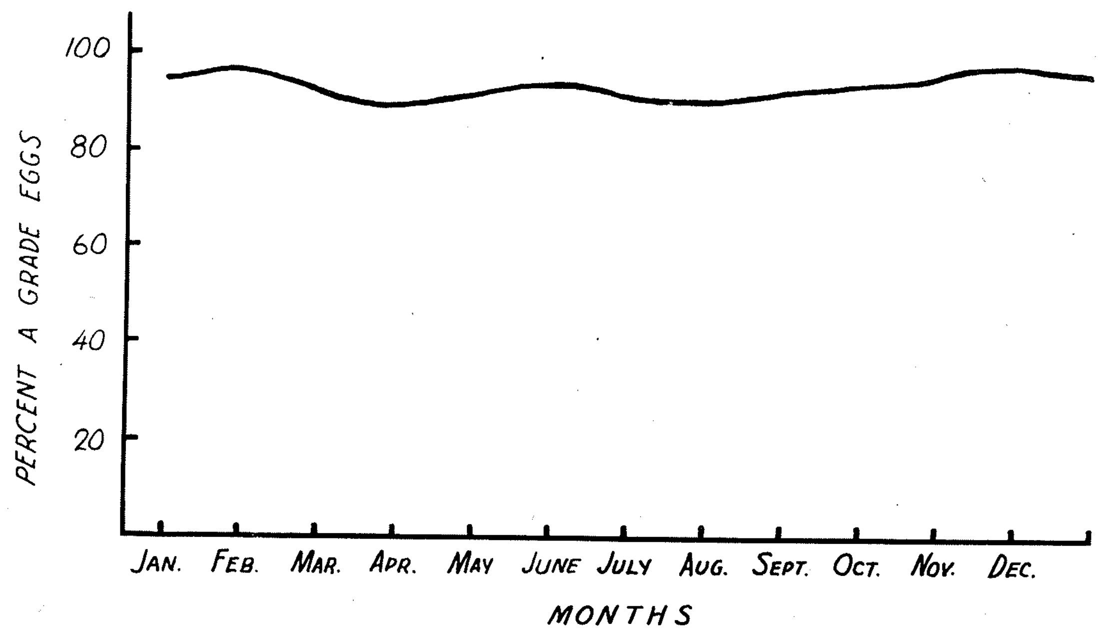


Figure 11. Trend of egg quality of Flock 1, during 1945.

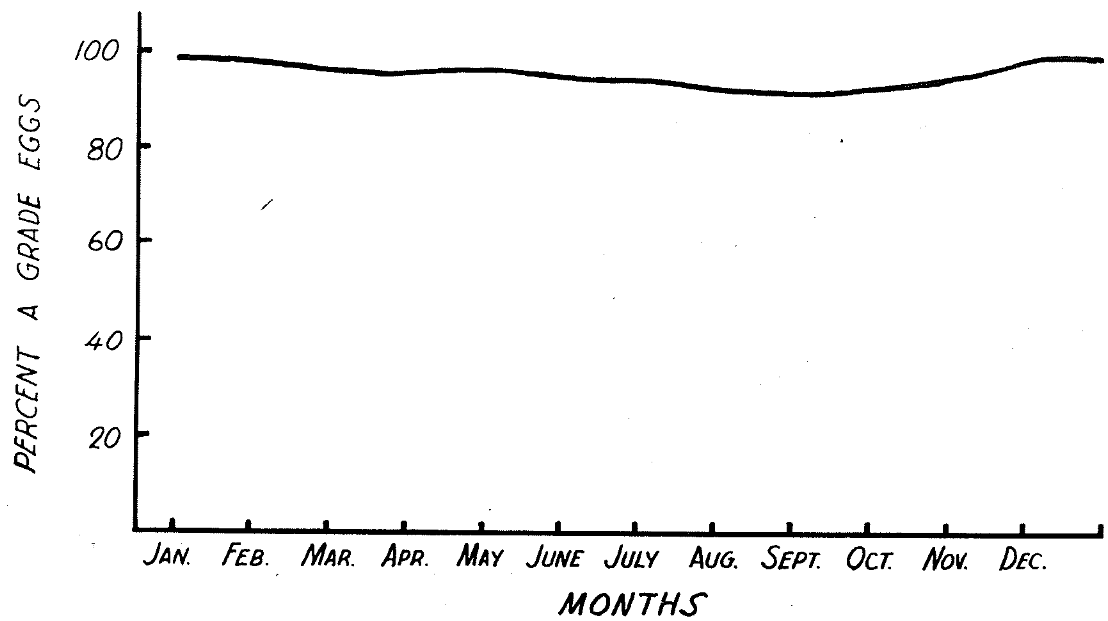


Figure 12, Trend of egg quality of Flock 2, during 1945.

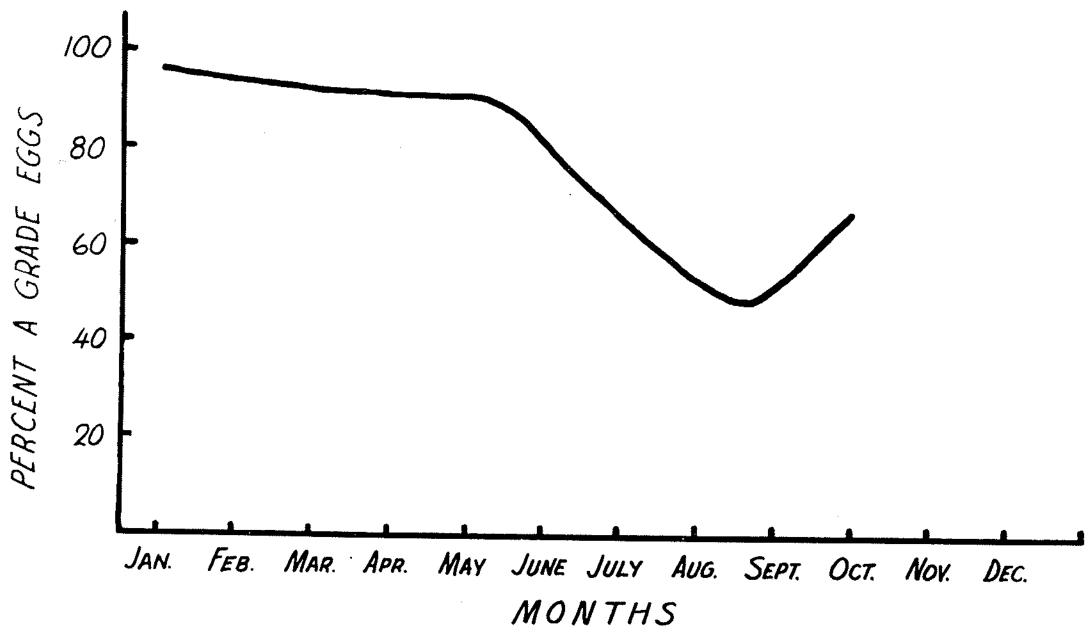


Figure 13. Trend of egg quality of Flock 3, during 1945.

