A STUDY OF EGG YOLK COLOR AS AFFECTED BY CERTAIN INGREDIENTS OF COMMON POULTRY FEEDS

by

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TABLE OF CONTENTS

INTRODUCTION

The variations in yolk color have an economic significance in the middle west. The most abundant poultry feeds in this area are largely xanthophyll bearing so that eggs from this section are highly colored. The U.S. Standards and Grades for eggs as set forth by the United States Department of Agriculture state that a U.S. Special must have a yolk that is "dimly visible." The relationship between the color of the yolk and its index of refraction for light causes the "golden yolk" of the mid-west fresh egg to appear visible or even plainly visible before the light of the candle. For this and other reasons, the fresh eggs from the middle west have been discriminated against on the eastern egg markets. The tendency for sectional discrimination is being gradually broken down by the constant efforts of both producers and shippers to obtain fresh eggs of uniform color and high quality. The very deeply colored yolk is still discriminated against, however, and it was for the purpose of determining how to produce more desirable yolk color that the Kansas Poultry and Egg Shippers Association established a Research Fellowship in the Agricultural Experiment Station of the Kansas State College in 1932.

REVIEW OF LITERATURE

For many years it has been recognized that the color of egg yolks was markedly affected by green feed. Dryden (1905) produced color in the yolk by feeding green alfalfa. It has been known for a long time that the pigments from yellow corn also cause the yolk of the egg to become darker in color (Stewart and Atwood, 1903). Palmer (1915) found xanthophyll to be the principal natural yellow pigment of the egg yolk, body fat, and blood serum of the hen. This pigment has been assigned the formula $C_{40}\ H_{56}\ O_2$ by Willstatter and Escher (1911). It will be observed that there is a difference of two oxygens between xanthophyll and carotin ($C_{40}\ H_{56}$), a yellow pigment which the hens do not seem to be able to use for coloring the egg yolk in the amounts occurring in ordinary feeds. Palmer and Kempster (1919) fed various rations to individual hens and recorded the yolk color both on the boiled egg and on the fresh egg with the Lovibond Tintometer. They did not attempt to ascertain the amount of pigment in the various ingredients of the ration. Parker, Gossman, and Lippincott (1925) reported on the effect of white and yellow corn and a number of green feeds fed in pen lots.

PURPOSE

The purposes of these studies were: (a) to ascertain the effects on egg yolk color due to the various ingredients of common poultry feeds, (b) to determine as far as possible the variation of egg yolk color which prevails among commercial and farm flocks fed and managed in different ways, and (c) to endeavor to work out a system of feeding and management of the laying flock which will give a more uniform yolk color.

MATERIALS AND METHODS

Method of Studying the Effect on Egg Yolk Color of Certain Feeds

In order to test the effect on egg yolk color of certain ingredients of the poultry ration, it became necessary to have some method by which each hen could be handled as an individual unit. The recent advances made in the field of individual hen batteries made it seem expedient to employ the use of this equipment.

A 32-hen unit battery arrived October 10, 1932 and was assembled in a clean, white-washed room where the experimental birds were continued until April 15, 1933. This battery is shown in figure 1. The room had two south windows, an overhead ventilator, and was heated by a gas

Figure 1

brooder stove. After the installation, electric lights were installed on either side of the battery and the birds were lighted until 10 o'clock each evening. Sixteen Rhode Island Red pullets and a like number of White Leghorn pullets were placed in the battery. The birds went through a molt but came back into production in good condition. The pullets were so arranged that two Leghorns and two Reds constituted a unit.

Each lot of four pullets was continued on the same feed for three weeks. Then they were changed back to the basal ration for two weeks to reduce the color of the yolk down to the same level as that produced by the control lot of pullets which were carried on the basal ration throughout the duration of the experiment. As the cod liver oil was the main source of vitamin A, it was freshly mixed every two weeks. If the pullets laid a few soft or weak shelled eggs, a few drops of fresh cod liver oil were given on their mash. Oyster shell was fed every other day in amounts that the birds would clean up readily. The eggs were gathered each day and held in a cooler until the conclusion of that phase of the experiment. In addition to the control lot, a similar group of four birds were held as reserves and used to replace any bird that died. The birds were allowed two weeks in which to become acclimated

to their new surroundings and to finish the bleaching process which had been started before the arrival of the battery. Before the first phase was begun, the birds were classified and rearranged on the basis of present and past production, the better hens being grouped on one side.

Common Ingredients and Preparation of Poultry Feeds Tested

The percentage composition of the feeds used in this study are given in table 1. The ingredients of all the 18 lots used are also listed. Lots 5, 6, 7, 8, 13, and 14 not listed here were used in connection with some work on egg flavor which was run concurrently with this work.

The feeds tested were white corn, yellow corn, yellow milo, wheat, oats, kafir, meat and bone scraps, three grades of alfalfa hay; wheat, rye, and alfalfa pasture. The white corn used was Pride of Saline, a Kansas-bred variety. The yellow corn was composed of three hybrid corns produced on the Kansas State College agronomy farm. A strain of Dwarf Yellow milo was used. The yellow pigment of grain is usually associated with the vitamin A content. No work could be found bearing on the character of the yellow pigment of yellow milo. Smith (1930) reports on a comparison of the vitamin A content of yellow milo and yellow corn, and Hewang and Morgan (1932) report on the use

