VARIATIONS IN THE BODY PLUMAGE OF EARLY FEATHERING CHICKS TO TWELVE WEEKS OF AGE

by

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INTRODUCTION

A bird with a minimum number of pinfeathers is valuable to the broiler grower and to the poultry processor. It enables him to present the consumer with an attractive product at a minimum cost. Broilers with many pinfeathers are costly to the producer and processor, because many of the pinfeathers will not be removed during the mechanical dressing process. The remaining pinfeathers have to be removed by hand, an operation which is costly in time and money. The innovation of high energy broiler rations, improved breeding methods, and better management practices have enabled farmers to produce market-size broilers at early ages. This has meant that feathers have less time to mature and the result is often a large number of pinfeathers.

Poultry breeders have felt that the pinfeather problem could be improved through the introduction of the sex-linked gene for early feathering (k) into their breeding flocks. This is easily accomplished because the sex-linked gene (k) is recessive to its allelomorph for late feathering (K). This means that all early feathering chicks selected will breed true, and cannot be heterozygous for type of feathering. Inherited factors other than the sex-linked gene also affect the rate of feathering. Strains varying in feather development have been established within late feathering chicks, however, this accomplishment has been reported within early feathering chicks only for the autosomal conditions "tardy" and "retarded"

which are described on pages six and seven. Some other variation has been observed within early feathering chicks. This variation may have been caused by autosomal modifying genes.

The present experiment was designed to provide more critical information on the nature of the variation in the body plumage of birds possessing the sex-linked gene for early feathering. Other major information sought concerned the relation of pinfeathers present at market-age to the replacement of the down and juvenile plumage.

REVIEW OF LITERATURE

Terminology

Several terms have been used to describe the effect of the sex-linked gene affecting feathering. Late feathering has been referred to as slow or poor feathering, whereas its recessive allelomorph, early feathering, has been referred to as fast, well, or rapid feathering. Various symbols were assigned to this condition. Serebrovsky (1922) called the gene causing late feathering "auke" and its recessive allelomorph "asuke". He assigned no symbols to these terms. Warren (1925) used the terms rapid and slow to denote the conditions. He assigned to the former the symbol (r) and to the latter the symbol (R). In later studies Warren referred to the factors as early and late feathering instead of rapid and slow. Hertwig and Rittershaus (1929) assigned to this sex-linked condition the symbol (K) for kurzer Flugel (short wing). This symbol has

been accepted by most authors as the symbol for the sex-linked feathering condition.

It is the author's belief that "early" and "late" are the more desirable terms to use when discussing the sex-linked gene for feathering because they denote a difference in the time that the feather emerges from the feather follicle. The other terms appear to show the speed at which the feather grows after its appearance from within the feather follicle, which may not necessarily differ in the two types. Throughout this thesis the terms early and late, with their respective symbols (k) and (K), will be used to denote the feathering due to the effect of the sex-linked gene.

Sex-linked Feathering

Serebrovsky (1922) reported evidence from matings of Barred Plymouth Rocks to Russian Orloffs of a sex-linked factor which retarded the feather development in the progeny, so that they had very small tails at one and one-half months of age. Warren (1925) found that Jersey Black Giant males mated to White Leghorn females produced F_1 progeny that were late feathering, while the reciprocal cross produced F_1 offspring in which the males were late feathering and the females early feathering. These findings were in accordance with Serebrovsky's namely, that the rate of feather development was due to a sex-linked factor. They also showed that early feathering, which is common to Mediterranean breeds, is a recessive allelomorph to late feathering.

The sex-linked gene influences the rate of feathering from hatching throughout the growing period, but has no influence on the feathering of mature birds. Based upon the descriptions given by Warren (1925, 1944), early and late feathering chicks can be classified into two definite groups at hatching time and at ten to twelve days by the appearance of their wing and tail feathers. At one day, early feathering chicks exhibit wing coverts that are thinner and are two-thirds to three-fourths the length of their respective primaries. In late feathering chicks the wing coverts and their primaries are the same size, or the coverts may be longer than the main wing feathers. Early feathering chicks will have a larger number of secondary wing feathers present than late feathering chicks at this age. Mueller, et al. (1952) reported that early and late feathering chicks may be separated into two groups up to twelve weeks of age. At twelve weeks of age late feathering birds had only immature juvenile main tail feathers while in early feathering birds a majority of the juvenile main tail feathers had been replaced prior to this time.

Snelling (1955) found no distinct differences between embryos possessing the sex-linked gene for early feathering and those with the allelomorph for late feathering until the nineteenth day of incubation. On the nineteenth day primaries number 1 and 2 (numbering distally from the axial feather) and their respective coverts were emerging from the feather follicle in early feathering embryos. The late feathering embryos

showed no emergence of these primaries and only slight growth of their coverts.

Danforth (1929) reported on experiments conducted in the transplanting of skin from one bird to another. Tissue was removed from the backs of early and late feathering chicks and was grafted in each case onto a bird of the opposite feathering type. He found that the rate of feathering in the transplanted tissue was dependent upon the genetic make-up of the donor and that the genotype of the host had no visible affect on the feather development. It may be concluded, therefore, that the action of the sex-linked gene is restricted to the feather follicle.