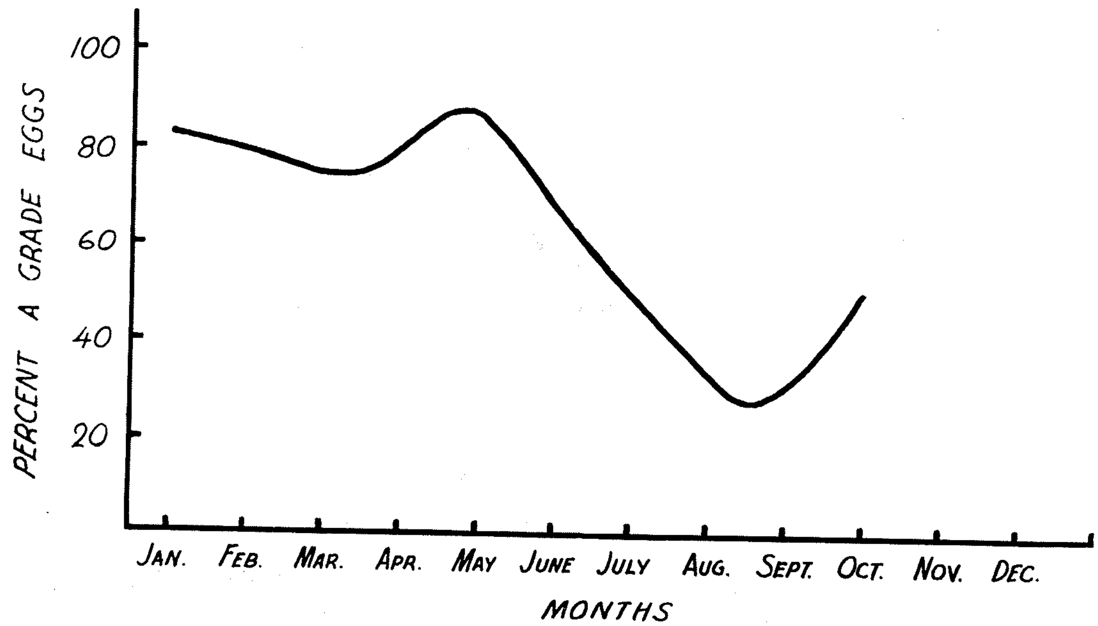


Figure 14. Trend of egg quality of Flock 4, during 1945.

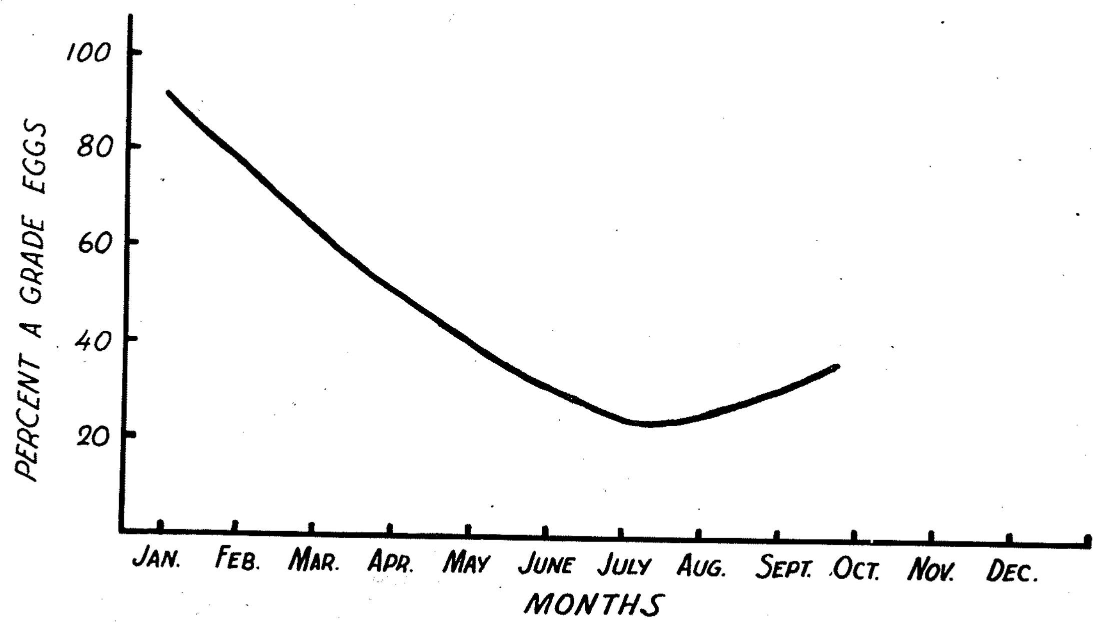


Figure 15. Trend of egg quality of Flock 5, during 1945.

VI. Effect of green feed and holding on egg quality under controlled conditions.

The project at the University poultry plant was planned in such a way as to provide a check on the survey data where a greater variety of conditions existed. The effect of uniform conditions of holding was determined by making quality determinations on eggs which had been saved every day for eight consecutive days. A sample of eggs straight from the nest provided a measure of the initial quality. Since the eggs were sorted as to the different levels of green feed received by the birds, the effects of this could be established.

The quality measurements were assembled under the headings of age of eggs in days, and diets, with reference to amount of green feed, i.e., pasture, alfalfa and no green feed with each diet. The results from the two pens of different breeds receiving that diet were grouped together. The findings are presented under the headings of the different quality factors. In all cases except grade, the mean values per day were used.

Candling grade

Records of the grading showed the fresh eggs to be 100 per cent A grade. After one day of holding there were two B grade eggs among those from the birds on pasture. The percentages of B grade eggs from this lot of birds were greater on succeeding numbers of days of holding, although they varied considerably from day to day. The eggs from the two pens receiving alfalfa contained one B grade egg on two different days. All the eggs from the pens receiving no green feed were graded as A quality. The numbers of eggs used per day in the experiment, and the grading results, are shown in Table XXIX. Graphical representation of the percentages of B grade eggs is shown in Figure 16.

Yolk shadow

The average values of yolk shadow for the three different diets were plotted against time of holding in days. In each case relation between time and yolk shadow, with yolk shadow as the dependent variable, was determined by the use of "orthogonal polynomials." This method is described by Goulden (14). The relationship was found to be linear in each case. The results of the fitting are shown in Figure 17.

An analysis of variance of the effects of diets and age is shown in Table XXX. Both effects, when tested against the interaction, were significant, with the greater part of the variance attributed to diets.

TABLE XXIX

Total eggs and percentage A grade eggs per day from pens of birds on diets differing as to amount of green feed.