Table 1. Percentage Composition of Rations*

Lot No.	White corn	Yellow corn	Dried butter-milk	Wood pulp fiber	Kafir	Wheat	Oats	Yellow milo	Meat and bone scraps	Ground alfalfa			Total
										Leaves	Hay	Stems	
1	--	70	20	4	--	--	--	--	--	--	--	--	94
2	35	35	20	4	--	--	--	--	--	--	--	--	94
3	52.5	17.5	20	4	--	--	--	--	--	--	--	--	94
4	70	--	20	4	--	--	--	--	--	--	--	--	94
9	62	--	17	5	--	--	--	--	--	10	--	--	94
10	62	--	19	3	--	--	--	--	--	--	--	10	94
11	62	--	18	4	--	--	--	--	--	--	10	--	94
12	35	--	20	4	--	--	--	35	--	--	--	--	94
15	35	--	20	4	--	35	--	--	--	--	--	--	94
16	62	--	17	5	--	--	--	--	--	10	--	--	94
17	62	--	19	3	--	--	--	--	--	--	--	10	94
18	62	--	18	4	--	--	--	--	--	--	10	--	94
19	35	--	20	4	35	--	--	--	--	--	--	--	94
20	35	--	20	4	--	--	35	--	--	--	--	--	94
21	70	--	10	4	--	--	--	--	10	--	--	--	94
22	62	--	17	5	--	--	--	--	--	10	--	--	94
23	62	--	19	3	--	--	--	--	--	--	--	10	94
24	62	--	18	4	--	--	--	--	--	--	10	--	94

*To each ration was also added:

3 per cent dried brewers' yeast
2 per cent cod liver oil
1 per cent salt (Na Cl)

This made a total of 100 per cent.

of yellow milo for growing chicks. A large acreage of milo is grown annually in certain sections of Kansas and it is widely used as a poultry feed. Yellow milo bears a small amount of some yellow pigment so it was considered advisable to check it in respect to effect on yolk color. The wheat, oats, and kafir produced on the Station's agronomy farm were the same as was used for mixing feed for the birds on the Kansas State College poultry farm. The meat and bone scraps were a high grade product and the same brand has been in use on the farm for several years. The alfalfa used was fourth cutting, about nine inches high and of good quality. It was a new seeding grown on a south slope of the poultry farm and was cut October 5, 1932 before a frost had damaged it. One-third of the hay was dried immediately to preserve the natural green color; a second one-third was weathered until it was approximately one-third bleached; the remaining one-third was two-thirds bleached. The leaves and stems were separated. The hay was graded and lots 9, 10, and 11 received the hay graded No. 1 bright green; lots 16, 17, and 18 received that which was graded No. 2; and lots 22, 23, and 24 received the No. 3.

Green Feeds Tested

In the fall of 1932, small plots of wheat, rye, and alfalfa were planted to be used for testing the effect of these green pastures on egg yolk color. It was hoped to run this phase of the experiment in March but a freeze on March 23 necessitated delaying it a little longer. The pastures were well enough along by March 27 to support the hens so a number of coops were set upon each plot of green feed and preliminary trials were carried out using hens from the battery that had been on the basal diet for a long enough period to have a very light yolk color. Two hens were selected for each pasture, one being placed in the coop at 7:30 a.m. and the other at noon. Some difficulty was encountered in getting the birds to eat the green feed for the first three days. Concurrently, another similar group in the hen battery was fed one-half ounce daily of each of the above green feeds. This was finely chopped and fed early in the morning. A smaller amount was used at the start allowing only what the birds would clean up before the green feed wilted. By these trials it was determined that the amount of xanthophyll in the fresh feed was sufficient to give the maximum yolk color in six days.

Explanation of the Basal Ration

Lot number 4 (table 1) was composed of as nearly xanthophyll and carotinoid-free components as was possible to secure. As the color of the yolks produced was not absolutely white, it was thought that the 20 per cent dried buttermilk might be bearing some xanthophyll. An investigation revealed that a plant compound or dye, anetta, is used by the manufacturers of the product to give the butter the proper yellow color. Some anetta was secured and fed by capsule to two hens. The resulting egg yolks were somewhat deepened in color.

Spruce wood pulp fiber was used to increase the fiber content of the basal ration to as nearly 7 per cent as possible. The hens in the battery had no opportunity to increase the fiber content of the ration by eating litter as is done by those housed in the ordinary manner. Therefore, it was deemed advisable to increase the fiber content somewhat. The yeast was to take care of any possible vitamin B deficiency that might result from some of the rather artificial rations that were prepared. The yeast may have contained small amounts of xanthophyll as yeast is frequently cultured on bran which is a good source of xanthophyll. The grains were all bought in large enough quantities to last for the duration of the experiment. This was

to avoid any discrepancy that might enter into the results due to different sources of material. All feed was ground and mixed by the author. All machinery and equipment used was carefully cleaned to eliminate contamination from other feeds.

In spite of the precautions taken, the yolks of the eggs from lot 4 were not colorless and upon extraction yielded small fractions of both xanthophyll and carotin. The spectrum readings were taken on the spectrophotometer of the Department of Chemistry to substantiate the results of the extraction.

Determination of Variations in Yolk Color of Farm Flocks

The cooperation of five farmers in the vicinity of Manhattan was secured for this portion of the experiment. Visits were made semi-monthly and a sample of six fresh eggs was taken at each visit. Three yolks were broken into a vessel and thoroughly mixed. Then a small sample was drawn and placed in a dish and the color determined and computed as described under the Method for Determination of Egg Yolk Color. No attempt was made to change the flock owner's plan of management. A record was kept of egg production, number of birds, feed, and management. It was hoped to gather data on feed costs but this idea was

abandoned as none of the farmers kept complete records.

A house of 200 White Leghorn hens and 200 White Leghorn pullets which were used in another experiment at the college poultry farm were also available for use in this study on yolk color and samples were gathered from this flock. The eggs secured were properly marked and dated.