It has been previously stated that during their growing period early and late feathering chicks may be divided into two definite groups according to the differences that exist in the development of their plumage. Within each group there are variations which are apparently due to sexual dimorphism, action of hormones, and autosomal modifiers. Definite grouping of birds with these variations has not been possible so that in most studies within groups classifications have been based on arbitrary feather scores. The amount of feathering over the back at various ages is one of the more popular ways of classifying the feathering of birds within these two groups.

Sexual Dimorphism

Several investigators have reported sexual dimorphism as

a factor in the rate of feather development. Martin (1929) reported that in late feathering chicks the females feathered out sooner than the males. Sexual dimorphism in late feathering chicks has also been reported by Jaap and Morris (1937), Radi and Warren (1938), Darrow and Warren (1944) and Glazener and Jull (1946).

Hays and Sanborn (1942) observed that early feathering females feathered more rapidly than early feathering males. Their findings were confirmed by Darrow and Warren (1944), Glazener and Jull (1946) and Hays (1952).

Modifiers of Early Feathering

The sex-linked gene for feathering is not the only genetic factor which affects the rate of feather development. Warren (1933) reported a simple autosomal recessive factor, "retarded", which modified the expression of ordinary early feathering in Single Comb White Leghorns. The gene for retarded feathering restricts the normal development of all but the first three secondary wing feathers in day-old chicks, and prevents development of the tail as well as the other secondaries up to ten days of age. The effects of the retarded gene are not visible in the plumage of adult birds.

McClary and Bearse (1941) reported an autosomal recessive gene in early feathering stock that caused individuals in a strain of Single Comb White Leghorns to feather slowly. Their description of the appearance of these individuals is very similar to that for chicks possessing the retarded factor.

Darrow and Warren (1944) described an autosomal recessive modifier, "modified early", which suppressed the normal expression of the sex-linked gene for early feathering. They suggested that this condition may be the same as retarded. When a retarded sire was mated to a modified early dam some of the progeny resembled the parents, but the others were normal. The fact that some of the progeny were normal indicated that additional modifiers were present.

Jones and Hutt (1946) observed an autosomal recessive mutation, "tardy" ($\underline{t}$), which affected the rate of feathering in Single Comb White Leghorn chicks. These chicks showed little or no development of secondary wing feathers at 10 days of age, while development of a tail did not start until about eight weeks of age. Through further tests they found that tardy was a recessive allele to the retarded factor reported by Warren (1933). Jones and Hutt (1946) designated the symbol ($\underline{t}^{e}$) for retarded. Tardy, like retarded, is not phenotypically visible in mature birds. Both are recessive to the allele for the normal condition, ($\underline{T}$). "$\underline{T}$" is the only member in this series of multiple alleles that permits the early feathering gene to express itself.

Simultaneously with the report of Jones and Hutt (1946), McGibbon and Halpin (1946) reported evidence of the allelic nature of three factors which they termed "normal", "retarded" and "slow". The use of the latter term is unfortunate, since many workers have used that term to designate the allelomorph

of early feathering. They may be the same series of alleles described by Jones and Hutt.

Other Factors Affecting Feathering

Hadi and Warren (1938) established two strains of late feathering chicks which differed genetically in degree of feathering. This was probably due to modifying genes acting separately from the sex-linked gene for late feathering. Hays and Sanborn (1942) suggested a dominant autosomal factor (K) for feathering that had a cumulative affect with the recessive sex-linked gene to produce complete back feathering in birds at eight weeks. This cumulative affect tended to reduce the sexual dimorphism in the rate of feathering. This may be the same genetic factor that Hadi and Warren had present in their late feathering strains.

Darrow (1941) observed variations in the feathering of birds possessing the sex-linked gene for early feathering. These variations were present at one day, ten days, and six weeks. He attributed these variations to the action of modifying genes. Hurry and Nordskog (1953) reported that only a small part of the total variation in the feathering of early and late feathering groups of chicks was due to the presence of the sex-linked gene for feathering. The variation in the early feathering group was as great as the variation in the late feathering group. The variation appeared to be large

enough to imply that the rate of feather development may be improved in birds that are homozygous for either (E) or (k).

Relation of Feathering to Growth Rate

Numerous investigators have reported on growth rate in relation to feather development. Martin (1929) observed that the rate of feathering over the back of Barred Plymouth Rocks was related to the rate of body growth in both males and females, with the heavier birds being the better feathered. A correlation coefficient of +.812 was found between body weight and feather development in late feathering Barred Plymouth Rocks by Gericke and Platt (1932). The validity of their results may be questioned, however, since these birds were raised on various rations with different protein levels, which affected feathering rate.

Marble (1954) obtained a significant positive correlation between body growth and rate of feathering at four, eight, twelve, sixteen and twenty weeks of age in both sexes of Single Comb White Leghorns, which are early feathering. The results were of greater significance during the early weeks than during the later ones. Jaap and Morris (1937) reported a low but significant correlation of +.62 between weight and feathering within late feathering chicks at eight weeks of age. However, the correlation coefficient between body weight and feather development in late feathering stock obtained by Radi and Warren (1938) was too low for any practical importance.

Warren and Payne (1945) found that early feathering New Hampshires tended to be heavier than late feathering ones at twelve weeks of age. This appears to be the first work where any comparison was made between early and late feathering individuals. The previous work cited was concerned with the variations present within either early or late feathering groups of birds. Glazner and Jull (1946) found in Barred Plymouth Rocks and New Hampshires, that chicks having six or more secondaries at hatching were heavier at ten weeks of age than were chicks with fewer than six secondaries.

