Feathering in Broiler Breeder Females

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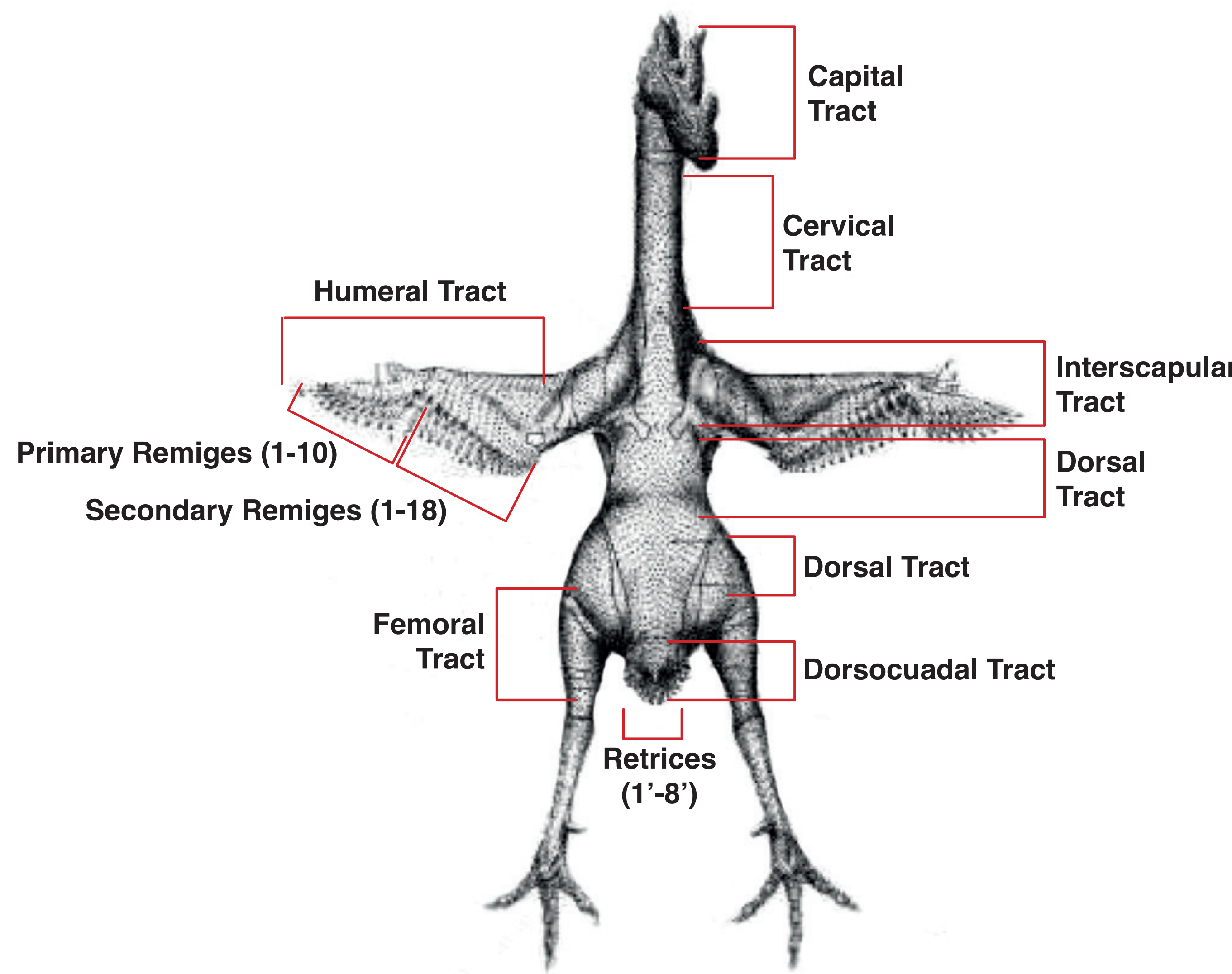
SUMMARY

Maintaining feather cover in broiler breeder hens is important for economic production and animal welfare. Feather cover, in particular at the dorsal region, is important for the hens' willingness to mate. Reduced coverage may lead to a loss in fertility and chick production, usually in the latter half of the production cycle. Feathers are an important body component with functions as varied as physical protection, insulation and thermal control, sexual display and flight. In spite of this, feathering studies have been limited in poultry research and there are many aspects of feathering in broiler breeders which are not well understood. This booklet presents our current knowledge about feathering in broiler breeder hens from a scientific point of view. For information that is applicable in practice, please refer to *A Practical Guide to Managing Feather Cover in Broiler Breeder Females (Dec. 2014)*.

Figure 1. Feather tracts of the back (dorsal) view.



INTRODUCTION

Appendages to the skin are widespread in vertebrate animals but the avian feather has been described as the most complex that has evolved. Feathers are a major organ of the body with functions which include physical protection, insulation and thermal control, sexual display and flight. Yet in our domestic birds feathers are significantly neglected in research and only really attract attention when the feathering is thinner or absent or if feathers are damaged.

As in all classes of poultry the growth and maintenance of feather cover is important in broiler breeders. Of particular importance is the effect that loss of feather cover on the back of females has on mating activity. Impacts to the skin which can arise from mating make hens reluctant to mate with a resulting decline in fertility and breeding performance. Diagnosis of the possible causes of this reduced feather cover in breeder hens is complicated. Feathering loss increases heat loss and represents an increase in metabolic energy requirement of the bird. If this is corrected by increasing feed allocations in cooler temperatures, it may lead to economic consequences, and if not corrected, it may also represent an economic consequence due to reduced egg output. Many factors may be involved and defects in feathering which arise in the later stages of the laying cycle may reflect events which took place at a much earlier stage, but which were undetected at the time.

BIOLOGY OF FEATHER GROWTH

FEATHERING STRUCTURES

Approximately 6000-9000 feathers are arranged in 20-30 definite areas of growth known as feather tracts or pterylae. These cover about 75% of the body surface. The feather free areas of the skin, or apteria, occur most notably under the wings, on the keel and the central portion of the breast. The specialist covert feathers of the wings and tail complete the plumage. **Figure 1** shows the main tracts of the back or dorsal region. The main dorsal (dorsopelvic) tract and the two thigh (femoral) tracts are those most likely to be instrumental in forming a barrier between the hen and male toes and spurs during mating.