System of Feeding and Management

To carry out this portion of the experiment, a house on the college poultry farm was reserved and filled with 125 pullets. It was a Kansas open front, straw loft house recommended for general farm usage and so divided as to allow 50 birds on one side and 75 birds on the other. One hundred and sixteen pullets were put in the house October 10, 1932 and so far as possible equal numbers of Rhode Island Reds and Single Comb White Leghorns were put on each side. Not all of the White Leghorns were in production at this time but each of the Rhode Island Reds had laid at least three eggs. Nine additional Rhode Island Red pullets were added as soon as they had reached maturity.

Several days before starting the hens on pasture in the spring of 1933, the individual egg records were studied and a group of hens selected from flocks 31 and 32. Three groups of hens were prepared for each of the three lots of green pasture. One hen from each flock was placed out of

doors at 7 o'clock each morning on each of the plots of green wheat, rye, and alfalfa range. The second lot was placed out at noon. These were brought in at 5:00 p.m. The last lot was left out until dark. The eggs of each hen were carefully marked and the color determination made. At the conclusion of this phase, all birds were allowed to range on wheat pasture after 4 o'clock for 10 days. Still another phase was used in which the hens were fed the same diet but allowed range ad libitum.

Method of Determining Color

Various means have been used in previous attempts to match or compare egg yolk colors. Palmer and Kempster (1919) used the Lovibond Tintometer on both raw and cooked egg yolk. Parker, Gossman, and Lippincott (1925) used a set of specially prepared color vials, each being assigned a numerical value by Ridgeway (1912). Stewart, Gans, and Sharp (1932) as well as numerous other workers in this field have used vials containing mixtures of pigments corresponding more or less to the variations in yolk color. There is such a wide range of color that the number of vials of varying shades of pigments would make this method prohibitive for use in work of this kind where minute variations are recorded. Munsell's classical treatise on the subject of color (1905) gives a very comprehensive

view of the field of color determinations. He amply describes the names and qualities of color and gives a glossary of terms which will be closely followed in this work. Since color has three dimensions, it is especially hard to work with. These dimensions are: (1) hue, the name of the color (red); (2) value or brilliance, the light of the color (its relative position in the scale between black and white); and (3) chroma, the strength of the color (color intensity).

In the studies herein reported, the egg was broken, removed from the shell and the albumen separated from the yolk. At first the color was taken on the yolk unbroken and then the yolk was thoroughly mixed and the second reading taken. Due to the fact that the yolk is laid down in concentric layers, the unbroken yolk may give a much deeper color than the same yolk when it is thoroughly mixed.

The method described gave the areas or percentage of color (table 2). The manners of approach to this subject are described by Nickerson (1929, 1932). By using the Munsell formulae and hue notation, the hue, brilliance, and chroma of each reading could be arrived at.

The equipment for obtaining the readings consisted of a box 14 inches wide, 14 inches deep, and 20 inches long painted white inside and illuminated with a 60 watt, 115

volt blue bulb on either side of the box. A small motor on which were mounted Munsell color discs was placed in the box and a small stand upon which to place the broken egg yolk was also provided. The colors were matched by observing the spinning wheel and the yolk through a comparator eye piece. This arrangement placed the color wheel in juxtaposition to the egg yolk. A few readings were taken at the beginning of each period before recording any data in order to give the eye a chance to adjust itself. Not more than six readings were taken consecutively in order to allow the eye to rest. This type of work was never conducted for a period longer than two hours at one time as the strain weakens the eye to a point where accurate discrimination between colors cannot be continued. In this experiment, Nickerson's (1929) directions were followed as closely as they could be applied to the material.

Formula for Determining Hue

For converting the percentage area of standard color into the terms of hue, the Munsell formula was used (1905).

$$\text{Hue Resultant} = Z - \frac{Ax\ Px}{Ax\ Px + Az\ Pz}\ (z - x)$$

Z = Number of first hue clockwise on hue notation

X = Number of second hue clockwise on hue notation

A = Area of color

P = Power number (brilliance x chroma)

N = Neutral

Y = Yellow

YR = Orange

Table 2. Sample of Data Taken on Each Egg

Hen No. 2512 Lot No. 13 Date of Reading, 4-8-33

Date laid	White N/9	Yellow Y 8/12	Orange YR 6/12	$\frac{Ax\ Px}{AxPx-AzPz}(z-x)$	Hue
3-31-33	3	50	47	4.13	YR 10.87
4- 2-33	3	43	54	4.81	YR 10.19
4- 3-33	3	36	61	5.50	YR 9.50
4- 4-33	3	33	66	6.00	YR 9.00

When the data of table 2 are applied to the above formula:

$$\text{Hue Resultant} = 25 - \frac{47(6x12)}{47(6x12) + 50(8x12)}\ (25-15)$$

The white is a neutral color, therefore, it is valueless and is not used in the calculation. The hue is arrived at by referring the hue resultant to the hue circuit.

The portion of the hue circuit into which egg yolk color falls is that portion YR 5, the standard orange, and Y 5, the standard yellow. Between these two points are ten complete units. YR 5.0 is a darker orange than YR 6.0 or YR 10.0. From YR 10 the notation starts another portion of the circuit with Y 1. It may be seen from this that the larger the notation within a unit of the circuit, the lighter the color.