Hays (1951) reported on the relationship between the degree of feathering up to eight weeks of age and the chick weight at eight and twelve weeks in 3200 early feathering Rhode Island Reds. He found that the sex-linked gene for feathering had no affect on body weight. However, he suggested an autosomal gene was present that affected the degree of back feathering and body weight at eight and twelve weeks. Godfrey and Farnsworth (1952) reported that the sex-linked gene (k) had no influence on body weight at ten weeks. It was their belief that the action of this gene is in the feather follicle and that it is not related to body growth.

Plumart (1952) found no significant difference in body weight between early and late feathering birds at eight weeks of age. At 12 weeks he obtained a barely significant difference of 0.17 pound in females favoring at this point the early feathering ones, but in males no significant difference was found.

Hurry and Nordskog (1953) observed that the sex-linked gene for early feathering did not increase body weight significantly in birds eight weeks of age. However, when all factors were included a fairly high phenotypic correlation between feathering at eight weeks and body weight at eight weeks was obtained.

EXPERIMENTAL PROCEDURE

Source of Chicks and Their Management

The stock used in this study consisted of 100 early feathering White Plymouth Rocks obtained from a commercial hatchery. All chicks were classified at one and ten days of age to make certain that they were early feathering. Three chicks were removed because they were late feathering. Four chicks died during the rearing period, leaving 93 birds at the conclusion of the experiment.

The chicks were wingbanded and dyed green on the day of arrival from the hatchery. The following day they were vaccinated intraocularly with Newcastle live virus vaccine.

After being reared in batteries for four weeks the chicks were transferred to a brooder house where they were grown under an electric brooder for the remainder of the experiment. A high-energy broiler ration containing a coccidiostat was fed during the entire rearing period.

Body weights were recorded to the nearest five grams at 10 and 12 weeks.

Dyeing of the Plumage

The pinfeathers present on dressed broilers are due to the replacement of down or juvenile plumage. The juvenile feathers replace down feathers and the adult plumage in turn replaces the juvenile feathers. For ease in distinguishing the down feathers from the other plumage, the day-old chicks were immersed in a commercial dye solution which dyed their plumage green. Some juvenile feathers were present on the wings of the chicks. Since none of these juvenile feathers were mature, however, only their unfurled terminal tips were dyed green.

At five weeks of age 24 juvenile feathers were dyed pink on each chick. A different color of dye was used for ease in distinguishing these dyed feathers from the down feathers and other plumage. Some chicks had many mature juvenile feathers growing in the pterylae where the dyeing was done, whereas others did not have any mature juvenile feathers in those tracts. Where possible, only mature feathers were dyed, but in those birds with an insufficient number of fully mature juvenile feathers, the most nearly mature feathers were dyed pink. The feathers that were dyed pink were selected in each of three pterylae, the back, right breast, and right femoral tracts. Three pterylae were used so the sampling would cover a relatively large area. Eight feathers were dyed in each tract.

Variation in the body plumage of the birds was observed at the time the feathers were dyed pink. It may be seen in Plate I that one bird had numerous feathers growing on the lateral

side of its body while the other bird had only a few feathers growing in this area.

The number of pink feathers molted was used as an indication of the number of pinfeathers that were present due to the rate of replacement of juvenile feathers. This was possible because, as stated previously, adult plumage replaces juvenile plumage.

Classification of Live Chickens

The live birds were classified according to their feathering condition at 1 day, 10 days, 6 weeks, 8 weeks, 10 weeks, and 12 weeks of age. The classifications were as follows:

One-day Classification: Upon arrival from the hatchery measurements (in mm.) were recorded for the length of the number 2 secondary on the left wing. The number 2 secondary (numbering proximally from the axial feather) was used because it is the first secondary wing feather to be seen on chicks of this age. The reason for this type of classification was to determine if the variation in the length of secondary feathers at one day of age was indicative of the feathering condition, particularly the number of pinfeathers, at later ages.

Ten-day Classification: In an effort to find variation among the body feathering of early feathering chicks, the back and breast pterylae were scored for the appearance of juvenile feathers. The back feather tract was chosen because it is the last tract to receive its feathers and is the region where most

EXPLANATION OF PLATE I

Fig. 1 An early feathering male, five weeks of age, showing bare areas on the lateral side of its body caused by a lack of development of the juvenile plumage.

Fig. 2 An early feathering male, five weeks of age, showing pinfeathers and immature feathers of the juvenile plumage appearing on the lateral side of its body. Less unfeathered area is present than in bird 1.

PLATE I

Fig. 1

Fig. 2

pinfeathers are found on broilers. In contrast, the breast tract is one of the first to show feather development.

All chicks were scored for the degree of back feathering, with the two scores used:

1 - No juvenile feathers, only down.

2 - Juvenile feathers in sheath stage.

No other scores were necessary because none of the juvenile feathers present on the back pterylae were out of their sheath at the time the classification was made.

All chicks were scored also for degree of breast feathering. Four scores were used because the feather development was further advanced than the feather development on the back tract. The scores used were:

1 - No juvenile feathers, only down.

2 - Juvenile feathers in sheath stage.

3 - From one to six juvenile feathers out of the sheath.