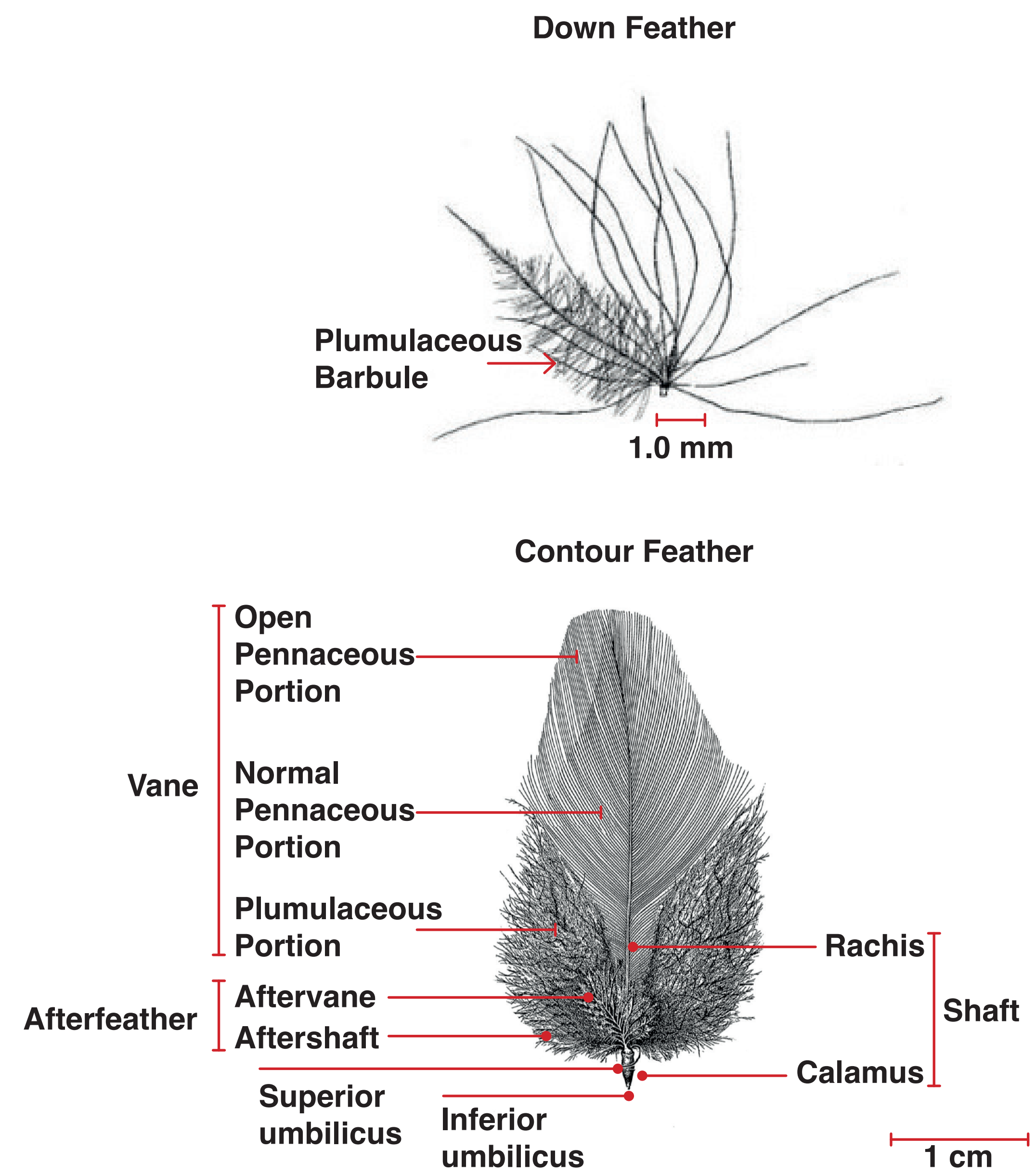
The diverse types of feather are conveniently seen in five categories;

- The large stiff feathers of the wings (remiges) and the tail (retrices)
- Contour feathers
- Down feathers or plumules
- Hair like filoplumes
- Tiny bristles on the face (a category called semiplumes may be included between contour and down feathers)

The remiges and retrices are large, stiff feathers characterized by asymmetric vanes which are almost entirely pennaceous (see **Figure 2**). The contour feathers form the predominant outer protective coating over the whole body. The major parts of a typical contour feather are shown in **Figure 2**. Down feathers are either those present at hatching (natal down) or those found on the apteria in gallinaceous poultry (definitive downs). The downs are wholly plumulaceous (**Figure 2**) and in adult birds appear to be distributed to meet the need for insulation. Filoplumes are hair like feathers which begin to emerge above the skin a few days after hatching. They are part of the system that provides sensory input for controlling the posture of larger feathers.

The main structures of a contour feather (**Figure 2**) consist of a shaft, or rachis, with two series of parallel barbs forming the vane. The vanes close to the skin (proximal) have a soft, fluffy texture (downy or plumulaceous) while the outer (distal) vanes are firm and compact (pennaceous). Barbules are attached to each barb with adjacent barbules interlocking to strengthen or stiffen the pennaceous vanes. Other feather types have similar structures but are very variable in detail.

Figure 2. Components of a feather at day-old (top) and of a typical contour feather (bottom). In the top figure only one barb is shown with barbules. (Lucas and Stettenheim, 1972)



THE FEATHER FOLLICLE

The development of feather follicles can first be seen in the 5-day embryo and fully differentiated follicles are present by day 16. At the time of hatching all follicles are present. The feather follicle (**Figure 3**) is a cylindrical invagination or pit in the skin epidermis with an extremely thin lining. This is surrounded by a layer of germinative epidermis which merges into the skin. Feather muscles attach to the outer layer of the follicle. Inside the pit are three germination layers which first form the sheath, rachis and barbs and later the calamus of the growing feather. The new cells are formed in the epidermal collar, a ring of proliferating tissue lying just above the dermal papilla at the bottom of the follicle. The dermal papilla itself forms the feather pulp which lies in the center of the developing cylinder. The pulp contains both blood vessels and nerves. The scheme of differentiation of feather elements is summarized in **Figure 4** on the following page.

Keratin is the main structural protein component of feathers. It is a scleroprotein which is virtually resistant to degradation by proteolytic enzymes. Keratin fibrils, held together by hydrogen bonding of helix proteins, provide the physical structure and strength of the feather. Cystine disulphide bonds in particular stabilize the strength of the protein structures.

Keratinization of embryonic feathers commences at about day 13 of incubation and is complete by day 19. The process takes place in the cytoplasm of each cell and in general occurs at the same time as cell proliferation. Feather pigments are laid down at the same time.

Figure 3. A feather follicle showing the main areas of cell proliferation. (From Yu et al. 2004)

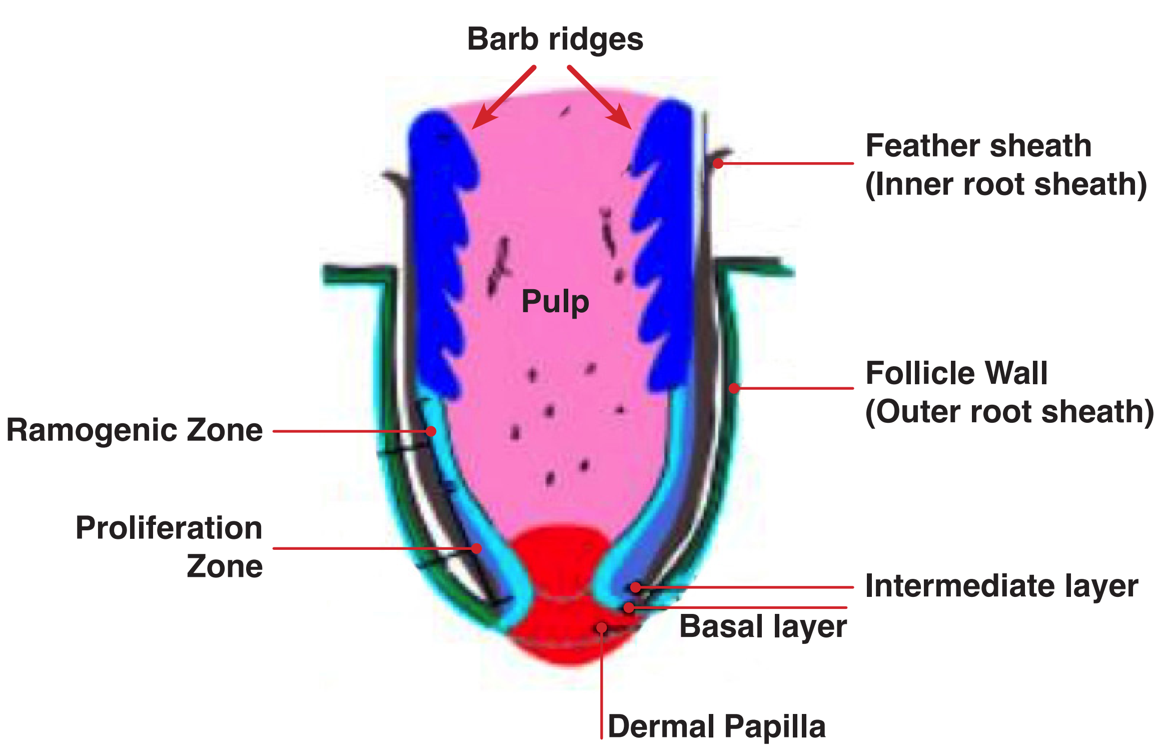
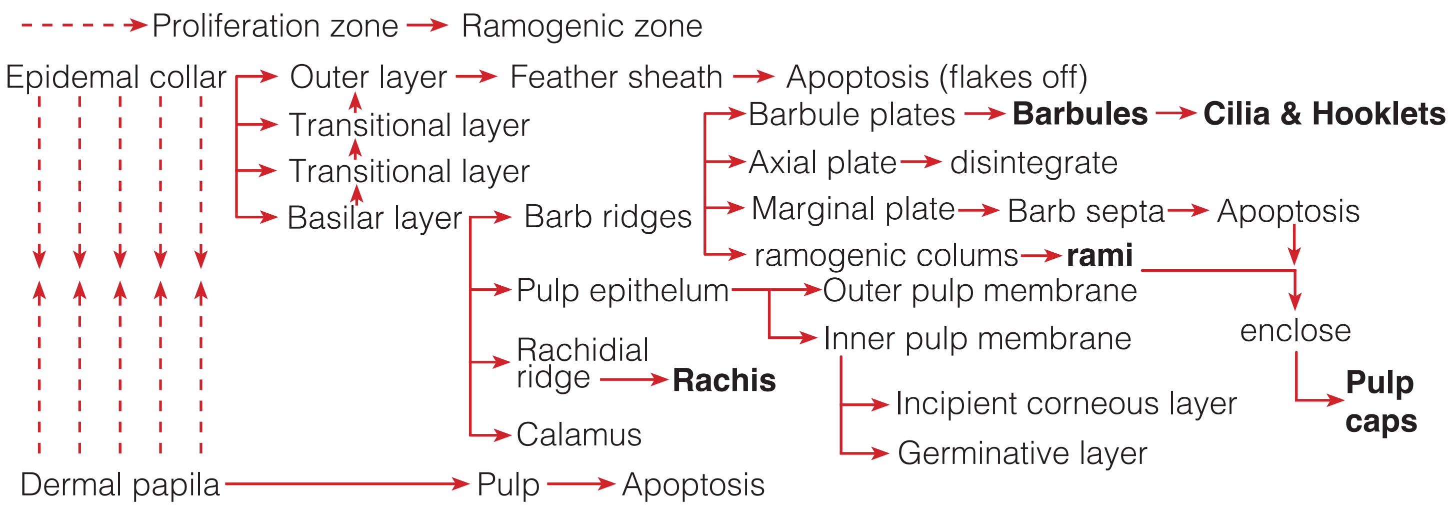