Table 3. Daily Advance in Yolk Color of One Hen on Xanthophyll Bearing Feed

Date laid	White N/9	Yellow Y 8/12	Orange YR 6/12	$\frac{Y(96)}{Y(96)+YR(72)}10$	Hue
3-28	11	75	14	1.22	Y 3.78
3-29	7	73	20	1.705	Y 3.39
3-30	8	48	44	4.075	YR 10.93
3-31	--	--	--	--	--
4- 1	8	48	44	4.075	YR 10.93
4- 2	3	35	62	5.705	YR 9.29
4- 3	3	32	65	6.038	YR 8.96
4- 4	0	33	67	6.036	YR 8.96
4- 5	--	--	--	--	--
4- 6	0	35	65	5.821	YR 9.18

DISCUSSION OF RESULTS

Discussion of Individual and Breed Variations

Table 3 shows the rapid daily advance in the color of the egg yolk during a ten-day period for a single hen. It shows an advance in color of 51 per cent in the ten days illustrated. Of this, 48 per cent occurred in the first six days and aptly shows the rapidity with which the coloring material is laid down in the egg. A change of 10 per cent is easily noticeable while the eye trained to color observation can detect changes of 5 per cent with a fair degree of accuracy.

Tables 4, 5, and 6 show the individual variation of the hens on the various samples of feed used. It was thought at first that the White Leghorns (L) laid eggs the yolks of which were somewhat lighter than those produced by their lot mates of Rhode Island Reds (R). However, the data compiled in table 7 disproved this general impression. In this table the data on four Rhode Island Reds and four White Leghorns through four different lots of feeding are presented, along with the average hue notation. In only one case (No.2604L) are all the differences positive. The differences range from .44 with 2617L to 1.72 with 2616L.

Table 4. Individual Variation of Yolk Color - Corn Tests

Lot No.:	Hen No. :	Hue note :	Lot No.:	Hen No. :	Hue note
1	2597R	YR 7.42 :	3	2592R	Y 1.95
	2599R	YR 8.46 :		2601R	Y 2.36
	2617L	YR 8.27 :		2604L	Y 2.39
	2602L	YR 8.92 :		2616L	Y 2.24
2	2587R	YR 10.71 :	4	2595R	Y 4.51
	2596R	Y 1.96 :		2598R	Y 4.49
	2605L	YR 9.83 :		2603L	Y 4.51
	2608L	YR 10.52 :		2609L	Y 3.91

Table 5. Individual Variation of Yolk Color - Alfalfa Tests

Grade	Lot No.	Hen No.	Hue	Lot No.	Hen No.	Hue	Lot No.	Hen No.	Hue
1	9	2597R	YR 9.55	11	2587R	YR 10.03	10	2601R	Y 2.01
		2599R	YR 10.62		2596R	YR 9.37		2592R	Y 1.88
		2617L	YR 9.86		2608L	YR 9.81		2616L	Y 2.49
		2602L	YR 9.81		2605L	YR 9.37		2604L	Y 2.21
2	16	2599R	YR 9.47	18	2601R	YR 10.52	17	2587R	Y 3.51
		2597R	YR 10.15		2592R	YR 10.28		2596R	No eggs
		2617L	YR 9.60		2616L	Y 1.70		2605L	Y 3.95
		2602L	YR 10.15		2604L	YR 10.26		2611L	Y 2.37
3	22	2587R	YR 9.70	24	2599R	YR 10.50	23	2592R	Y 1.40
		2596R	YR 9.70		2597R	YR 10.14		2601R	Y 1.59
		2611L	YR 10.23		2614L	Y 1.6		2604L	Y 2.24
		2605L	YR 9.70		2617L	YR 10.71		2616L	Y 2.90

Table 6. Individual Variation of Yolk Color of Five Other Common Feeds Tested

Lot No.	Hen No.	Hue	Lot No.	Hen No.	Hue
12	2590R	Y 3.44	19	2588R	Y 4.05
	2595R	Y 3.32		2595R	Y 4.06
	2615L	Y 3.72		2612L	Y 4.06
	2612L	Y 3.83		2615L	Y 4.05
15	2586R	Y 3.87	20	2595R	Y 4.08
	2600R	No eggs		2588R	No eggs
	2608L	Y 3.77		2615L	Y 4.08
	2613L	Y 3.97		2612L	Y 4.00
			21	2586R	Y 4.39
				2600R	Y 4.39
				2608L	Y 4.06
				2613L	Y 4.02

Table 7. Variation in Yolk Color of Individual Hens from Mean Hue Notation

Rhode Island Reds					Single Comb White Leghorns				
Hen No.	Lot No.	Hue note	Average hue note	Difference	Hen No.	Lot No.	Hue note	Average hue note	Difference
2597	1	YR 7.42	YR 8.27	-.79	2617	1	YR 8.27	YR 8.27	--
	9	YR 9.55	YR 9.66	-.11		9	YR 9.86	YR 9.66	+.20
	16	YR 10.15	YR 9.84	+.31		16	YR 9.60	YR 9.84	-.24
	24	YR 10.14	YR 10.60	-.46		24	YR 10.71	YR 10.60	+.11
2587	2	YR 10.71	Y 1.33	-.42	2604	3	Y 2.39	Y 2.24	+.15
	11	YR 10.03	YR 9.65	+.38		10	Y 2.21	Y 2.15	+.06
	17	Y 3.51	Y 3.28	+.23		18	Y 2.63	Y 2.55	+.08
	22	YR 9.70	YR 9.81	-.11		23	Y 2.24	Y 2.03	+.21
2599	1	YR 8.46	YR 8.27	+.19	2616	3	Y 2.24	Y 2.24	--
	9	YR 10.62	YR 9.66	+.96		10	Y 2.49	Y 2.15	+.34
	16	YR 9.47	YR 9.84	-.37		18	Y 1.70	Y 2.55	-.85
	24	YR 10.50	YR 10.60	-.10		23	Y 2.90	Y 2.03	+.87
2601	3	Y 2.36	Y 2.24	+.12	2605	2	YR 9.83	Y 1.33	-.50
	10	Y 2.01	Y 2.15	-.14		11	YR 9.37	YR 9.65	-.28
	18	Y 3.02	Y 2.55	+.47		17	Y 3.95	Y 3.28	+.67
	23	Y 1.59	Y 2.03	-.44		22	YR 9.70	YR 9.81	-.11

In table 8 a comparison of the differences between hens of high and low intensities are presented. In this case only one hen of low intensity is presented. However, hen 2605L (table 7) was also considered to be of low intensity. Low intensity in this instance refers to a hen having an average monthly production of 35 per cent or less. Only four hens of this intensity were found in the 32 used in the hen battery. Of this number, two laid no eggs of value as they were not carried on any lot presented in this paper. The variation in neither 2592R or 2605L is constant. No hen of the entire 32 having an average monthly intensity of better than 50 per cent had all positive variations.