Age	Diets	No.A grade	No.B grade	Total	% A grade
0	Pasture	19	0	19	100
	Alfalfa	21	0	21	100
	No green feed	14	0	14	100
1	Pasture	10	2	12	83.4
	Alfalfa	17	0	17	100
	No green feed	12	0	12	100
2	Pasture	6	7	13	46.4
	Alfalfa	18	0	18	100
	No green feed	11	0	11	100
3	Pasture	6	11	17	35.3
	Alfalfa	16	1	17	94.4
	No green feed	12	0	12	100
4	Pasture	7	11	18	38.9
	Alfalfa	17	1	18	94.1
	No green feed	11	0	11	100
5	Pasture	8	9	17	47.1
	Alfalfa	22	0	22	100
	No green feed	11	0	11	100
6	Pasture	10	7	17	61.1
	Alfalfa	20	0	20	100
	No green feed	13	0	13	100
7	Pasture	4	9	13	30.8
	Alfalfa	20	0	20	100
	No green feed	17	0	17	100
8	Pasture	10	5	15	66.7
	Alfalfa	17	0	17	100
	No green feed	10	0	11	100

TABLE XXX

Results of analysis of variance of yolk shadow, in arbitrary units, classified as to ages of eggs and diets of birds.

Variance due to	D.F.	Mean Square	F value
Diets	2	33.0378	499.82##
Ages	8	.6464	9.78##
Interaction	16	.0661	
Total	26		

##Exceeds the 1% point

Yolk color

Examination of the mean values of yolk color per day for the three diets indicated that the relation between yolk color and length of holding was linear.

The regression coefficients were calculated and the lines of best fit were plotted in Figure 18. The significance of the regression coefficients was tested by means of the "t" test, using the standard errors. In the case of the results due to pasture, a trend was observed showing a loss in color of slightly more than .50 units in eight days. However, the variation in color was so great, as is usually the case where birds are on pasture, that the relatively large standard error caused the regression coefficient to be non-significant.

The trend of yolk color, due to age, of the eggs from birds receiving no green feed was very slight and was not significant.

In the case of the alfalfa diet a marked decline of yolk color from 10.80 to 8.86 units was observed in the regression line. Testing of the regression coefficient yielded a highly significant "t" value pointing to a definite trend toward a lightening in the color of the yolk with age.

The analysis of variance (Table XXXI) showed the variation between diets to be highly significant, whereas the effect of age or time of holding, when the three diets were combined, was not significant.

TABLE XXXI

Results of analysis of variance of yolk color, in arbitrary units, classified as to ages of eggs and diets of birds.

Variance due to	D.F.	Mean Square	F value
Diets	2	165.9536	450.23##
Ages	8	.7902	2.14
Interaction	16	.3682	
Total	26		

##Exceeds the 1% point

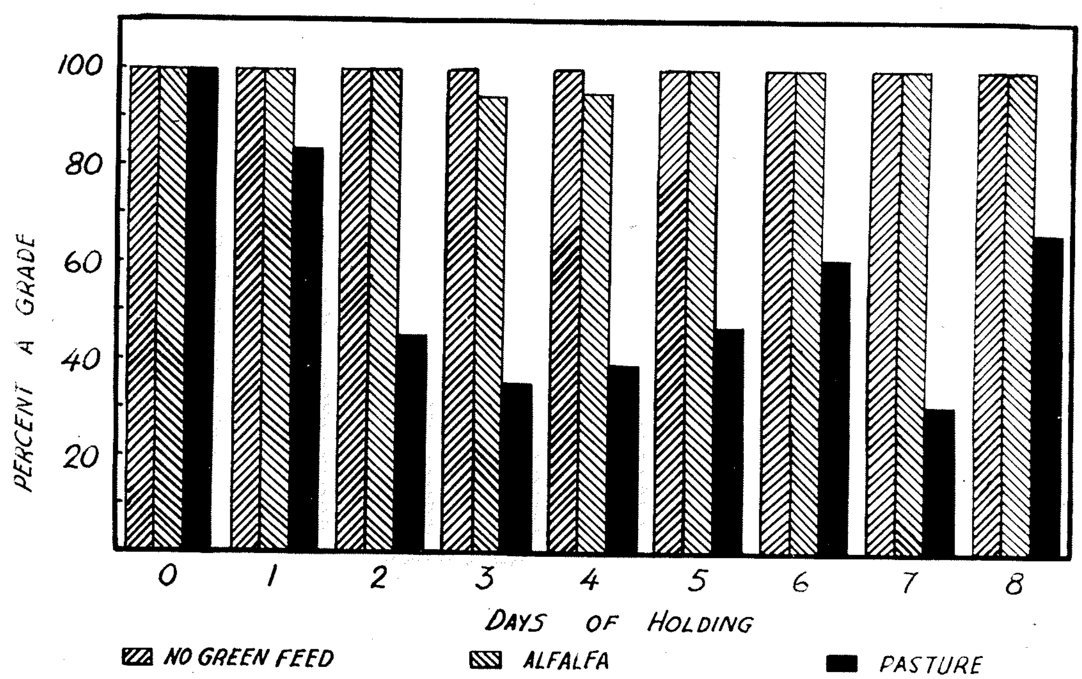


Figure 16. Effect of length of holding on grading quality of eggs from birds on three different levels of green feed.

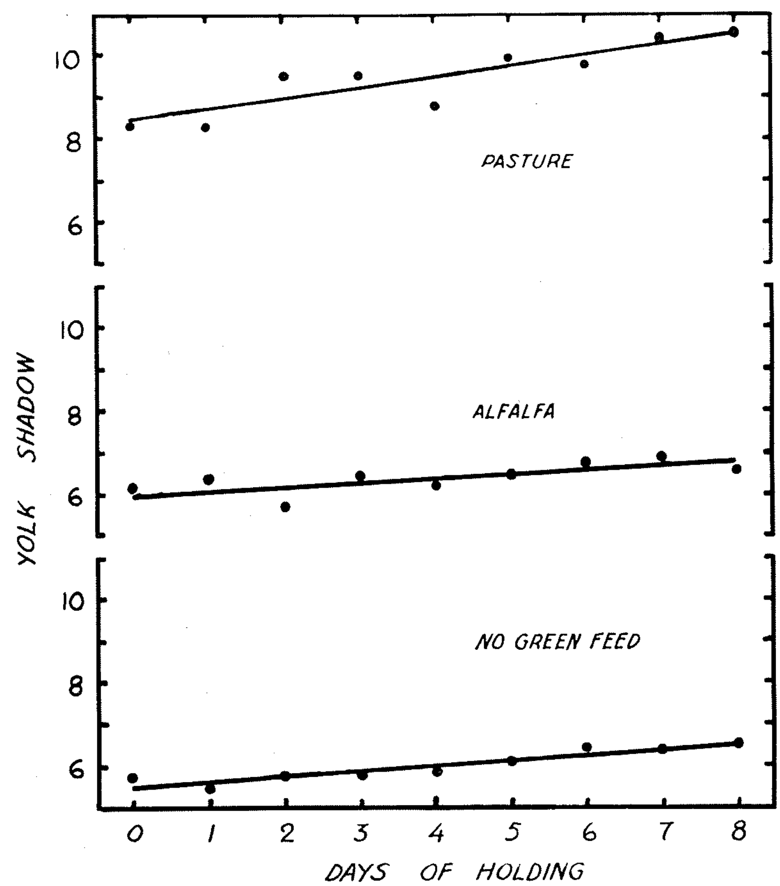


Figure 17. Effect of three different levels of green feed and length of holding on yolk shadow.