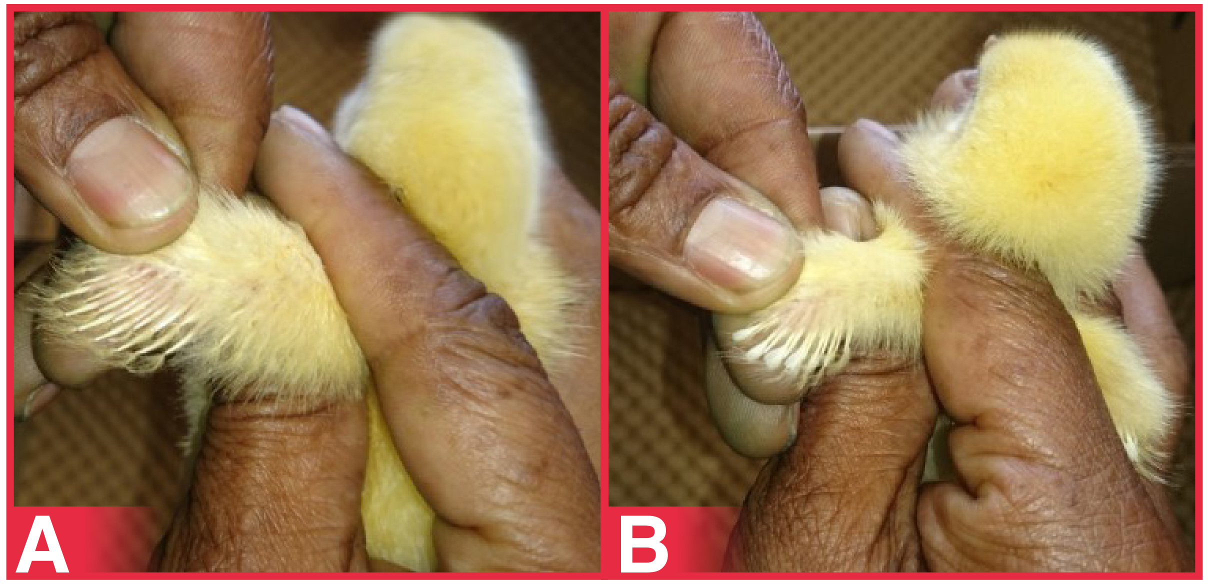
Figure 4. Scheme showing the lineage of different feather cell types and structures. (From Yu et al., 2004 and Lucas and Stettenheim, 1972).



GROWTH AND DEVELOPMENT OF FEATHERS

By the time of hatching the growth of natal down is complete and a first phase of feather replacement has been initiated (**Figure 5**).Shortly after hatching the sheath of each feather dries and flakes away. The feather barbs spread out, barbules are freed from the barbs and the natal down becomes fluffy (**Figure 2** on page 5). The appearance of the feathers at hatch and in early growth is strongly influenced by segregation at a single sex-linked gene K (late) and k (early).

Figure 5. Day-old chicks showing the natal down and the initial appearance of the first phase feathers. The left hand chick (A) carries the fast-feathering gene (k) and the right hand chick (B) the slow-feathering gene (K).



Starting with the down plumage at day-old there are three feather replacements as the chick, juvenile and adult plumage replaces the previous generation. Although the pattern of feather replacement within each feather tract is very orderly, the time at which each molt is initiated within each tract and the time of completion varies between birds and also between feather tracts. Thus at any age more than one generation of feathers will be present in a tract and the variation within a flock is very complex. In summary a chicken is losing and growing feathers somewhere on its body at all times prior to maturity.

The measurement of feather growth is a difficult undertaking and the results are likely to be influenced by a number of variations in experimental procedure. As a result the available data are rather variable, few in number and difficult to compare. **Figure 6** shows total feather weight plotted against body weight in broilers grown under experimental pen conditions in various laboratories. There is a great deal of variation in these data but the cause of this is unknown. In those experiments where both sexes were used, feather weight at a given body weight was higher in females compared to males. The results of those studies which used different strains of commercial broilers suggest that this is a relatively small source of variation.

In broilers the increase in total feather weight with time can, like body weight itself, best be described by a sigmoid growth curve. **Figure 7**, from a study carried out in 1999, shows the curves for male and female broilers of two commercial broiler strains. As noted above, the two strains are very similar and both show projected mature feather weights of about 300g (0.66 lb) in males and 220g (0.49 lb) in females. Maximum growth rates of feathers of about 4.5g (0.01 lb)/day and 3.5g (0.01)/day occurred in males and females respectively at 40-45 days of age. These descriptions are based on the weights of feathers remaining at the time of slaughter and no allowance is made for feathers which have grown but dropped off.

Figure 6. Graph showing the total weight of feathers in broilers plotted against body weight. Data from Edwards et al. (1973), Fisher et al. (1981), Gous et al. (1999), Håkansson et al (1978), Özkan et al. (2002), Sakomura et al (2006a,b), Stilborn et al. (2004).