Table 8. Comparison of Yolk Color Variations in Hens of High and Low Intensity

Hen No.	Intensity	Lot No.	Hue note	Average hue note	Difference
2592R	Range 9 to 22 eggs monthly	3	Y 1.95	Y 2.24	-.29
		10	Y 1.88	Y 2.15	-.27
		18	Y 2.84	Y 2.55	+.29
		23	Y 1.40	Y 2.03	-.63
2601R	Range 16 to 24 eggs monthly	3	Y 2.36	Y 2.24	+.12
		10	Y 2.01	Y 2.15	+.14
		18	Y 3.02	Y 2.55	-.47
		23	Y 1.59	Y 2.03	-.44

There is an indication that hens of high intensity produce a lighter colored yolk than those of low intensity (see table 10). In this table showing semi-monthly variation of eight farm flocks, it will be noted that in flocks 29 to 32 inclusive, while the birds were confined, that there is a gradual decrease in yolk color from February through the season of high production until green feed is supplied to the normal ration.

Discussion of the Effects on Egg Yolk Color of the Various Ingredients of Common Poultry Feeds

Table 9 presents the following data: the lot number with the particular ingredient tested and its amount; the average hue notation for the four hens used in the lot; and the percentage variation from the eggs produced on the basal ration. A comparison of lots 1, 2, and 3 (table 9) in which 70, 35, and 17.5 per cent respectively of yellow corn were used indicates that the hen is not capable of using xanthophyll for coloring the egg yolk in direct proportion to the amount fed.

Lot 3 (17.5 per cent yellow corn substituted for an equivalent amount of white corn) gave an increase of 2.37 units of color over the basal ration, lot 4. On this basis lot 2 (35 per cent yellow corn) should have given a variation of 4.74 units of color. Instead, it gave a variation of 3.28 units. Calculated on the basis of lot 3, the

variation for lot 1 should have been 9.48 units, instead it was 7.12 units.

Lots 9 and 11 (table 9) which received 10 per cent of bright green alfalfa leaves (1st grade) and whole plant, respectively, gave readings that indicate the hens used about an equal amount of color from both the leaves and the hay.

Table 9. Average Color Notations of Egg Yolks Produced from Each Experimental Ration

Lot No.	Per-centage	Ingredient tested	Hue	note
1	70	Ground yellow corn	YR	8.27
2	35	Ground yellow corn	Y	1.33
3	17.5	Ground yellow corn	Y	2.24
4*	70	Ground white corn	Y	4.61
9	10	No.1 ground alfalfa leaves	YR	9.96
10	10	No.1 ground alfalfa stems	Y	2.15
11	10	No.1 ground alfalfa hay	YR	9.65
12	35	Ground yellow milo	Y	3.57
15	35	Ground wheat	Y	3.87
16	10	No.2 ground alfalfa leaves	YR	9.84
17	10	No.2 ground alfalfa stems	Y	3.28
18	10	No.2 ground alfalfa hay	YR	10.69
19	35	Ground kafir	Y	4.05
20	35	Ground oats	Y	4.05
21	10	Meat and bone scraps	Y	4.22
22	10	No.3 ground alfalfa leaves	YR	9.81
23	10	No.3 ground alfalfa stems	Y	2.03
24	10	No.3 ground alfalfa hay	YR	10.60

* Basal ration.

Lots 16 and 18 (table 9) which received alfalfa which had been about one-half bleached (2nd grade) also gave similar results. Lots 22 and 24 (table 9) which received a like amount of alfalfa that had been about two-thirds bleached (3rd grade) also produced yolks, the colors of which were of practically the same hue. These data would indicate that hens can use only a portion of the xanthophyll borne in bright green alfalfa and there is very little difference in the utilization of the color from alfalfa hay and alfalfa leaves of the same grade. Lots 10, 17, and 23 (table 9) show that there is very little difference in the utilization of color from alfalfa stems of the different grades of alfalfa hay used in this study. From a summary of the work with ground alfalfa hay, leaves, and stems (table 9) it is shown that while exposure to the sun and rain may destroy the xanthophyll, enough remains in even the bleached samples to color the yolk as highly as did the bright green samples.

Lot 20, being fed 35 per cent ground oats, and lot 19, 35 per cent kafir (table 9), indicate that from these samples of grain, the hens could utilize about the same amounts of xanthophyll. Neither would be a very good substitute for yellow corn, however, as far as xanthophyll content is concerned. An equal amount of yellow corn contained four

units more utilizable color. Lot 12, receiving 35 per cent yellow milo (table 9) gave a unit color notation which closely approximates the notation of both yellow milo and kafir. Wheat, the other grain commonly used in Kansas poultry rations, gave a reading of Y 3.87 which shows it is very low in the ingredient which colors egg yolk. The meat and bone scraps, lot 21, (table 9) is also very low in xanthophyll.