4 - Seven or more juvenile feathers out of their sheath.

Six, Eight, Ten, and Twelve Week Classification: The total number of feathers dyed pink (24) minus the number of dyed feathers present at each age gave the number of dyed feathers molted after five weeks of age. The difference in number of dyed feathers molted at each age gave the number of dyed feathers molted for each period.

Each chick was scored for the amount of down and number of pinfeathers present at these various ages. The same basis for scoring was used for each period. There was a progressive

decrease in the amount of down present for each successive classification period, but the pinfeather scores remained quite constant throughout the growing period. These data were not used in the analysis because most of the birds fell into the same group when classified. It is believed that a better method of scoring the variation would have been to use two classification systems, one similar to that mentioned above where the same standard applied throughout the experiment and another with a different standard used each time the birds were classified.

Dressing of the Chickens

One of the main concerns of the poultry producer and processor are those pinfeathers that cannot be removed during the mechanical dressing process. The pinfeathers that are removed are of little concern to him. To provide conditions similar to those for the processor, 76 of the birds 12 weeks of age were taken to a commercial dressing plant where they were killed, slack-scalded (128°F.), and put through a mechanical picking machine. The birds were removed from the shackles at the end of the picking line before any hand pinning and singeing was done and then were returned to the laboratory for further classification.

To insure perpetuation of the stock only 76 of the 93 birds used in this study were killed and dressed.

Classification of Dressed Chickens

Pinfeather counts were made in the three pterylae in which

feathers had been dyed pink. Each dressed bird was also scored for the total amount of down that was present. This was an indication of the amount of down replaced by juvenile feathers. The scores used were:

1 - No down.

2 - Very slight scattering of down.

3 - Slight scattering of down.

4 - Moderate amount of down.

5 - Much down.

In an effort to measure the consistency of the classification 25 birds were reclassified for dressed down scores. Twenty-four birds were given the same score both times and one bird was classified one score lower the second time than in the original classification.

RESULTS

Day-old Feather Length

The length of the number 2 secondary ranged between 8 and 18 mm. for the males, with a mean length of 12.97±1.62. The mean length for females was 13.60±1.67 with extremes of 10 and 18 mm. The difference between sexes in mean day-old feather length was 0.63±1.19, a value that was not significant, indicating that sex had little effect on the length of the number 2 secondary wing feather at one day of age. Table 1 shows the distribution of birds with respect to the length of the number 2 secondary at one day of age.

Table 1. Distribution of birds with respect to day-old feather length.

Feather length (mm)	Males No.	Males %	Females No.	Females %	Total No.	Total %
10 or less	3	6.97	1	2.00	4	4.30
11	4	9.30	6	12.00	10	10.75
12	13	30.23	5	10.00	18	19.35
13	7	16.28	8	16.00	15	16.13
14	10	23.26	17	34.00	27	29.03
15	3	6.98	6	12.00	9	9.68
16 or more	3	6.98	7	14.00	10	10.75
Total	43	100.00	50	100.00	93	99.99

Ten-day Feathering Scores

Evidence that sexual dimorphism was present in early feathering chicks was shown by the back and breast feathering scores taken at 10 days of age. According to the data summarized in Table 2, 74.42 percent of the males had no juvenile feathers in their back pterylae (score of one), in contrast to only 44.0 percent of the females with such a score. The data in Table 2 also show that only 16.28 percent of the males had juvenile feathers that were out of their sheaths (scores of three and four) in their breast pterylae, whereas 48.0 percent of the females had such juvenile feathers.

Highly significant chi-square values of 9.23 and 9.54 ($p = 0.01$) were obtained with regard to sex for the distribution of ten-day scores on the back and breast tracts, respectively.

Considerable variation in feather development within each sex was observed at ten days. No juvenile feathers were found in the back pterylae of some males while the backs of others had several juvenile feathers present. This condition was also present in females. Females had a wider variation in feather development in their breast tract than did males. The data in Table 2 show that 52.0 percent of the females had no juvenile feathers in their breast tract that were out of the sheath stage, 28.0 percent had less than six juvenile feathers out of their sheaths and 20.0 percent had more than six juvenile feathers that had emerged from their sheaths. None of the males had more than six juvenile feathers out of the sheath stage.

Table 2. Distribution of birds for ten-day feathering scores.

Region	Score	Males		Females		Total	
		No.	%	No.	%	No.	%
Back	1	32	74.42	22	44.00	64	58.06
	2	11	25.58	28	56.00	39	41.94
	Total	43	100.00	50	100.00	93	100.00
Breast	1	-	0.00	-	0.00	-	0.00
	2	36	83.72	26	52.00	62	66.67
	3	7	16.28	14	28.00	21	22.58
	4	-	0.00	10	20.00	10	10.75
	Total	43	100.00	50	100.00	93	100.00

It may be observed in Plate II that one chick had only one juvenile feather present in its breast tract at 10 days of age while the other chick had several such feathers, with some already out of their sheaths. Examples of variation in feather development at 10 days on the shoulder tract and in tail size are shown in Plate III.

The breast pterylae in both sexes showed more feather development than did the back pterylae. According to the data shown in Table 2 juvenile feathers were present in the breast tract of every chick classified at 10 days of age. Juvenile plumage had appeared in the back tract of only 41.94 percent of the birds. While none of the juvenile feathers appearing in the back pterylae were out of their sheaths, 33.33 percent of the birds possessed in their breast tract juvenile feathers which had emerged from their sheaths.