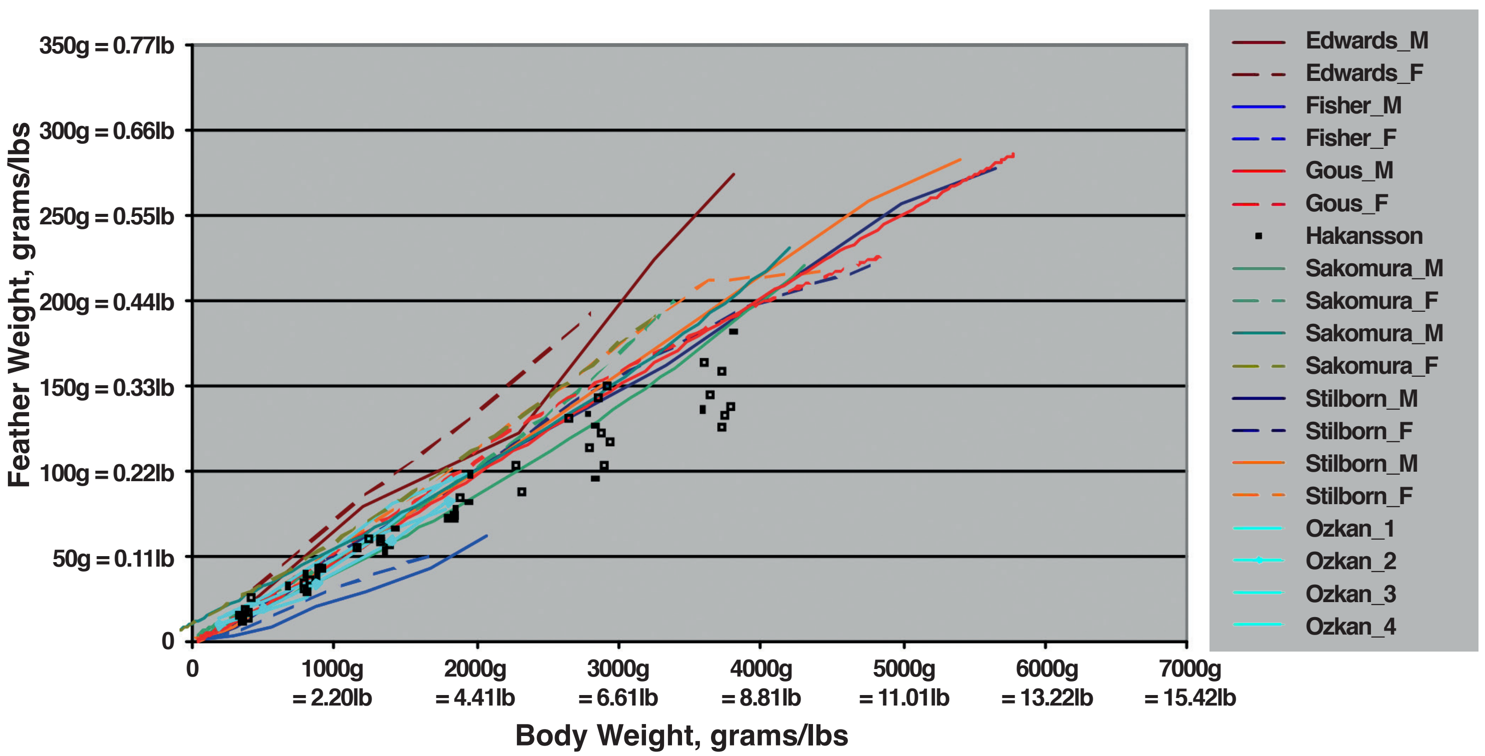
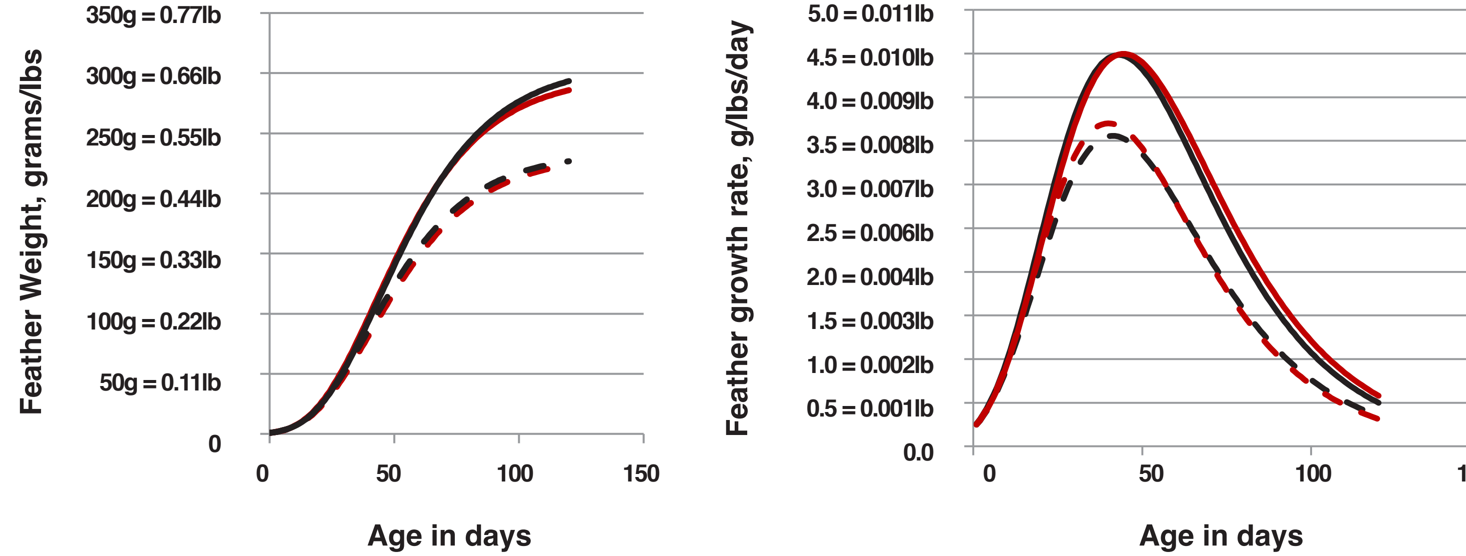


Figure 7. Growth rate of feathers in broilers (Gous et al.,1999)

Left figure; fitted Gompertz growth curves for total feather weight in male (solid lines) and female (broken lines) broilers of two strains; Right hand figure; derived feather growth rate curves.