Discussion of the Variations of Egg Yolk Color Among Commercial and Farm Flocks

A summary (see table 11, Appendix) of the number of birds in each flock, the type of farm, the breed of poultry kept, the rations used, and the methods of management is presented for each of the eight flocks used in this study. While a total of 2321 birds were kept on the farms cooperating in this work, only six eggs were taken from each flock semi-monthly. Rhode Island Reds, White Plymouth Rocks, Buff Orpingtons, and White Leghorn hens and pullets were used. Two of the farms were primarily breeding establishments; three were strictly commercial businesses producing high quality eggs for wholesale and retail establishment; and the remaining three flocks were slightly better than the average farm flock in this vicinity.

Flock number 25 used a mash formula supplied by the Department of Poultry Husbandry of the Kansas State College

and manufactured by a local milling company. All birds were confined from January 30 to April 25 (table 11) which was the duration of this study. The yolk color (table 10) of flock number 25 is fairly constant from January 30 to March 27. The 1.98 unit increase of March 27 over March 10 is probably due to an increased consumption of yellow corn. There is of course, the possibility of securing eggs from hens which prefer yellow corn to wheat. The variations from March 27 to April 25 illustrate the variations or lack of uniformity of egg yolk color which may prevail in a flock when yellow corn is used in the scratch ration.

Flock number 26 (table 11) used a similar mash but the combination of green alfalfa hay fed twice daily together with yellow corn scratch grain probably accounts for the 30 per cent variation. The mash moistened with sour milk and fed at noon was very good as an egg stimulant but it had a laxative effect. The increase (table 10) from YR 8.08 April 8 to YR 6.60, April 25 is explained by the fact that the flock was allowed to forage around the barnyard after April 15. No definite plots of green range were provided but ample blue grass and early green weeds were available.

Flock number 27 (table 11) was fed a mash secured from the same source as flocks numbers 25 and 26. All birds were confined during the duration of the experiment but yellow

Table 10. Semi-Monthly Variation of Color Notation in Eggs from Eight Farm Flocks

Flock No.	Jan. 20	Feb. 10	Feb. 25	March 10	March 27	April 8	April 25
25	YR 8.85	YR8.34	YR 8.61	YR 9.48	YR 7.50	YR 8.86	YR 9.48
26	YR 9.68	YR6.76	Y 1.70	YR 8.07	YR 8.41	YR 8.08	YR 6.60(1)
27	YR 7.73	YR5.61	YR 9.15	YR 8.41	YR 7.50	YR 8.08	YR10.90
28	YR 9.68(2)	YR9.37	YR 8.23	YR10.20	YR10.11	Y 1.39	YR 9.18(3)
29	YR 9.04	YR9.47	YR 9.36	Y 1.00	Y 1.00	YR10.72	YR10.90
30	YR 9.68	YR9.92	YR 9.37	YR10.21	YR10.30	Y 1.19	Y 1.00
31	YR10.29(4)	Y1.37(5)	Y 1.72	Y 1.96	Y 1.96	YR 8.41(6)	YR 6.54(7)
32	Y 1.10	Y1.08	YR10.97	Y 1.59	Y 1.11	YR 7.82(6)	YR 6.54(7)

(1) Free range after April 15
(2) Birds allowed to range on limited amount of orchard grass until March 1
(3) Green feed cut and fed in yard
(4) Yellow corn and wheat scratch
(5) Change made from yellow to white corn February 1
(6) Range after 4:00 p.m.
(7) Unlimited range.

corn was given in the evening and bright green alfalfa hay was used as scratch material. This manner of feeding and management accounts for the variation from YR 10.90 to YR 5.61.

Flock number 28 was fed a very good commercial egg mash, the exact formula of which is not available. Yellow corn scratch grain was given of an evening. However, the amount fed was governed by the condition of the birds. Being a heavy, inactive breed and in close confinement, only enough grain was fed to keep the hens in good flesh. The birds were allowed to range in a small orchard until March 1. At this season of the year very little green orchard grass was available. About the middle of April a small amount of green grass was cut and thrown into the yard daily.

Flock number 29 (table 11) was fed a home-mixed mash with a scratch grain of wheat given each evening. Only about 12 per cent of the entire ration consisted of yellow corn and less than 4 per cent was alfalfa leaf meal. All birds of this flock used in this study were confined the duration of this experiment. The effect of this manner of feeding is shown in the color notations from month to month (table 10). This yolk color compared favorably with that of one lot of eggs produced in California which had a hue notation of YR 10.87.

Flock number 30 was handled as a commercial flock. These 400 White Leghorns were divided into four lots and all received identical feed. Two lots, however, received morning lights. They received the college mash and were also hopper-fed wheat and yellow corn. The variations (table 10) from period to period are easily accounted for by the individual preference for yellow corn over wheat.

Flock number 31 was fed the college mash. At the onset of the experiment the regularly recommended scratch ration of equal parts of wheat and yellow corn was used. This was changed February 1 and white corn was substituted for the yellow corn in the scratch ration (table 10). This change accounted for the 1.07 unit change between January 30 and February 10. After this, the yolk color of eggs from this flock was very uniform. Several hundred eggs were broken from this flock and the uniformity was quite good and comparable only to the uniformity of flock 29. From April 1 to April 15 this flock was allowed to range after 4 o'clock on green wheat (table 10). This increased the color 1.55 units. From April 15 until April 25 the flock was allowed free range. This increased the color 1.87 units over the previous color and 4.52 units over the yolk color while confined.