Molt of Dyed Juvenile Feathers

The number of dyed feathers molted in each feather tract at 6, 8, 10, and 12 weeks was obtained. Table 3 contains these data expressed in terms of cumulative percentage of dyed feathers molted. Less than one percent of the dyed feathers had molted when the birds were six weeks of age (one week after the feathers were dyed). At eight weeks slightly more than 10 percent of the dyed feathers had molted, with the majority of them being molted from the back tract.

EXPLANATION OF PLATE XI

Fig. 1 The breast tract of an early feathering female at ten days of age with only 1 juvenile feather.

Fig. 2 The breast tract of an early feathering female at ten days of age showing several feathers of the juvenile plumage, with some that have emerged from their sheaths.

PLATE II

Fig. 1

Fig. 2

EXPLANATION OF PLATE III

Fig. 1 Dorsal view of an early feathering male at ten days of age showing little juvenile feather development on the shoulders, and a short tail. The dyed tips of feathers indicate the amount that had emerged from the sheath at one day of age.

Fig. 2 Dorsal view of an early feathering male at ten days of age showing many juvenile feathers on the shoulders, and a long tail.

PLATE III

Fig. 1

Fig. 2

At ten weeks of age over 45 percent of the dyed feathers had molted. Again the greatest amount of molting of dyed feathers (57.66 percent) occurred in the back pterylae. The breast tract was second with 48.39 percent, while only 22.04 percent of the dyed feathers had been molted in the femoral tract. Females molted an average of 1.24 dyed feathers more per bird than did the males. The difference between the two sexes was not significant ($t = 1.379$). It should also be noted that no significant values were obtained with regard to sex and number of feathers molted in the three individual pterylae where the juvenile feathers had been dyed pink.

The females had molted a significantly greater number of their dyed feathers than had the males when the birds were 12 weeks of age ($t = 2.136$). The highest proportion of dyed feathers for both sexes was molted from the back pterylae (84.14 percent), followed by those in the breast tract (76.86 percent) and those in the femoral tract (47.98 percent).

Down Scores on the Dressed Chickens

The data summarized in Table 4 show that 97.37 percent of the birds had down present (scores of 2, 3, 4, and 5) after the dressing process. All of the birds had down present before they were dressed, therefore, down must have been removed during the dressing process. No accurate measure was made of how much down was removed during dressing, however, it was estimated that about one third of the down was removed. There was

Table 3. Molt of the juvenile feathers dyed in 5-week old White Plymouth Rocks.

Age	Area	Percentage of dyed feathers molted		
		Males	Females	Total
Six weeks	Breast	0.00	0.25	0.13
	Thigh	0.29	0.50	0.40
	Back	2.36	2.00	2.16
	Total	0.87	0.92	0.90
Eight weeks	Breast	9.88	13.50	11.85
	Thigh	1.16	3.00	2.16
	Back	17.44	15.50	16.40
	Total	9.50	10.67	10.13
Ten weeks	Breast	45.35	51.00	48.39
	Thigh	19.48	24.25	22.04
	Back	54.74	60.00	57.66
	Total	39.92	46.00	43.19
Twelve weeks	Breast	72.67	80.00	76.88
	Thigh	41.86	53.25	47.98
	Back	80.81	87.00	84.14
	Total	65.70	73.58	69.94

no indication of sexual dimorphism with regard to down scores in dressed birds. The chi-square value obtained for the distribution of dressed birds with regard to down scores and sex was 2.58, which is not significant. Practically half of the chicks received high scores (4 or 5) for this factor, indicating that in some early feathering chicks a considerable portion of the down had not been replaced by juvenile plumage by 12 weeks of age. The greatest amount of down was present in the femoral and abdominal areas.

Table 4. Distribution of down scores for 76 dressed broilers.

Down score	Percentage of birds		
	Males	Females	Total
1	2.63	2.63	2.63
2	26.32	18.42	22.37
3	31.58	21.05	26.32
4	18.42	36.84	27.63
5	21.05	21.05	21.05
Total	100.00	99.99	100.00

Pinfeathers Present After Dressing

The mean number of pinfeathers present in the three feather tracts on the dressed birds was 36.8±18.66 for males and 41.3±19.56 for females. The difference of 4.8±4.38 was

not significant, indicating that in this study sex did not affect the number of pinfeathers on the dressed birds. Table 5 shows the distribution of birds with regard to number of pinfeathers. About 8 percent of the birds had fewer than 16 pinfeathers while about 12 percent had more than 60 pinfeathers. The mean number of pinfeathers present was 38.89±19.13. The coefficient of variation was 49.78 percent, indicating that there was considerable variation within the birds with regard to the number of pinfeathers present after the birds were dressed. With such large variation, differences between groups would need to be very great to attain statistical significance.

Table 5. Distribution of dressed birds for number of pinfeathers present in back, right breast, and right femoral tracts.

Pinfeathers No.	Males		Females		Total	
	No.	%	No.	%	No.	%
0 - 15	4	10.53	2	5.26	6	7.89
16 - 30	12	31.58	9	23.68	21	26.32
31 - 45	11	28.95	13	34.21	24	32.89
46 - 60	7	18.42	9	23.68	16	21.05
61 or more	4	10.53	5	13.16	9	11.84
Total	38	100.00	38	99.99	76	99.99

Table 6 shows that only 10.06 percent of the total number of pinfeathers counted in the three pterylae were in the breast tract. The femoral pterylae contributed 32.41 percent and

the back pterylae 57.51 percent of the total number of pinfeathers counted.