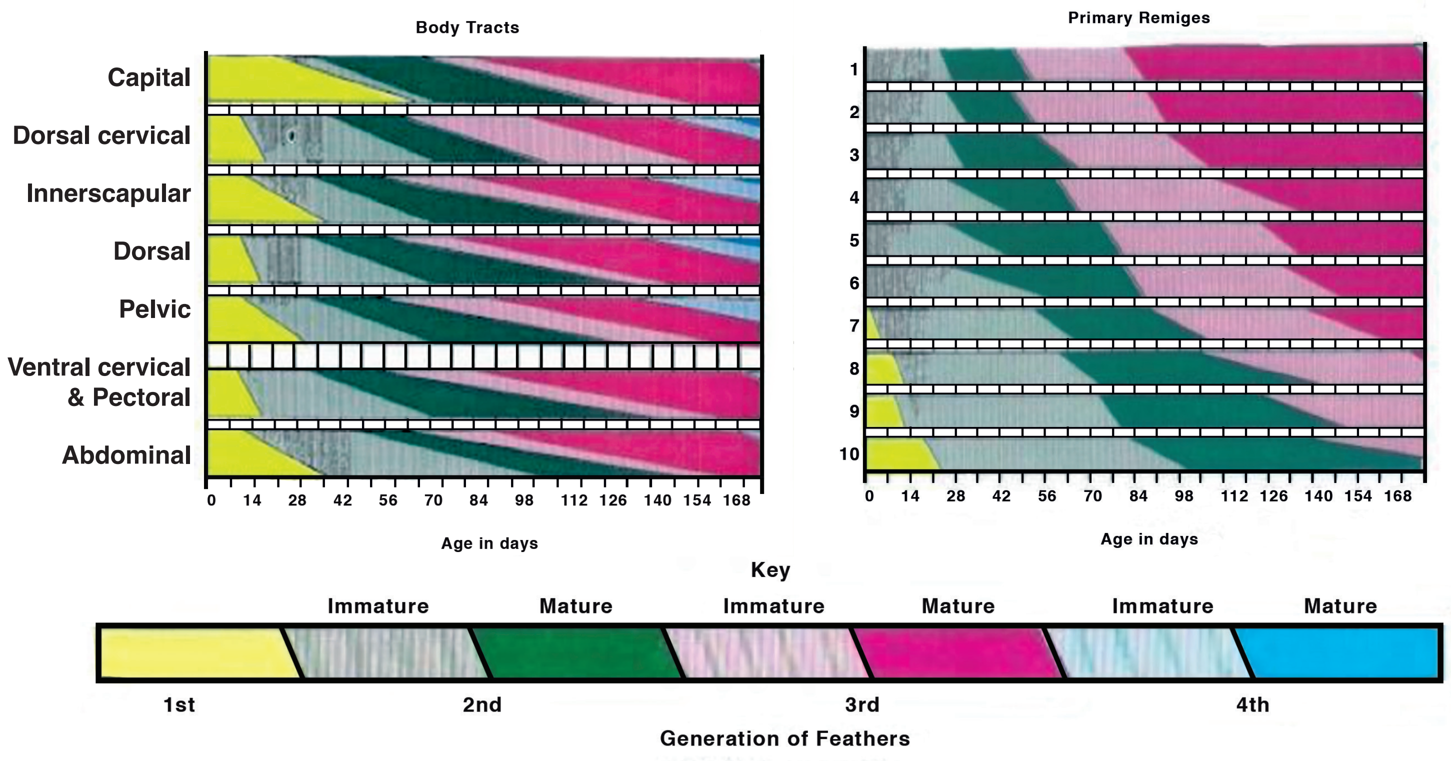


MOLTING

The periodic replacement of all or part of the plumage is known as molt. Molts occur during development as the plumage changes from natal down to maturity and also seasonally. In a true molt the feather follicle enters a period of growth known as anagen and the new growing feather “pushes out” the existing feather. Each molt is named for the incoming plumage and the completed plumage enters a rest or telogen phase. In the avian world as a whole, the pattern and timing of molts are both variable and are well coordinated with the physiological conditions of the organism. Regulation is at the local and organism level and the molt is modulated by the environment. For example, in flying birds major wing feathers are molted alternately in the right and left wing so as to maintain balance. In farmed broiler breeder hens kept for a single cycle most birds will follow a single cycle of molts.

The sequence of molts in broiler breeder females under a controlled feeding regime has not been described in detail. **Figure 8** shows some data for body tracts and the primary remiges from Single Comb White Leghorn chickens (SCWL) (Lucas and Stettenheim, 1972). Thus, for the dorsal tract, it can be seen that the first (natal down) generation of feathers starts to be replaced at about 10 days and has disappeared in all birds by about 18 days. The successive stages then go through similar cycles but it can be seen that the variability among birds tends to increase as the stages progress. Note that the 4th mature stage, which starts to appear in some tracts on some birds, is incomplete by the end of the study at 175 days.

Figure 8. History of feathers during successive natural molts in different body tracts (left graph) and in the primary remiges (right graph). The key to the immature and mature stages of the four successive molts is shown below. Data for SCWL chickens from Lucas and Stettenheim, (1972).



Feather germs can also be induced to enter anagen by plucking of the feathers but a broken feather will not re-grow. Feather loss can also occur without replacement, e.g. for special adaptation such as the preparation of a brood patch. In adult birds suboptimal feed or water, high levels of zinc or iodine, low levels of calcium or sodium or the administration of many pharmaceutical agents may induce a change of feather cover irrespective of age. The circumstances in which suboptimal management can induce feather loss have not been clearly defined but there is field evidence in broiler breeders that general mis-feeding and poor body weight control can lead to a partial or continuous feather loss molt after peak production. This is discussed on page 19 in **Internal Study - 2.**

THE COMPOSITION OF FEATHERS

Information about the chemical composition of feathers is useful for the calculation of nutrient requirements. An atypical composition, if it can be detected, might also be useful in the diagnosis of feathering problems.

While the composition of dry feathers is fairly well established, information about moisture content is notably lacking and is variable. This situation mainly reflects the great practical difficulties of collecting fresh feathers quantitatively during experiments.

In many studies the feathers may become wet and thus information about the dry matter content is lost and the results are reported on a dry matter basis. If only sample feathers are analyzed the composition of these will vary, and may be atypical. Sakomura et al., (2003) reported that the average moisture content of feathers from broiler breeder hens aged 3 to 20 weeks was 9.03%. Other data, however, suggest that figure may be much too low.

The two main components determining the moisture content of feathers are the proportion of feather pulp (with high – 80-85% – and fairly constant moisture content) and the remaining feather which has about 45-50% moisture until the later stages of maturity when the moisture content is less than 10%. For individual follicles with the feathers going through successive cycles of molt and renewal these changes could be traced and quantified but such data are not available at the present time. The proportion of total feather weight accounted for by pulp varies from about 50% in young feathers falling to zero in mature feathers (**Figure 9**). When a feather reaches its maximum total weight moisture content is about 50% (Smith and Bath, 1995).

Only one extensive study of the moisture content of feathers is available (**Figure 10**). These results suggest that the moisture content of feathers declines from a high of 65% in young chicks to about 25% in mature birds. These data can be used in the calculation of amino acid requirements although better data referring specifically to broiler breeders are required.

Figure 9. Data showing the pulp content of feathers in relation to the time of regrowth. The four lines shown as symbols are for feathers from individual birds where regrowth was stimulated by feather removal (Lillie, 1940). The data shown as squares are for “saddle” feathers from two Brown Leghorn capons; the data shown as circles are for breast feathers from two White Leghorn cockerels. The data shown as broken lines are for individual primary wing feathers taken from growing broilers (W.K. Smith and H.M. Bath, unpublished information). In this case the start of feather growth was estimated by extrapolating the weight of the freshly plucked feather back to zero.