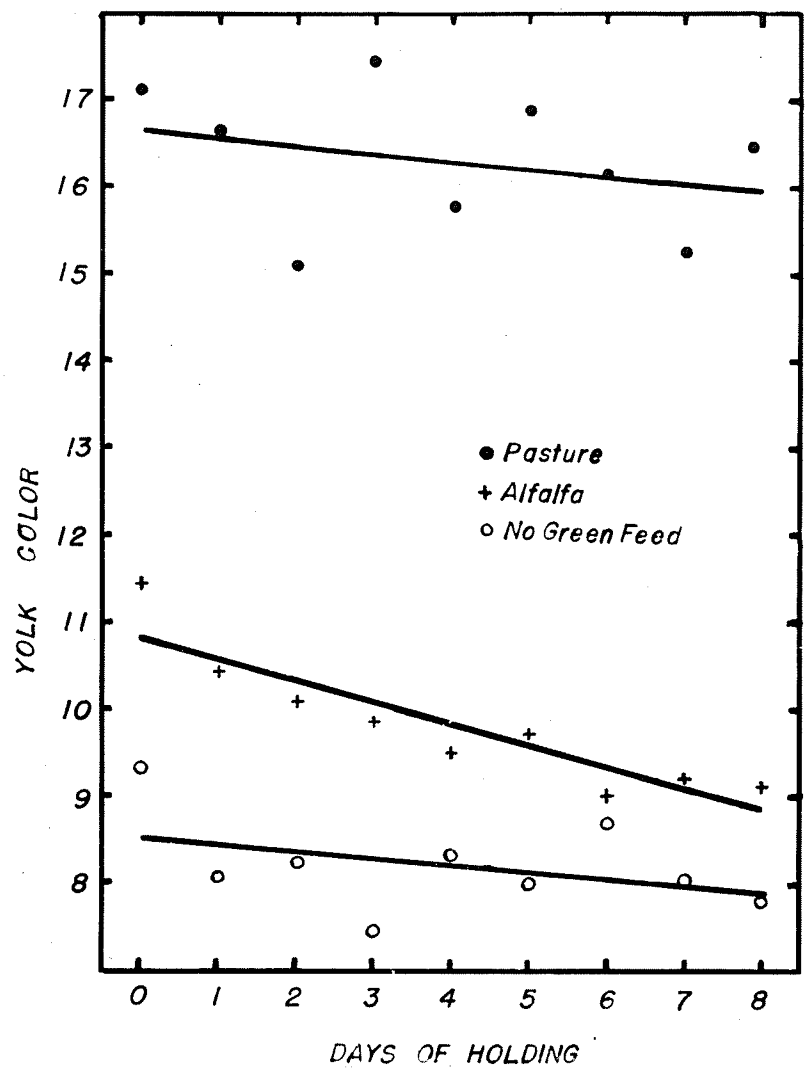


Figure 18. Effect of three different levels of green feed and length of holding on yolk color.

Albumen score

Figure 19 shows the lines of best fit to the averages of the albumen score per day of storage for the three diets. Some irregularity of variation can be seen to have occurred from day to day. This can be partly explained by external variations such as temperature and humidity. Also, a smaller error would have occurred with a larger number of variates. The curvilinear trend in the alfalfa diet seems to be quite reasonable. The surprising rise in the curve for pasture eggs was chiefly due to the exceptional quality of the eight day old eggs. The reason for their comparatively good quality is not known; it could have been associated with temperature.

The above lines were fitted again by the use of "orthogonal polynomials". An analysis of variance is shown in Table XXXII. No difference was found to exist between levels of albumen quality due to diets. The highly significant variance for ages was split up into its linear, quadratic and cubic components to determine the general trend of albumen quality.

The results showed a strong tendency toward a linear trend, or a proportional lowering of albumen quality per day. The quadratic effect was also significant. The sum of squares for interaction was broken up similarly to determine whether or not the general effects of time on albumen score were the same for all three diets. No significant interactions were obtained, indicating a similar trend for all three diets.

TABLE XXXII

Results of analysis of variance of albumen score, in arbitrary units, classified as to ages of eggs and diets of birds.

Variance due to	D.F.	M.S.	F value
Diets	2	.05888	2.41
Ages	8	.35397	14.48##
Interaction	16	.02444	
Ages -			
Linear effect	1	2.2200	90.83##
Quadratic effect	1	.49980	20.45##
Cubic effect	1	.03000	1.23
Remainder	5	.01639	
Interaction -			
Linear effect x diets	2	.00457	0.96
Error	21	.04731	
Quadratic effect x diets	2	.01264	.48
Error	18	.02605	

##Exceeds the 1% point

Albumen height

The trend of albumen height, illustrated in Figure 20, was much the same for the three different diets. A quadratic relationship between time and albumen height existed in the case of the eggs from the birds without green feed. Analysis of the data produced results very similar to those for albumen score, as shown in Table XXXIII. Again, there was no significant difference between diets, but the effect of time of holding was very pronounced. This was shown mainly in a linear trend, although again there was a tendency to the quadratic as well. There was no marked difference between diets as far as these trends were concerned.

TABLE XXXIII

Results of analysis of variance of albumen height, in inches, classified as to ages of eggs and diets of birds.

Variance due to	D.F.	M.S.	F value
Diets	2	.000139	.85
Ages	8	.003038	18.64##
Interaction	16	.000163	
Ages -			
Linear effect	1	.018585	114.02##
Quadratic effect	1	.004041	24.79##
Cubic effect	1	.000144	.88
Remainder	5	.000310	
Interaction -			
Linear effect x diets	2	.000021	.053
Error	21	.000394	
Quadratic effect x diets	2	.000231	1.10
Error	18	.000210	