Flock 32 (table 11) was used to obtain a comparison between the well-managed farm unit which is usually confined

during the winter and the average flock which may be confined in the winter only to facilitate ease of egg gathering but which is haphazardly fed. This flock was litter-fed only wheat and yellow corn. To balance this diet and keep down some feather pulling which started soon after the pullets were housed, it was thought advisable to supplement this whole grain ration with meat and bone scraps. This was at first hopper-fed ad libitum. When it became evident that the pullets were gourging themselves and wasting such large amounts, the method of feeding was changed. A limited amount was given at regular weekly intervals. This flock was confined until April 1. At this time they were allowed wheat range after 4 o'clock. This accounted for an increase in yolk color of 2.30 units (table 10). After April 15 the flock was allowed unlimited wheat range. This change in management increased the yolk color 1.28 units over the previous color and 4.52 units over the notation taken on March 27 while the flock was still confined.

Discussion of the Effect of Green Feeds on Egg Yolk Color

A summary of the effects on yolk color of succulent green feeds is shown in tables 12 and 13. Table 12 presents a summary of the data taken on the individual hens which were allowed limited range on wheat, rye, and alfalfa.

Table 12. Summary of the Effects on Egg Yolk Color of Rye, Wheat, and Alfalfa Range

Range	Morning range				Noon range				Evening range				Average all readings
	Hen No.	Flock	Hue	Average hue	Hen No.	Flock	Hue	Average hue	Hen No.	Flock	Hue	Average hue	
Rye	2466L	32	YR8.75	YR8.58	2465L	32	YR7.15	YR7.32	2493R	32	YR7.85	YR8.35	YR8.09
	2514L	31	YR8.41		2549R	31	YR7.50		2512L	31	YR8.85		
Alfalfa	2461L	32	YR7.96	YR7.25	2467L	32	YR6.91	YR6.73	2507R	32	YR7.50	YR7.38	YR7.12
	2511L	31	YR6.54		2548R	31	YR6.54		2556R	31	YR7.26		
Wheat	2497R	32	--	YR8.75	2478L	32	YR7.16	YR7.61	2491R	32	YR7.26	YR7.87	YR7.95
	2561R	31	YR8.75		2513L	31	YR8.07		2547R	31	YR8.49		
Average all readings				YR8.08				YR7.22				YR7.87	

Table 13. Effect on Egg Yolk Color of Supplementing the Basal Ration with Green Feed

Range	One-half oz. fed daily			Range four hours daily		
	Hen No.	Hue	Average hue	Hen No.	Hue	Average hue
Wheat	2603L	YR 9.22	YR 9.87	2586R	YR 8.85	YR 8.35
	2609L	YR 10.52		2600R	YR 7.85	
Alfalfa	2589R	YR 10.81	YR 10.41	2610L	YR 7.26	YR 7.26
	2598R	YR 10.01		2612L	YR 7.26	
Rye	2608L	YR 7.62	YR 7.84	2611L	YR 7.26	YR 7.85
	2613L	YR 8.75		2615L	YR 8.43	

The average hue notation is given for each of the three green ranges used. From the data presented (table 12) it would appear that rye contains less xanthophyll than either wheat or alfalfa. When a measured amount of green feed was fed, rye gave the darker color (table 13). It is probable, however, that in this instance what was actually measured was the consumption. The wheat and rye were both rather large when consumed (about six inches high). The alfalfa was much smaller and probably more tender than either of the other plants. It was about two inches high and the birds ate it rather close to the ground. This may account for the alfalfa giving 1.77 units more color than the rye (table 12). The averages (table 12) of the morning, noon, and evening

ranges for all three of the green feeds would indicate that morning range would give the lightest yolk color. Here again the figure is probably a measurement of the green feed consumed. During the period at which these data were collected, the weather was very cloudy. There were several light rains and a heavy dew on several mornings. The hens which were placed out on the damp mornings received full benefit of these phenomena and in all probability did not eat as much as they would have under more ideal conditions. However, the differences (table 12) between those receiving noon range and those receiving range only during the evening is not so great as would be expected. In every case, the yolk color of the morning lot of eggs was less than that produced by the noon lot. The yolk color of the evening lot was also less in all cases than that obtained at noon.

Table 13 shows the effect of the three green feeds on eggs from hens fed the basal ration. One-half ounce of green feed was pulled, cut up, and fed daily to six hens of the battery lot. From this work it was observed that rye gave 2.03 units more color than wheat while alfalfa gave .59 unit less color than wheat. When six more birds were allowed to consume as much green feed as they wished for a period of four hours, it was again indicated that alfalfa bore more xanthophyll than either rye or wheat. This is a verification of the former observation that the point being

measured was food consumption rather than the amount of usable pigment.

Production Summary of Flocks 30, 31, and 32

Table 14 is presented as a production summary of flocks 30, 31, and 32 for a six month period. The feed was weighed and the monthly consumption figured. The total consumed for each flock during the period of the experiment is presented. The feed costs are calculated from figures secured monthly from a mill which manufactures and sells feeds mixed after the K.S.C. formulas. The eggs from flock 30 were marketed on a graded basis while the value of eggs from flocks 31 and 32 were calculated on the straight buying price prevailing locally the first of each month.

Table 14. Six Month Production Summary of Flocks 30, 31, and 32

Flock number	30	31	32
Pounds feed consumed	17,749	3,284	1,574
Total feed cost	$ 146.31	$ 32.86	$ 10.49
Total dozen eggs	2,862.5	419.65	144.56
Net receipts for eggs	$ 394.10	$ 63.41	$ 23.39
Feed cost per dozen eggs	0.0511	.0671	.0726
Profit over feed costs	247.79	30.55	12.90

It may be observed that flock 30 (table 10) which was confined had a lower feed cost per dozen eggs than did either of the other two flocks. Table 11 reveals, however, that flock 30 had a darker yolk color than the other two flocks

while they were confined. This was due, no doubt, to the free choice of wheat and yellow corn whole grain which was hopper-fed. There is very little difference in feed cost per dozen eggs between flocks 31 and 32.