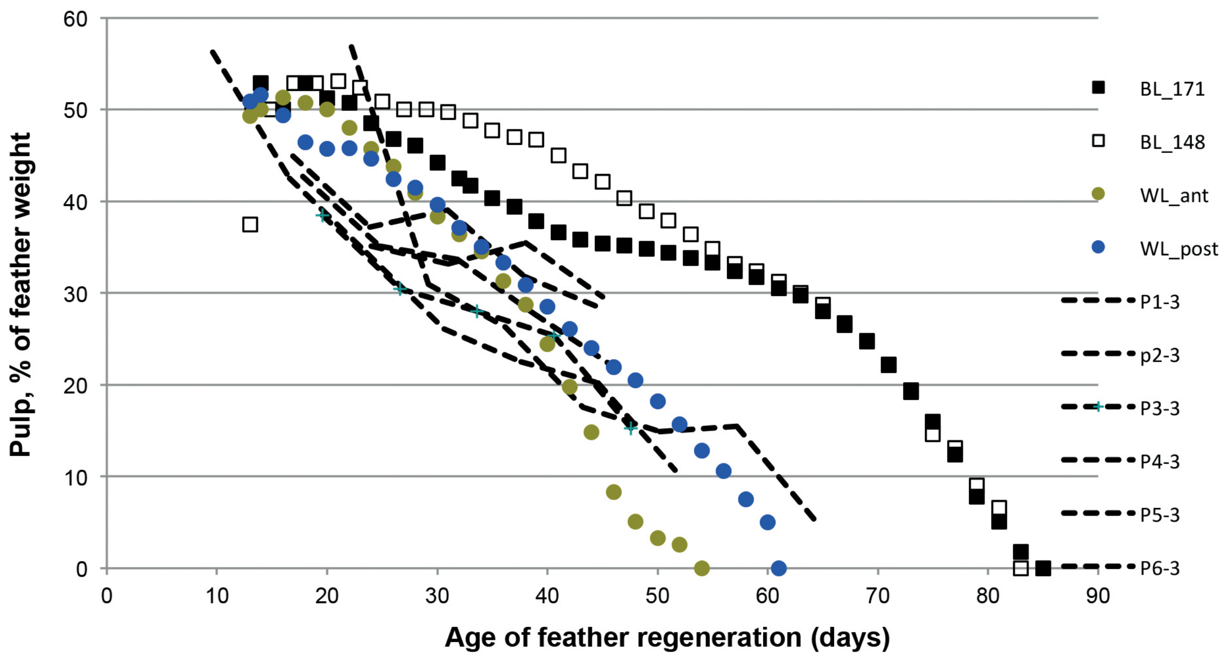
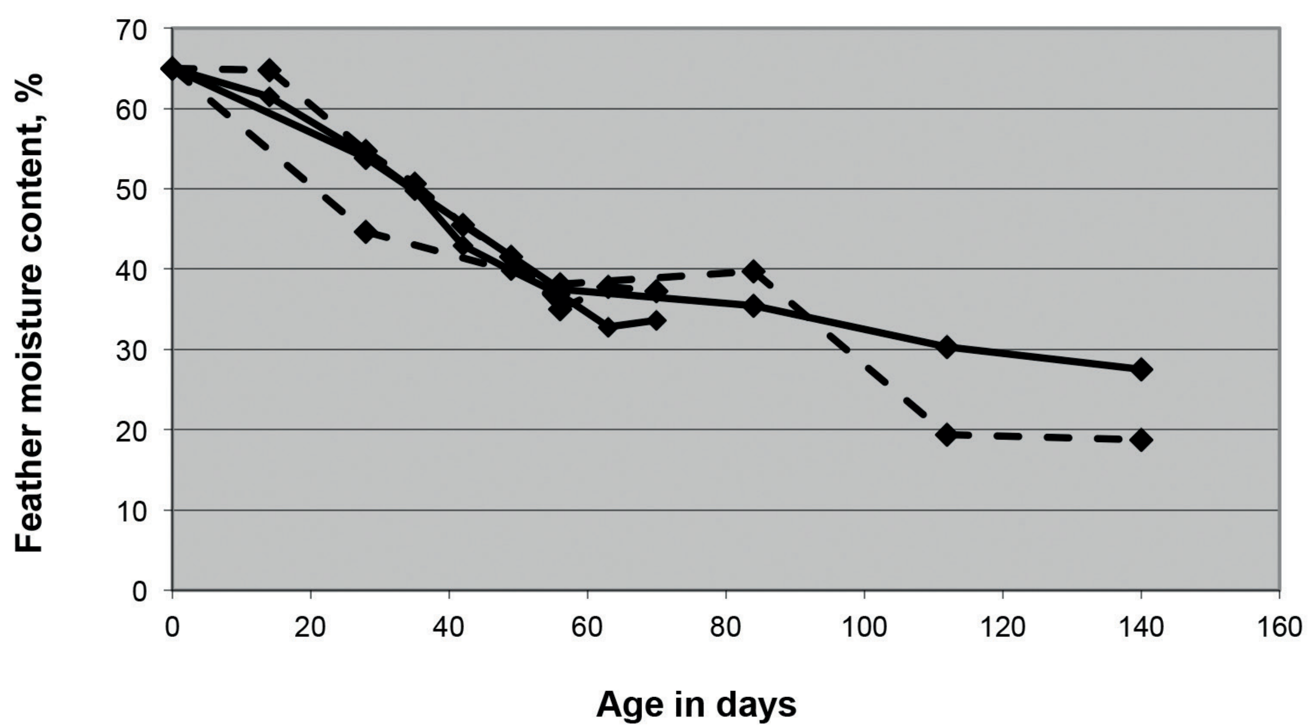


Figure 10. The moisture content of feathers in growing broilers. Data for males (solid lines) and females (broken lines) from two experiments are shown. From Edwards et al (1973).

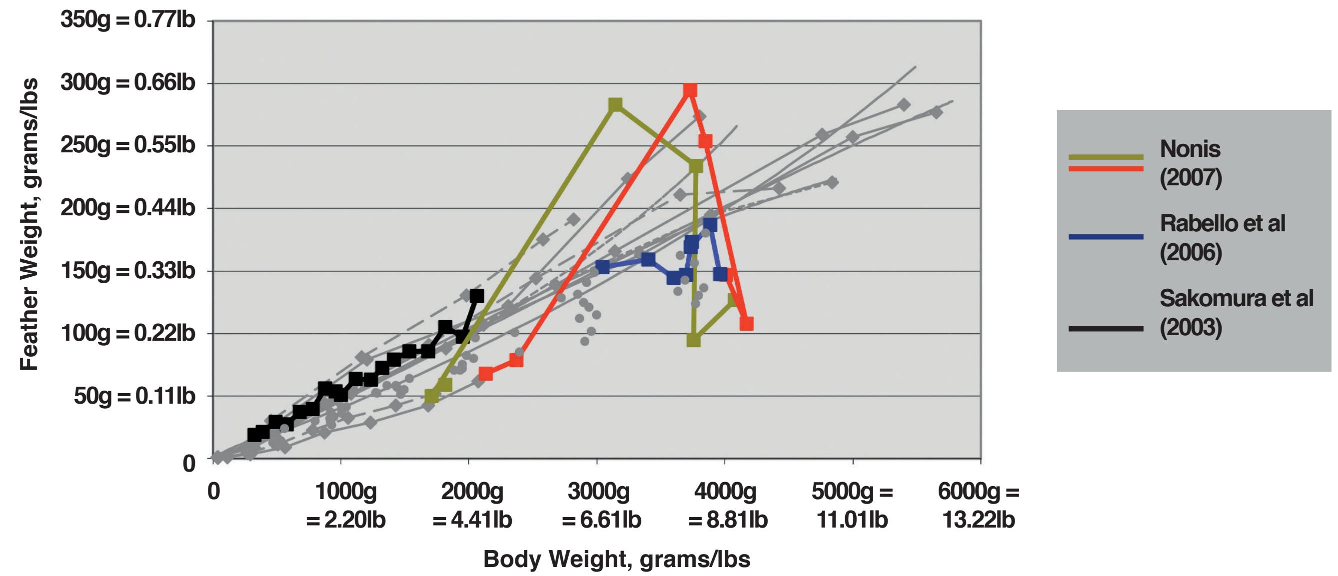


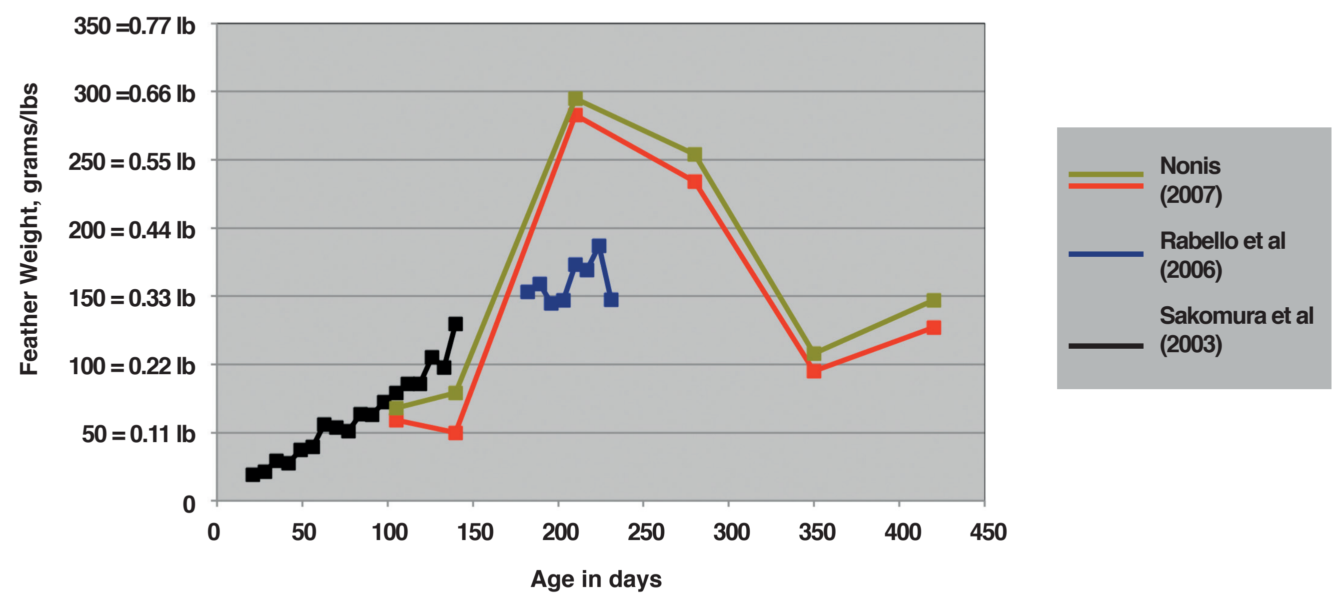
FEATHER GROWTH IN BROILER BREEDER FEMALES

When the available data on broiler breeders are added to **Figure 6** (see **Figure 11 upper**), no general difference between broiler breeders following a controlled feeding program and ad libitum fed broilers can be seen. When feather weight is plotted against age **(Figure 11 lower)** there is no clear overall pattern. The data reported by Nonis (2007) show an interesting pattern in feather weight with a rapid increase between 20 weeks and peak egg production at 30 weeks, followed by extensive feather loss during the remaining laying period.