##Exceeds the 1% point

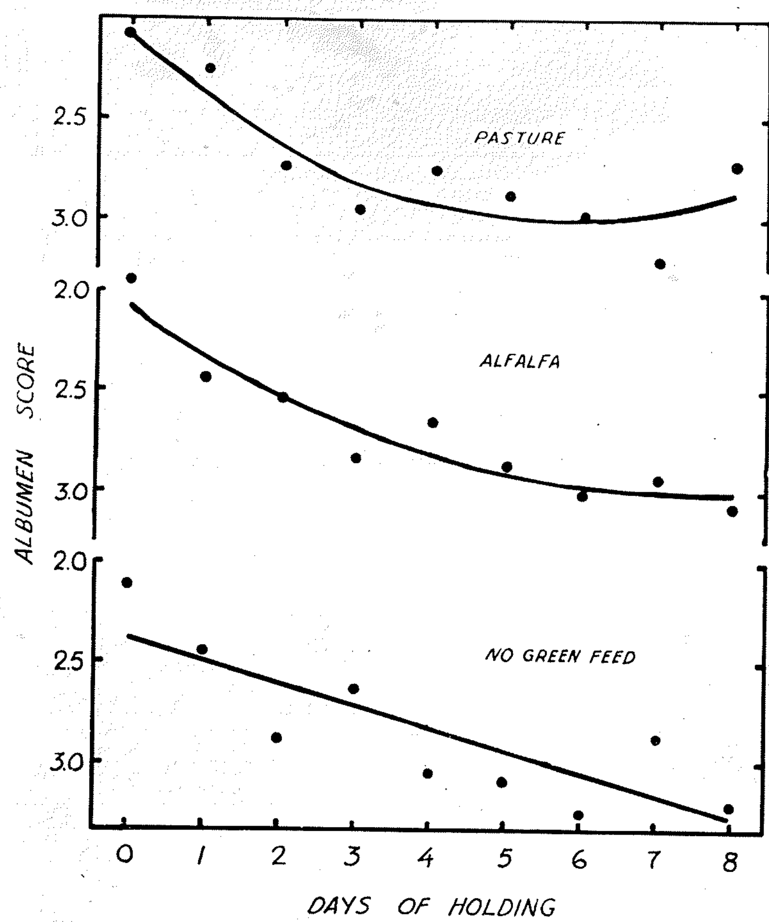


Figure 19. Effect of length of holding on albumen score for three different levels of green feed.

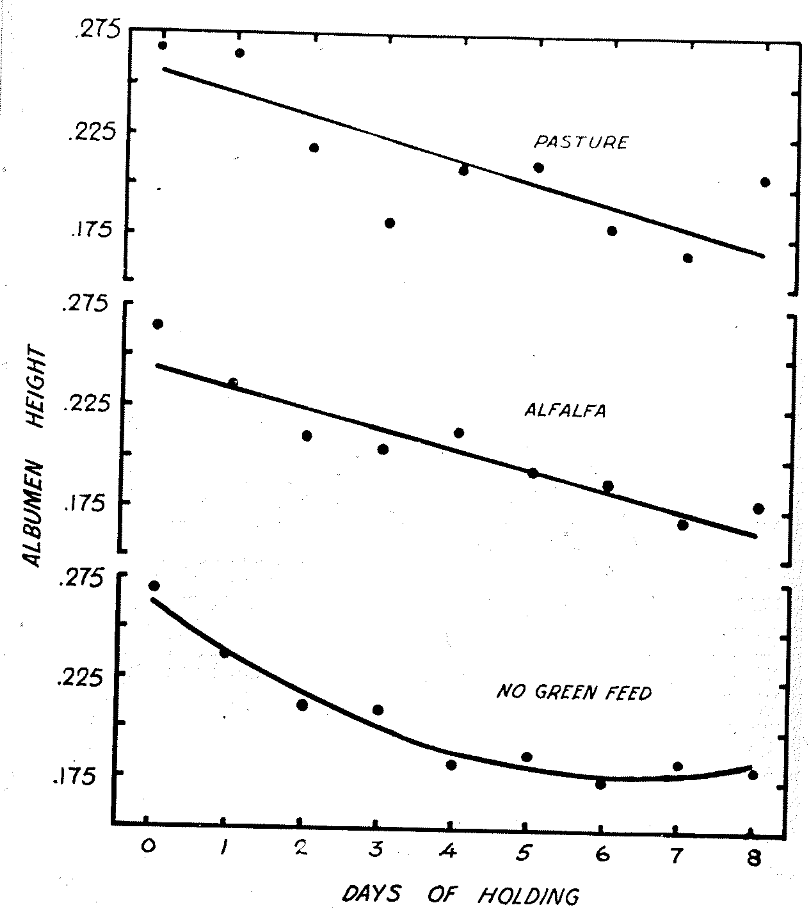


Figure 20. Effect of length of holding on albumen height for three different levels of green feed.

DISCUSSION

The results of a survey of egg quality on Manitoba farms have been presented. Supplementary to this was a controlled project carried out at the University of Manitoba poultry plant. Investigation was made of the various aspects of egg quality in relation to farm production and also in relation to commercial candling.

In commercial grading the egg is judged by its external appearance when held before the candling lamp. Yolk shadow is one of the main criteria used in deciding the grade. Yolk shadow is not in itself a direct measure of egg quality, but it is influenced to a certain extent by actual interior quality factors such as albumen condition and yolk color, albumen quality being the important measure of quality. Therefore, yolk shadow was considered as a quality factor in the study made. Judgment of egg quality by considering yolk shadow is made on the basis of its association with the above interior quality factors. However, dark yolk color produces dark yolk shadow, whereas high albumen quality decreases the intensity of yolk shadow. Therefore deep yolk shadow may indicate a dark colored yolk, poor albumen quality, or a combination of both. Moderately dark color of yolks will not influence the yolk shadow if the albumen condition is good enough to offset it. But in an egg where the albumen, although slightly weakened, is still of A quality, a dark colored yolk will tend to indicate a greater deterioration in quality than has actually taken place, judging by the yolk shadow. Thus complete reliance upon the depth of yolk shadow as a basis of judgment of interior quality would lead to some erroneous conclusions.

The independent effect of each factor in determining grade was derived by calculation of the "discriminant function". It is interesting to note that, in spite of the greater degree of correlation between yolk shadow and yolk color as compared with that between yolk shadow and albumen quality, the order of importance with regard to the independent effect was changed. The order was: albumen height, albumen score, yolk shadow and yolk color. The albumen height was shown to be a more accurate measure of grade than albumen score.

The relative importance of albumen quality in determining grade was almost twice that of yolk shadow in June and three to four times as important in September. This indicates that other factors such as air cell size, and position and shape of the yolk, played a part of equal importance to yolk shadow in determining grade in June.

The importance of these increased later in the season as the albumen quality became lower.

Variation in albumen quality had a direct effect on the appearance of the egg before the candling lamp. If these differences were marked, the eggs appeared either as A grade or as B or C. It was observed that dark yolk color caused a slightly weak albumen to be more apparent than it would have been otherwise. Yolk color, however, did not affect the grade if the albumen condition was good enough. Eggs having an albumen height of .300 inches or more would candle as A grade even though the yolk color was 18 to 20 units; but any weakening of the albumen caused a deeper yolk shadow, giving the grader the idea that the interior quality was worse than it actually was. For example, the mean yolk color of the eggs obtained from Flock 2 (Figure 12) in June was 16.13 units. The mean albumen height was .272 inches for the nest eggs and .252 inches for the three day old eggs. Four of the thirty-six eggs were B grade. The depth of yolk color in each of these eggs was 20, 21, 18 and 20 units respectively and the corresponding albumen heights were .261, .189, .288, and .207 inches. When the independent effect of yolk color was considered, with the albumen in a uniform condition, yolk color had less effect.