Recommendations

In view of the results reviewed in this paper, there are several recommendations that could be made. It should be understood that this is in no way a comprehensive study of the field. Many results obtained in this work, however, verify observations of practical poultrymen.

The first recommendation is directed to the commercial egg producer. The confinement method of handling the laying flock gives the most uniform results by eliminating the possibilities of getting large amounts of waste grains or green feeds. In this study, the eggs from this type of flock were produced at a lower feed cost per dozen. The all-mash method of feed, or mash fed with a scratch grain that bears only small amounts of xanthophyll is the best method of securing a uniformly colored product. Feeding yellow corn and alfalfa hay either in the hopper or litter causes a wide variation in the resulting egg yolk color. This substitution of white corn for yellow corn and adding ground alfalfa to the mash will reduce the color greatly

thereby making a greater uniformity.

For the general farm flock owner who allows his birds to range during the spring months, limiting the time which the birds are allowed to range, will control yolk color somewhat.

Even limited amounts of range, however, will cause a lack of uniformity due to individual tastes. Feeding a ration practically devoid of xanthophyll while the birds are allowed green range will prevent the yolk color from becoming too dark. A mash containing 24 per cent yellow corn and 8 per cent alfalfa leaf meal will give a uniform yolk color when the scratch ration consists of grains low in xanthophyll.

It should be kept in mind that when white corn is substituted for yellow corn in the ration, some other method of supplying vitamin A should be employed. Sherwood and Fraps (1932) have shown that a ration containing 8 per cent of ordinary alfalfa hay does not supply sufficient vitamin A for a heavy producing flock. The best recommendation is to supply the type of egg yolk which your market demands. That, in all cases, is a uniform color.

SUMMARY

1. The law of diminishing utility seems to apply to the utilization of the xanthophyll of yellow corn. The increase of color at a 70 per cent level was 2.36 units less than would be expected when calculated from results obtained at the 35 per cent level.

2. Alfalfa leaves and hay grading number 1 (bright green) gave no more color to the yolk than did either grades number 2 or number 3. There is very little difference in the amount of color a hen can utilize from alfalfa hay and leaves of the same grade.

3. Yellow milo, wheat, kafir, oats, and meat and bone scraps all contained small amounts of xanthophyll when tested biologically.

4. The color of the yolk may deepen as much as 24 per cent in one day. The greatest advance occurs during the first six days of feeding after which the advance is at a much slower rate.

5. A well balanced mash containing not over 8 per cent alfalfa and 24 per cent yellow corn gives a uniformly light golden yolk when the birds are confined and equal parts of white corn and wheat were used as the scratch grain.

6. Feeding alfalfa hay either in the litter or in a wall hopper increases yolk color as much as 4.54 units and

gives a wide variation in the eggs from the same flock.

7. One-half ounce of green rye fed daily gave 2 units more color to the yolks than did an equivalent amount of either green wheat or green alfalfa.

8. Limited time (4:00 p.m. until dark) on green wheat range increased yolk color 2.3 units while the same flock allowed wheat range ad libitum increased the yolk color 4.52 units.

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Table 11. Feeding and Management of Farm Flocks used in the Study

Flock number	Number of birds	Type of farm	Breed	Ration	Management
25	368	R.O.P. and Certified breeding	Rhode Island Reds	**K.S.C. Commercial Mash** Corn meal 100 lbs. Ground oats or barley 100 lbs. Wheat bran 100 lbs. Wheat shorts 100 lbs. Meat and bone scraps 100 lbs. Alfalfa leaf meal 100 lbs. Salt 35 lbs. 1% potent cod liver oil from November to April **Scratch Grain** 1/3 wheat; 2/3 yellow corn	All birds confined
26	163	Certified breeding flock	White Rocks	**K.S.C. Commercial Mash** **Scratch Grain** Wheat at morning; yellow corn at evening. Alfalfa hay fed twice daily.	Birds confined until April 15. Wet mash with sour milk at noon.
27	600	Farm flock	White Leghorns	**K.S.C. Commercial Mash** **Scratch Grain** Yellow corn at evenings. Alfalfa hay litter daily.	All birds confined. Wet mash with sour milk at noon.
28	350	Commercial flock	Buff Orpingtons	**Mash** An 18% protein commercial Egg Mash. **Scratch Grain** Yellow corn at evenings.	All birds confined. Limited amount of cut green feed given in yard in April. Hot mash at noon.
29	240	Commercial flock	White Leghorns	**Mash** Yellow corn meal 25.0 lbs. Wheat shorts 25.0 lbs. Meat and bone scraps 20.0 lbs. Wheat bran 12.5 lbs. Alfalfa leaf meal 7.5 lbs. Charcoal 6.0 lbs. Milk 5.0 lbs. Salt 1.0 lb. **Scratch Grain** Wheat at evenings.	All birds confined
30	400	Commercial flock	White Leghorns	**K.S.C. Commercial Mash** Wheat and yellow corn hopper-fed.	All birds confined. 200 under morning lights.
31	125	Farm flock	65 White Leghorns 60 Rhode Island Reds	**K.S.C. Commercial Mash** Equal parts of wheat and yellow corn at evenings. White corn changed for yellow corn February 1, 1933.	All birds confined until April 1. Scratch fed evenings.
32	75	Farm flock	37 White Leghorns 38 Rhode Island Reds	**No Mash fed** 4 lbs. meat and bone scraps hopper-fed once weekly. **Scratch Grain** Equal parts of wheat and yellow corn.	All birds confined until April 1.