Figure 11. (Upper) Total weight of feathers in broiler breeder females plotted against body weight. The data for broilers shown in **Figure 6** are shown in grey for comparison. Data from Nonis (2007) green and red lines; Rabello et al. (2006) blue line; Sakomura et al. (2003) black line.

Figure 11 (Lower) Total feather weight in broiler breeder pullets plotted against age. Data as in the upper figure.





In spite of the data shown in **Figure 11** those experiments which have directly compared controlled feed programs with ad libitum fed birds indicate that reduced feed supply has differential effects on feather growth and the growth of other tissues. Data from Smith et al. (1994) and Kampeni (1993) show that, relative to ad libitum fed birds, the feathers of feed controlled broiler breeder females are modified as follows;

i. Body weight and feather weight are both reduced by controlling feed but proportionally the reduction in feather weight is less than in the whole body. Thus, dry feather weight expressed as g/100g (lb/0.22lb) body weight is increased by 1-2 percentage points (**Table 1**).

ii. Feather length is reduced only slightly by controlling feed. **Figure 12** on page 15 shows feather length of a primary remige in early and late feathering genotypes. Prior to the first molt, controlled feeding has no effect on feather length. New feathers emerging after the molt tend to be slightly shorter in the feed controlled birds but they quickly catch up so that by 110 days none of the treatments are significantly affecting the length of these feathers. The overall pattern is similar in the other feather tracts and relative feather length (feather length/body weight, mm/kg, in/lb) is consistently greater in the feed controlled birds (Kampeni, 1993). As a result, feather cover appears visually to be improved by controlling feed. This difference is seen particularly in the keel region (**Figure 12,** page 13).

iii. The weight of individual feathers is however reduced and dimensions of all feather components are smaller. The data in **Table 1** illustrate this for the primary remiges.

Table 1. Feed programs and feather dimensions.

Genotype and feeding level	Early ad libitum	Early controlled	Late ad libitum	Late controlled	Signif.*
Body weight g (lb)	4162 (9.17)	1531 (3.37)	5259 (11.58)	1475 (3.25)	
Dry Feather wt g (lb)/bird	154 (0.34)	75 (0.17)	142 (0.31)	59 (0.13)	†††
g (lb)/100g (0.22lb) Body Wt	3.7 (0.008)	4.9 (0.011)	2.7 (0.006)	4.0 (0.009)	†††
Primary remiges: Length mm (in)	191 (7.52)	182 (7.17)	191 (7.52)	176 (6.93)	ns
Weight mg (oz)	473 (0.017)	314 (0.011)	478 (0.017)	371 (0.013)	†††
Vane width mm (in)	52 (2.05)	47 (1.85)	55 (2.17)	50 (1.97)	†
Calamus mm (in)**	3.84 (0.15)	3.15 (0.12)	3.81 (0.15)	3.16 (0.12)	†††
Barb mm (in)**	0.12 (0.005)	0.10 (0.004)	0.17 (0.007)	0.09 (0.004)	†††

Observations at 110 days of age.
*significance of feeding effect, † ($P<0.05$), ††† ($P<0.001$). ns not significant.
**thickness of calamus and barbs.
Genotypes: early (k) and late (K) feathering commercial grandparents lines.
Feeding: ad libitum or controlled according to breeders recommendations.
Comercial broiler feeds used throughout.
From Smith et al., 1994

In addition to these data about the effect of feed control on the weight, size, and dimensions of feathers it has also been shown that controlling feed delays the onset of molt during the growing stage. **Figure 14** shows the timing of molt between stages 2 and 3 in primary remiges and back feathers (Kampeni, 1993). These data are also compared with those for Single Comb White Leghorn (SCWL) chickens shown in **Figure 8**.

Compared to ad libitum feeding, the effect of feed control is always to delay the molt. The magnitude of this delay varies somewhat but in general is about 1 week. There is an indication that the delay was greater in the later molting wing feathers (4&7) than in the earlier molting feathers. The delay in back feather molt is less than in the wing feathers but is nevertheless real.

For the feed regimes the information about time of molting in broiler breeders is similar to that in **Figure 8** for SCWL chickens. For back feathers the two sets of data are different and imply that molting in this tract is much earlier in the broiler breeder hens.

Figure 12. The sequence of elongation and shortening shows the course of the juvenile (stage 2-3) molt (Kampeni, 1993).

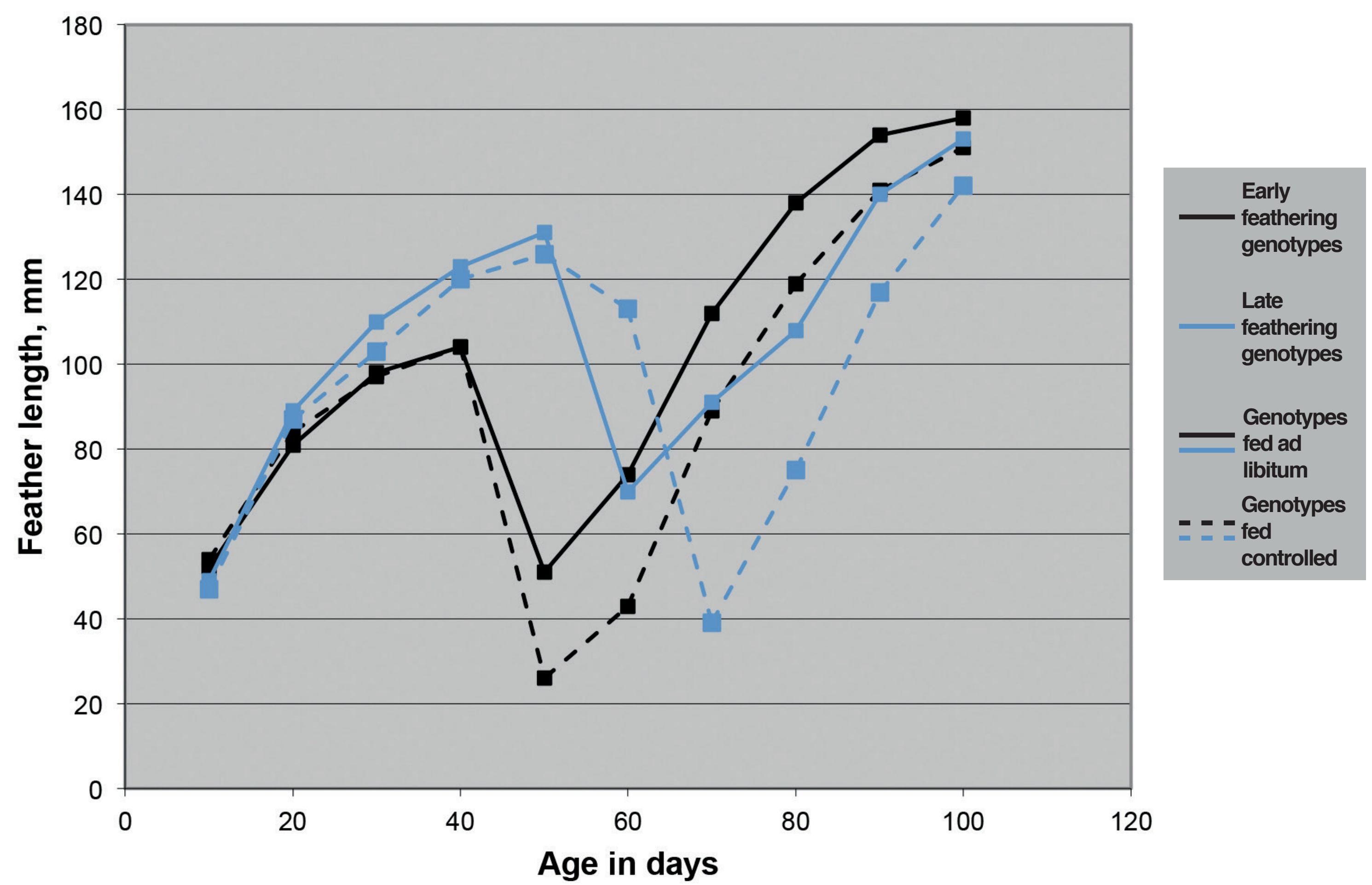


Figure 13. Feather cover (at 42 days) of controlled fed (left) and ad libitum (right) fed broiler breeder hens. From Kampeni (1993)