When the yolk color was light, eggs passed as A grade with lower albumen quality than was possible when they had dark yolks. That is, the actual interior quality, as measured by the condition of the albumen, had to be considerably lower in order that the eggs would appear as B grade in candling. Eggs from a flock with a mean yolk color of 16.35 and with a mean albumen height for the three day old eggs of .239 inches, graded 50 per cent B grade, as compared with Flock 2 with a similar yolk color but better albumen. In contrast to this, the sample from another flock, where the birds were kept indoors without any green feed, contained 100 per cent A grade eggs. Yet the mean albumen height, although being quite good for the nest eggs (.280 inches), went down to .216 inches for the three day old eggs. Five of these eggs were below .210 inches. However, the yolk color was quite light; its mean value for the thirty-six eggs was 8.64 units. Similarly the albumen height of the eggs from Flock 1 (Figure 11) declined from .273 to .209 inches on the third day, while the mean yolk color was 8.15. All the eggs in the sample were graded A.

In the light of the above data it is obvious that yolk color plays an important part in the commercial grading of eggs. In addition, supporting evidence is given by the results of the project at the University poultry plant where practically all the B grade eggs were from the birds receiving unlimited green feed (Figure 16). The reason for the exceptionally good grade of eggs from Flock 2 (Figure 12) was the quality of the albumen. It was above average for the nest eggs and there was a drop in the mean value of only .020 inches in three days. In the case of Flock 1 (Figure 11) and other similar indoor flocks, the albumen quality was not so good but the light yolk color made it more difficult to detect deterioration in quality.

The high albumen quality of the eggs from Flock 2 was maintained through frequent gathering and suitable holding conditions. The same grade was obtained by other flocks where the yolk color was lighter, even though less care was given to the eggs. Depth of yolk color is neither a necessary indication of inferior egg quality, since it is usually the result of carotenoid pigments in the feed (37), nor is it necessarily associated with poor albumen quality.

The extremes of climate in Canada are responsible for the transition from the mild appearance of winter eggs to the darker yolks of slightly stronger flavor, in spring and summer eggs, resulting from the release of birds on fresh,green pasture. Consumers object to this change, since they prefer the lighter colored yolks. It is probably desirable that eggs with considerable depth of yolk color and only moderate quality of albumen be placed in B grade in candling. However, the fact that eggs which have the same, or slightly poorer, albumen quality pass the candler as A grade because their yolk color is lighter, is not entirely satisfactory.

Practical poultry producers begin to suspect the greater tendency of eggs from outdoor flocks to grade as B's if the quality is not particularly good. Their proposed manner of remedy is frequently entirely wrong and is not very beneficial to the poultry industry. Instead of realizing the need of improving their methods of gathering and holding the eggs, they frequently contemplate keeping the birds indoors, without green feed, as a solution to the problem. Thus their eggs would pass the grader as A quality more easily, due to the lighter colored yolks. This was well illustrated in the case of a flock, mentioned previously, where, at the time of visit in June, the eggs in the sample obtained were all A grade. On breaking these eggs, the mean albumen height for the three day old eggs was only .216 inches, lower than the mean for all the B grade eggs in June. The yolk color was very light - 8.64 units. The temperature of the room where the eggs were kept was 69°F. - the same as the outside temperature.

Yet this flock owner was regularly obtaining a good grade for his eggs. When the flock was revisited in September, it was found that the birds had been allowed to run out since the middle of July and examination of the weekly grading reports showed that the proportion of B grade eggs had increased greatly.

In examination of the results of the analysis of the discriminant function, it is difficult to say that any one factor is entirely independent of another in grading. Of the four factors considered, yolk shadow is the only one which can be directly measured in candling. Since grading is chiefly an estimation of the condition of the albumen, the only method of doing this is by judgment of the yolk shadow, air cell size and yolk shape and position. Yolk color is an incidental factor by which the grader is influenced, unconsciously or otherwise.

It seems that some adjustment in the grading regulations is needed. Eliminating green feed from the diet of the birds in order to decrease the yolk color will probably better the flock owner's financial position but will not help the industry, since low initial quality will show up rapidly during continued storage. Greater emphasis should be given to grading factors other than yolk shadow, e.g., the shape and position of the yolk. Thus, if the supporting albumen is weak, the yolk will tend to become flabby and flattened, failing to remain well centered when twirled in candling. Grading standards might be adjusted slightly, depending on the season of the year. Thus, dark yolk shadow in winter eggs should be viewed with suspicion. The other auxiliary factors relating to the yolk, as well as air cell size, could be given relatively greater emphasis in the summer season when yolks are darker.

Although public demand favors a mild colored yolk, the emphasis should still be placed on albumen condition, since that is the real criterion of egg quality. Extremely dark or olive-colored yolks are, of course, objectionable since they often result from weeds and barnyard offal in the hen's diet. A very satisfactory arrangement appears to be to have the birds indoors until about 2.00 p.m. They will then have received a full ration, consumption of green feed after that time will not be excessive, and a uniform yolk color similar to Number 12 in Figure 3 will result.

No attempt was made in this survey to treat statistically the effect of temperature of holding conditions on egg quality. Conclusive evidence has been presented by various workers (39, 55) regarding the importance of this factor. However, general information was obtained on the frequency of gathering eggs, temperature of holding and frequency of delivery to the egg station. The results shown in Table XXVIII and the illustrations of the trends on individual farms (Figures 11 to 15) indicate that gathering and holding had a great deal of influence on the grade. In some cases conditions were fairly satisfactory for short holding, but delivery was made only once in eight or ten days; the result was a poor grade. Extreme ignorance and carelessness as to the importance of frequent gathering and rapid cooling of the eggs were displayed by many flock owners. It is the author's contention that an extensive campaign of education along this line would accomplish a great deal in improving the quality of eggs from Manitoba farms.

Comparison of the June and September eggs showed decreases in yolk color and albumen quality in September which were statistically significant. The yolk shadow was also slightly lighter, showing that it was influenced more by the decrease of 1.5 units of yolk color than by the fact that the albumen height was .011 inches lower. There was no increase in the proportion of B grade eggs in the samples obtained in September. It was unfortunate that circumstances were such that it was not possible to make a more complete survey consisting of four trips instead of two, to the district concerned. In that way, by obtaining a measure of the egg quality under winter conditions, and again at other critical times of the year, a true measure of the seasonal trend could have been obtained. However, the records of individual farms, illustrated in Figures 11 to 15, give ample próof of the seasonal drop in quality and of the variation that occurs between farms due to conditions of management.

Stewart, et al (48) found that with increased yolk color there was a slight tendency toward a lowering of the albumen quality. Results obtained from this project did not support their theory. The results of the controlled experiment at the University indicated that there was no change in albumen quality with differences in yolk color. The survey results which were based on a large number of determinations showed correlations between yolk color and albumen height of .1113 and .1253 in June and September respectively. These correlations were significant beyond the 1% point. The trend was slight but it indicated that there was slightly better albumen quality in eggs with darker yolks. It seems quite reasonable that the eggs produced by birds consuming a fair amount of green feed, which was intended by nature to provide the necessary constituents for growth and reproduction, should be of better quality than those from birds receiving little or no green feed with consequent possibility of an unbalanced diet.