Table 6. Location of pinfeathers present on the dressed birds.

Feather Tract	Pinfeathers	
	Number	Percent
Breast	298	10.08
Femoral	958	32.41
Back	1700	57.51
Total	2956	100.00

Relationship of the Number of Pinfeathers Present After Dressing to the Classification of Live Birds At One and Ten Days of Age

The data presented in Table 7 show that a change in feather length did not result in a change in the number of pinfeathers. The correlation coefficient between the length of the number 2 secondary at one day of age and the number of pinfeathers present after dressing was +.090 for males and +.225 for females. When the two sexes were combined, the correlation coefficient was +.080. These values were not statistically significant.

Males and females were divided into separate groups when the relationship between number of pinfeathers and the feathering at ten days of age was determined, because sex was found to be a significant factor affecting the degree of feathering in chicks at ten days of age. Correlation coefficients between the

10 day back scores and the total number of pinfeathers were -.092 and -.236 for males and females, respectively. The correlation coefficient between 10 day breast scores and the number of pinfeathers was -.279 for males and +.094 for females. These values indicate that no significant relationship existed between the feathering scores on the back and breast pterylae at 10 days and the number of pinfeathers on the birds after they were dressed.

The mean number of pinfeathers present in the back pterylae of males dressed at 12 weeks of age with 10 day back scores of one and two was 19.8 and 18.1 respectively. Females with a 10 day back score of one averaged 25.0 pinfeathers in their back tract after dressing while those with a score of two averaged 25.7 pinfeathers. The chi-square values for the distribution of birds with respect to 10 day back scores and number of pinfeathers in the back tract after dressing were 0.44 for males and 0.01 for females. Neither value was significant.

The mean number of pinfeathers present in the breast tract of males at 12 weeks of age with respect to 10-day breast scores was 4.53 and 2.50 for scores of two and three. For females the mean number of pinfeathers was 3.76, 3.33, and 3.63 for breast scores of two, three, and four, respectively. The chi-square values for the distribution of birds with respect to 10-day breast scores and number of pinfeathers in the breast tract were 0.43 and 0.03 for males and females respectively. These values were also not significant.

Table 7. Comparison of day-old feather length (No. 2 secondary) with the number of pinfeathers left on the dressed birds.

Feather Length (mm)	No.		Average Number of Pinfeathers							
			Breast		Thigh		Back		Total	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
10 or less	2	1	2.5	9.0	7.5	6.0	17.5	19.0	22.5	35.0
11	3	5	4.0	3.0	15.3	10.6	21.3	23.8	40.7	37.4
12	12	2	4.4	6.0	13.5	17.5	19.3	7.5	37.2	31.0
13	6	7	3.7	2.3	9.5	7.7	21.0	24.2	34.2	31.1
14	9	14	4.1	4.1	11.0	12.1	17.8	26.9	32.9	43.1
15	3	5	7.0	3.6	17.3	19.2	19.7	33.4	44.0	56.2
16 or more	3	4	3.3	2.5	20.3	11.3	20.0	30.3	43.7	44.0

Relationship of the Number of Pinfeathers After Dressing to the Molting of Juvenile Feathers

The number of pinfeathers present on the birds dressed at 12 weeks of age was compared to the number of juvenile feathers molted by 8, 10, and 12 weeks. Correlation coefficients of +.125 and +.105 were obtained between the number of pinfeathers on the dressed birds and the number of pink feathers molted at eight and ten weeks, respectively. Neither value was significant.

Correlation coefficients of +.149 for males and +.144 for females were obtained for the relationship between pinfeathers present after dressing and the number of juvenile feathers molted to 12 weeks of age. Neither value was significant. When the two sexes were combined a correlation coefficient of +.114 was obtained between the two factors. This value was not significant, therefore, the number of pink feathers molted by 12 weeks of age was not associated with the number of pinfeathers after dressing.

Table 8 shows the relation of dyed feathers molted by 12 weeks to the number of pinfeathers present on birds dressed at that age.

Relationship of the Number of Pinfeathers Present After Dressing to the Down Scores of the Dressed Birds

Since sex had no significant effect on the number of pinfeathers nor the down scores on the dressed birds, both sexes were grouped together for analyzing the relationship between the two factors. A highly significant correlation coefficient

Table 8. Comparison of dyed feathers molted by 12 weeks to number of pinfeathers on dressed birds.

Feathers Molted by 12 Weeks, Number	No. Birds		Average Number of Pinfeathers							
			Breast		Thigh		Back		Total	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
0 - 4	-	-	-	-	-	-	-	-	-	-
5 - 8	4	-	3.00	-	7.25	-	14.00	-	24.25	-
9 - 12	3	-	5.33	-	12.00	-	21.33	-	38.66	-
13 - 16	12	9	3.58	4.44	10.84	13.22	20.00	20.44	34.42	38.10
17 - 20	12	20	6.42	3.58	15.92	11.74	23.50	29.37	45.83	44.69
21 - 24	7	9	1.71	2.89	15.14	11.44	13.92	30.11	30.14	44.44

of +.851 was obtained. A low down score was associated with few pinfeathers and a high down score was associated with a large number of pinfeathers. This relationship may be observed in Plate IV. From the data summarized in Table 9 and Fig. 1 it may be observed that for each increase in down score there was an increase in the number of pinfeathers present. The pinfeather increase was smaller between birds with down scores of four and five than between those with lower down scores.