The noticeable manner in which the yolk color became lighter with increased age of the eggs was very interesting. The trend was observed in both the June and the September eggs. It was more marked in eggs from flocks on restricted pasture. The results of the controlled experiment supported these findings, although the trend for the pasture eggs was not significant due to the large standard error. However, use of a larger number of variates would probably have produced a significant trend. This finding was one which was not anticipated since it has not been reported by other workers. Further investigation of this factor would require a controlled experiment where a large number of eggs were produced daily. The birds would receive a diet containing color-producing constituents such as alfalfa, administered in such a way as to cut down variation in yolk color between individual birds. Saving the eggs daily over a period of time and breaking a number of fresh eggs as a check each day would establish proof of this trend. It is probable that it results from a slight oxidation of the carotenoid pigments in the yolk.

Comparison of the data for flocks on unrestricted pasture with that for restricted flocks yielded one important fact. There was no significant difference in albumen quality. Therefore the fact that there were 27.1 per cent B grade eggs from the unrestricted flocks as compared with 15.9 per cent for the restricted, must be attributed to some cause other than inferior albumen quality. Since the percentage of B grade in the nest eggs was about the same in both cases, and since they increased more rapidly in the case of the unrestricted flocks, it appears that the difference was due to exposure of the darker yolks as the albumen became weaker, causing a darker yolk shadow as seen by the grader.

The experiment in shipping yielded additional information regarding individual farms. There was, naturally, a great deal of variation in yolk shadow and yolk color between farms due to differences in feeding. There were also highly significant variations in albumen quality, which resulted from differences in frequency of gathering, type of handling and initial albumen quality.

The variance which was attributed to the effects of shipping was due to the deterioration which occurred during two time periods: firstly, the time the eggs were kept in the egg station before shipping and, secondly, the time spent in transportation. Coles (10) observed a 20 per cent deterioration in quality due to shipping eggs a similar distance. Since the time spent in actual transportation was three days and the time in the egg station beforehand varied from one to three days, the drop in quality which was solely the result of time could be taken as the amount of deterioration which would occur during five to six days of holding without shipping. An estimate of the extent of this deterioration can be obtained from the results of the controlled experiment. Here, the initial quality was similar to the estimate of .264 inches as the mean albumen height for the eggs that were shipped. At five to six days the albumen height was about .185 inches. The albumen height of the three day old eggs, after shipping, was .198 inches. Thus, by this means of comparison, it appears that the actual effect of handling and shaking of the eggs during transportation by railroad was negligible.

The importance of care of the eggs on the farm prior to shipping was again emphasized by the results. The two highest values for albumen height of three day old eggs after shipping, .217 and .220 inches respectively, were for the eggs from two farms where the eggs were gathered three times daily and cooled immediately. The initial quality of these eggs was no better than it was for the eggs from some other farms where conditions of care were not so good and the final quality was, as a result, lower.

The controlled experiment was carried out for the purpose of eliminating some of the variations which occurred between farms and confirming any conclusions which were drawn from the results of the survey. Due to circumstances beyond the control of the author, the experiment was not carried out on a larger scale. Because of shortage and inefficiency of help, a very close check was necessarily kept on the feeding of the birds. The eggs were gathered and marked by the author, in order to avoid any confusion as to the diets of the birds by which they were laid.

SUMMARY

1. A survey of egg quality on Manitoba farms was made during 1945. Twenty-nine farms were visited in June and twenty-eight in September. General information regarding management was obtained, and quality determinations were made for 2,532 eggs. Records of the seasonal trend were obtained in the case of five farms.

2. A controlled experiment at the University of Manitoba poultry plant provided information supplementary to the results of the survey.

3. The order of importance of the independent effect of the quality factors studied, in differentiating between grade, is: albumen height, albumen score, yolk shadow and yolk color.

4. Yolk color is significantly correlated with yolk shadow, but its effect is influenced by the condition of the albumen. High albumen quality will completely mask normal variations in yolk color.

5. There is no difference in albumen quality produced by different levels of green feed.

6. Yolk color plays an important part in the grading of eggs due to its effect on yolk shadow, causing a tendency to exaggerate the deterioration in quality in eggs with dark yolks. Medium or low quality albumen is not as noticeable in candling eggs with light colored yolks.

7. Differences in frequency of gathering eggs and in temperatures of holding are responsible for a great deal of the variation in egg quality which occurs between Manitoba farms. Rapid cooling and frequent delivery are also factors of importance.

8. The seasonal drop in egg quality, occurring on many Manitoba farms, could be largely eliminated by proper methods of management and care.

9. The effect of transportation by rail on egg quality, outside of the normal deterioration due to age, was found to be negligible.

Bibliography

(1) ALBRIGHT, W. P. and R. B. THOMPSON. Variations of egg yolk color and characteristics produced by environment. Poultry Sc. 14:373-5. 1935.

(2) ALMQUIST, H. J. Relation of candling appearance of eggs to their quality. California Agr. Expt. St. Bulletin 561. 1933.

(3) ALMQUIST, H. J. and B. R. BURMESTER. Characteristics of an abnormal type of egg shell. Poultry Sc. 13:116-122. 1934.

(4) ALMQUIST, H. J., J. W. GIVENS and A. KLOSE. Transmission of light by egg albumen. Industrial and Engineering Chemistry. 26:847. 1934.

(5) ALMQUIST, H. J., B. O. NELSON and F. W. LORENZ. The effect of shaking on the quality of eggs. U.S. Egg and Poultry Mag. 40(12):13-16. 1934.

(6) ALMQUIST, H. J., and F. W. LORENZ. Firm white of fresh and storage eggs. Poultry Sc. 14:340-1. 1935.

(7) BOTSFORD, H. E. Relation of candled appearance to broken-out condition of eggs. American Creamery and Poultry Prod. Rev. 81:248-50. 1935.

(8) BRYANT, R. L. and P. F. SHARP. Effect of washing on keeping quality of eggs. Jour. Agr. Res. 48:67-89. 1934.

(9) CARD, L. E. and H. J. SLOAN. The effect of different diets on interior egg quality. Poultry Sc. 13:313-4. 1934.

(10) COLES, R. Egg candling and yolk quality. U.S. Egg and Poultry Mag. 46(2):92-95. 1940.

(11) COX, G. M. and W. P. MARTIN. The use of a discriminant function for differentiating azotobacter populations. Iowa State Coll. Jour. of Sc. 11(3):323-31. 1937.

(12) DENTON, C. A. and H. W. TITUS. The effect of fresh cereal grass on interior quality of eggs. Poultry Sc. 20:188-192. 1941.

(13) GOULDEN, C. H. Methods of Statistical Analysis. John Wiley & Sons, New York. 1939.

(14) GOULDEN, C. H. Experimental design for cereal chemists. Cereal Chemistry 21(3):159-171. 1944.

(15) HEIMAN, V. and J. S. CARVER. The albumen index as a physical measurement of egg quality. Poultry Sc. 15:141. 1936.

(16) HEIMAN, V. and J. S. CARVER. The yolk color index. U.S. Egg and Poultry Mag. 41:40-41. 1936.

(17) HEIMAN, V. and L. A. WILHELM. The relationship between yolk index, percentage of firm white and albumen index. Jour. Agr. Research 54:551-7. 1937.

(18) HEIMAN, V. and L. A. WILHELM. The transmission of xanthophylls in feeds to the yolk of the hen's egg. Poultry Sc. 16:400-3. 1937.

(19) HENDERSON, E. W. and H. L. WILCKE. Effect of ration on yolk color. Poultry Sc. 12:266-73. 1933.

(20) HERRINGTON, B. L. and P. F. SHARP. The effect of holding on the appearance of the opened egg. U.S. Egg and Poultry Mag. 40(11):37-39. 1934.

(21) HOLST, W. F. and H. J. ALMQUIST. Measurement of deterioration in the stored hen's egg. Hilgardia 6:49-60. 1931.

(22) HUNTER, J. A., A. VAN WAGENEN and G. O. HALL. Seasonal changes in interior egg quality of S.C. W. L. hens. Poultry Sc. 15:115-118. 1936.

(23) JEFFREY, F. O. Changes in pullet-year albumen index as affected by age of bird. Poultry Sc. 20:298-301. 1941.

(24) KNOX, C. W. and A. B. GODFREY. Breed differences - effect of egg weight and antecedent production in respect to thick albumen. U.S. Egg & Poultry Mag. 39(12):48-51. 1933.

(25) KNOX, C. W. and A. B. GODFREY. Variability of thick albumen in fresh-laid eggs. Poultry Sc. 17:159. 1934.

(26) KRISHNAN, T. S. The relation of the candling appearance of eggs to their thick white percentage. Indian Jour. of Vet. Sc. and Animal Husbandry. 13:141-5. 1943.

(27) LORENZ, F. W. and H. J. ALMQUIST. Determination of the percentage firm white. U.S. Egg and Poultry Mag. 40(11):30-33. 1934.

(28) LORENZ, F. W. and W. E. NEWLON. A field survey of ranch egg quality. Poultry Sc. 23:418-30. 1944.

(29) LORENZ, F. W. and L. W. TAYLOR. The inheritance of albumen quality characteristic of chicken eggs. Jour. of Agr. Res. 61:293-302. 1940.

(30) LORENZ, F. W., L. W. TAYLOR and H. J. ALMQUIST. Firmness of albumen as an inherited characteristic. Poultry Sc. 13:14-17. 1934.

(31) MACDONALD, A. J. and T. S. KRISHNAN. Some factors affecting the internal quality of eggs. Indian Jour. of Vet. Sc. and Animal Husbandry. 12:318-33. 1942.

(32) MUNRO, S. S. The effect of heredity on interior egg quality and shell composition. Poultry Sc. 17:17-27. 1938.

(33) MUNRO, S. S. and GEORGE ROBERTSON.
A method of measuring strength of yolk membrane.
U.S. Egg and Poultry Mag. 41(12):48-50. 1938.

(34) PARKER, S., S. S. GOSSMAN and W. A. LIPPINCOTT.
Studies on egg quality. I. Variations in yolk color.
Poultry Sc. 5:131-45. 1926.

(35) PARSONS, C. H., and L. D. MINK. The correlation of methods of measuring the interior quality of eggs.
U.S. Egg and Poultry Mag. 43:484-511. 1937.

(36) PAULHUS, N. G. and J. M. GWIN. Factors affecting candled and broken-out appearance of fresh white-shelled eggs.
Poultry Sc. 19:357. 1940.

(37) PENNINGTON, M. E. A review of the accomplishments in the field of poultry products research.
Proceedings of Seventh World's Poultry Congress. 1935.

(38) PENNINGTON, M. E., M. J. TRUE, A. D. RICH and A. A. KISSS. Yolk index and thick white in eggs graded by candling for interior quality.
U.S. Egg and Poultry Mag. 40(5):43-6. 1934.

(39) PERRY, J. E. A study of the effects of incubation temperature upon the quality of infertile eggs.
U.S. Egg and Poultry Mag. 44:537. 1938.

(40) POWELL, C. K. and P. F. SHARP. Decrease in interior quality of hen's eggs during storage as indicated by the yolk.
Indust. and Eng. Chem. 22:908-10. 1930.

(41) RINGROSE, R. C. and C. L. MORGAN. A study of the effect of green feed on interior egg quality.
Poultry Sc. 18:125-8. 1939.

(42) RINGROSE, R. C. and C. L. MORGAN. The relationship of protein supplement to interior quality.
Poultry Sc. 15:219-22. 1936.

(43) SCHAIBLE, P. J., J. A. DAVIDSON and J. M. MOORE. The egg yolk surface in fresh eggs. U.S. Egg and Poultry Mag. 42:479. 1936.

(44) SCHROEDER, CARL H. Interior egg quality. U.S. Egg and Poultry Mag. 39(6):44-6. 1933.

(45) SKOGLUND, W. C. and A. E. TOMHAVE. Frequency of gathering eggs and effect upon interior egg quality. Poultry Sc. 20:322. 1941.

(46) SNEDECOR, G. W. Method of expected numbers for tables of multiple classification with disproportionate sub-class numbers. Jour. of Amer. Stat. Ass. 29:389. 1934.

(47) SNEDECOR, G. W. and G. M. COX. Disproportionate sub-class numbers in tables of multiple classification. Research Bulletin 1180, Ames, Iowa. 1935.

(48) STEWART, G. F., A. R. GANS and P. F. SHARP. The relation of the color of yolk to interior quality as determined by candling and from the opened egg. U.S. Egg and Poultry Mag. 38:44-48. 1932.

(49) VAN WAGENEN, A. and G. O. HALL. The inheritance of certain characteristics affecting egg quality. Poultry Sc. 15:405. 1936.

(50) VAN WAGENEN, A. and H. S. WILGUS, JR. The determination and importance of the condition of the firm albumen in studies of egg-white quality. Jour. of Agr. Research. 51:1129-37. 1935.

(51) WARREN, D. C. and R. M. CONRAD. Growth of the hen's ovum. Jour. of Agr. Research. 58:875-96. 1939.

(52) WILGUS, H. S. JR. and A. VAN WAGENEN. The height of the firm albumen as a measure of its condition. Poultry Sc. 15:319. 1936.

(53) WILHELM, L. A. Egg quality - a literature review.
U.S. Egg and Poultry Mag. 45:565-73. 1939.

(54) WILHELM, L. A. Factors affecting interior egg quality.
Proceedings of Seventh World's Poultry Congress 1939.

(55) WILHELM, L. A. and V. HEIMAN. The effect of temperature and time on the interior quality of eggs.
U.S. Egg and Poultry Mag. 44:661-3. 1938.

(56) WILHELM, L. A. and V. HEIMAN. The seasonal changes in interior egg quality of new-laid eggs.
Washington Agr. Exp. St. Tech. Bull.358. 1938.

(57) YATES, F. The analysis of multiple classifications with unequal numbers in the classes.
Jour. of Amer. Stat. Ass. 29:51. 1934.