Table 9. Comparison of down scores with number of pinfeathers for dressed birds.

Down Score, Dressed Birds	No. Birds	Average Number of Pinfeathers			
		Breast	Thigh	Back	Total
1	2	1.50	4.00	8.00	13.50
2	17	2.94	7.35	14.88	25.17
3	20	3.40	10.90	19.80	34.00
4	21	3.61	15.86	27.38	47.85
5	16	5.00	16.75	28.75	50.50

Relationship of the Molting of Juvenile Feathers to the Down Scores of the Dressed Birds

The distribution of dyed feathers molted at 10 or at 12 weeks with regard to the down scores of the dressed birds were not significant for the males, with chi-square values of 0.55 and 1.58 for 10 and 12 weeks, respectively. Significant chi-square values of 4.60 and 3.89 were obtained between these

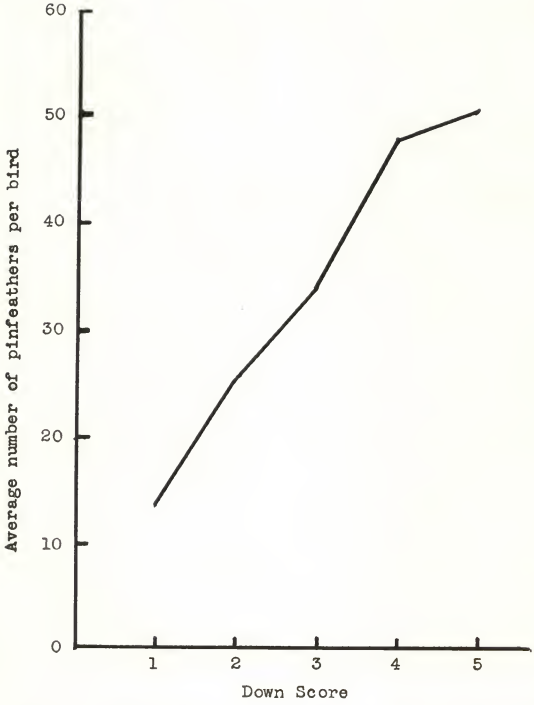

Fig. 1. Relationship between the number of pinfeathers present after dressing and the down scores of the dressed birds. Data obtained from 76 birds dressed at 12 weeks of age.

factors in females at the two ages. When the two sexes were grouped together chi-square values of 2.63 and 3.36 were obtained between the two factors at 10 and 12 weeks, respectively. The values were not significant.

Comparison of Live Body Weight and Number of Pinfeathers Present After Dressing

From the results summarized in Table 10 it may be assumed that the number of pinfeathers on the dressed birds was independent of body weights at 10 or at 12 weeks. The variation in body weight was slight between the birds differing with respect to number of pinfeathers.

Table 10. Comparison of body weight at 10 and 12 weeks with the number of pinfeathers present after dressing.

Pinfeathers, Number	Male	Female	Av. 10 Week Wt. Male	Av. 10 Week Wt. Female	Av. 12 Week Wt. Male	Av. 12 Week Wt. Female
0 - 15	4	2	1195.00	1040.00	1508.75	1290.00
16 - 30	12	9	1232.50	953.33	1609.58	1198.89
31 - 45	11	13	1146.36	1006.38	1486.82	1217.31
46 - 60	7	9	1155.71	907.78	1521.42	1188.33
over 60	4	5	1152.50	826.00	1498.75	1115.00

DISCUSSION

The results of this study indicate that variation exists in the feather development of birds possessing the sex-linked

EXPLANATION OF PLATE IV

Lateral views of early feathering males, dressed at 12 weeks of age, prior to any hand pinning or singeing. The two birds represent the extremes for the birds included in the present study.

Fig. 1 Many pinfeathers and much down present.

Fig. 2 Very few pinfeathers and a very slight scattering of down present.

PLATE IV

Fig. 1

Fig. 2

gene for early feathering. These findings are in accord with those of Darrow (1941) and Hurry and Nordskog (1953). Variations in this study were observed at 1 day, 10 days, 5 weeks, 6 weeks, 8 weeks, 10 weeks, 12 weeks, and after dressing at 12 weeks.

The variation at one day was not as great as the variation that existed at later ages. At ten days of age the chicks could be placed in definite groups according to their body plumage. Juvenile feathers had appeared in the back pterylae of some chicks while other chicks had only down feathers present in their back pterylae. Juvenile feathers were present in the breast tracts of all chicks used in this study by ten days. These birds could be accurately classified into definite groups according to the development of the juvenile feathers present.

The observation was made at five weeks that some birds had mature feathers of the juvenile plumage while others did not. Variation was present among birds with regard to the molting of their juvenile feathers at various ages. The largest variation was found in the number of pinfeathers on the dressed birds. Perhaps the variation in the other factors had a cumulative affect which caused this large variation.

The variation within the early feathering birds used in this study appeared to be great enough to suggest that further improvement in feather development could be made in birds that already possess the sex-linked gene for early feathering. In this study it was not possible to determine the type of genetic factors causing this variation, as the stock was not pedigreed.

The breast pterylae is among the first feather tracts in which juvenile plumage appears, while the back pterylae is one of the last feather tracts in which juvenile feathers appear. In this study there were almost six times as many pinfeathers counted in the back tract as in the breast tract. The assumption can be made that, at broiler age, there will be fewer pinfeathers present in those areas where juvenile feathers appear early than in those areas where the juvenile feathers appear late.

No relationship was found between the number of pinfeathers on the dressed birds and body size of the chicks at ten or at 12 weeks of age.

Differences due to sex were observed at ten days and 12 weeks. The females had considerably more juvenile feather development in the breast and back pterylae than did males at ten days of age. At 12 weeks a significant difference existed between sexes for rate of molt of juvenile feathers with the females molting a larger number of their dyed feathers than the males. Evidence of sexual dimorphism in early feathering chicks, with females feathering more rapidly than males, had been previously reported by Radi and Warren (1938), Hays and Sanborn (1944), Glazener and Jull (1946) and Hays (1952).

Since sexual dimorphism was found in live birds at 12 weeks, it appears logical to expect it to be present in the birds after dressing. However, no significant differences between sexes were obtained for dressed down scores or pinfeathers present on the dressed carcass. The sexual dimorphism present

in the juvenile plumage of live birds had little or no effect on the appearance of the birds dressed at 12 weeks of age.

To the author's knowledge, no work has been reported on the source of the pinfeathers on market-age broilers. The pinfeathers that are present are the result of either juvenile plumage replacing down feathers or postjuvenile plumage replacing juvenile plumage. No significant relationship was obtained between the number of pinfeathers present on dressed birds and the number of juvenile feathers molted to 12 weeks, nor between the number of juvenile feathers molted at eight or at 10 weeks of age.

A highly significant relationship between the down scores on the dressed birds and the number of pinfeathers present was obtained. Those birds having the greatest amount of down also had the greatest number of pinfeathers, while those with little down had few pinfeathers.

Since a highly significant relationship existed between the down scores of the dressed birds and the number of pinfeathers present and no significant relationship existed between the juvenile feathers molted to 12 weeks and the number of pinfeathers present it may be assumed that the variation in pinfeathers present on the birds dressed at 12 weeks of age was primarily due to juvenile feathers replacing down feathers rather than postjuvenile feathers replacing juvenile feathers.

SUMMARY AND CONCLUSION

A study was conducted to provide more critical informa-

tion on the body plumage of birds possessing the sex-linked gene for early feathering and the source of pinfeathers present on market-age broilers. The results were:

1. Variation was observed in birds possessing the sex-linked gene for early feathering at 1 day, 10 days, 5 weeks, 6 weeks, 8 weeks, 10 weeks, 12 weeks, and after dressing at 12 weeks of age, with the coefficient of variation being largest for pinfeathers present after the birds were dressed.

2. No relationship existed between body weight at 10 and 12 weeks and the number of pinfeathers after dressing.

3. Sexual dimorphism was observed during the growing period with the females feathering more rapidly than the males, but it was not evident after the birds were dressed at 12 weeks of age.

4. Some down feathers were apparently removed during the mechanical dressing process.

5. The pinfeathers present on the carcass of broilers dressed at 12 weeks of age were of the juvenile and adult plumage, with the juvenile pinfeathers apparently composing the majority of those present.

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VARIATIONS IN THE BODY PLUMAGE OF EARLY FEATHERING CHICKS TO TWELVE WEEKS OF AGE

by

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AN ABSTRACT OF A THESIS

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The purposes of this study were to (1) provide more critical information on the nature of the variation in the body plumage of early-feathering birds and (2) determine whether pinfeathers present in 12 week old chickens are juvenile or postjuvenile feathers.

The 100 birds used in this study were early feathering White Plymouth Rocks obtained from a commercial hatchery. At one day of age the chicks were immersed in a commercial chick dye solution which dyed their down green. At five weeks of age pink dye was used to mark juvenile feathers in each of three feather tracts on each chick. Dyeing of the down and juvenile feathers was done to facilitate identification of such feathers until they were replaced by subsequent plumage.

Each chick was classified according to its feathering condition at 1 day, 10 days, 6 weeks, 10 weeks, and 12 weeks of age. At 12 weeks of age the birds were taken to a commercial dressing plant where they were killed, slack-scalded (temperature 128°F.), and put through a mechanical picking machine. Pinfeather counts and scoring of the down present were made on the dressed birds before any handpinning or singeing was done.

Sexual dimorphism was observed at 10 days and 12 weeks of age, with the females feathering more rapidly than the males. No sex difference was observed in the number of down feathers or pinfeathers in the dressed birds.

The pinfeathers present on broilers dressed at 12 weeks of age were of both the juvenile and the postjuvenile plumage. The significant coefficient of correlation (+.551) between the score for down feathers and the number of pinfeathers in dressed birds indicates that the number of pinfeathers present at 12 weeks was dependent upon the amount of down being replaced. On the other hand, no relationship was observed between the number of pinfeathers in the dressed birds and either the number or the time of molt of juvenile feathers.

No relationship existed between the live body weight and the number of pinfeathers on the dressed birds.