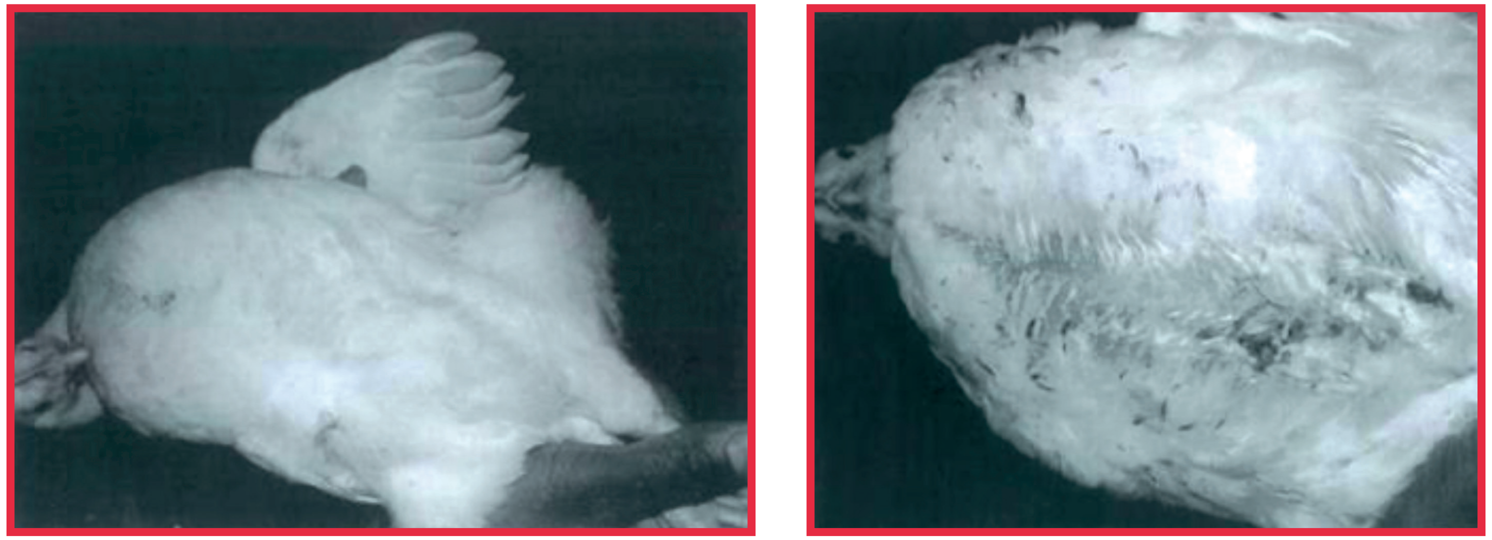
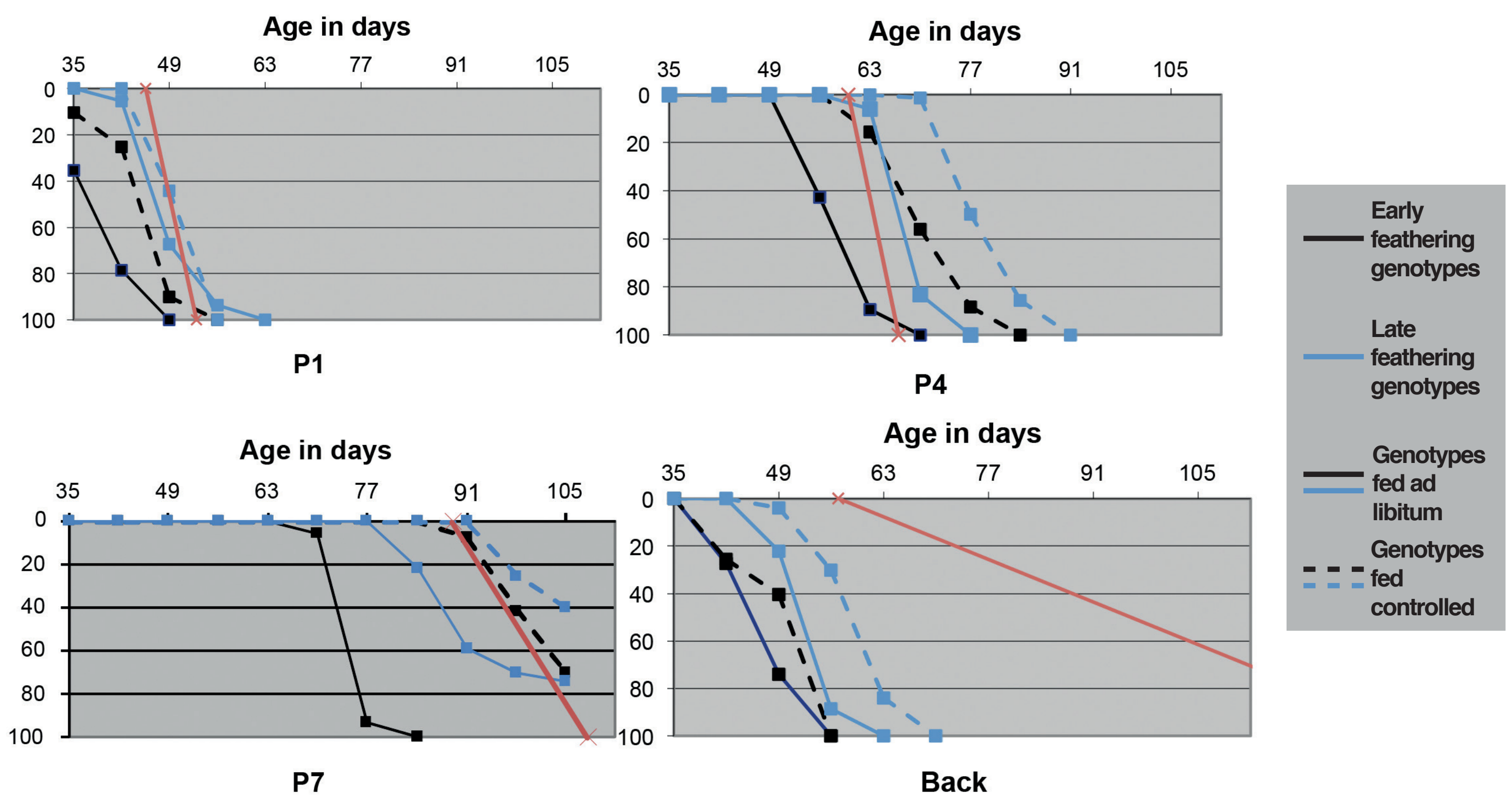


Figure 14. History of feathers during the chick-juvenile (stage 2-3) molt in three remiges (P1, P4 and P7) and in back feathers. The data show the percentage of the birds that have molted at each age and are for early (black lines) and late (blue lines) feathering genotypes, and for ad libitum (solid lines) and controlled feeding (broken lines) in broiler breeder hens (Kampeni, 1993). The data for the red lines were taken from **Figure 8**.



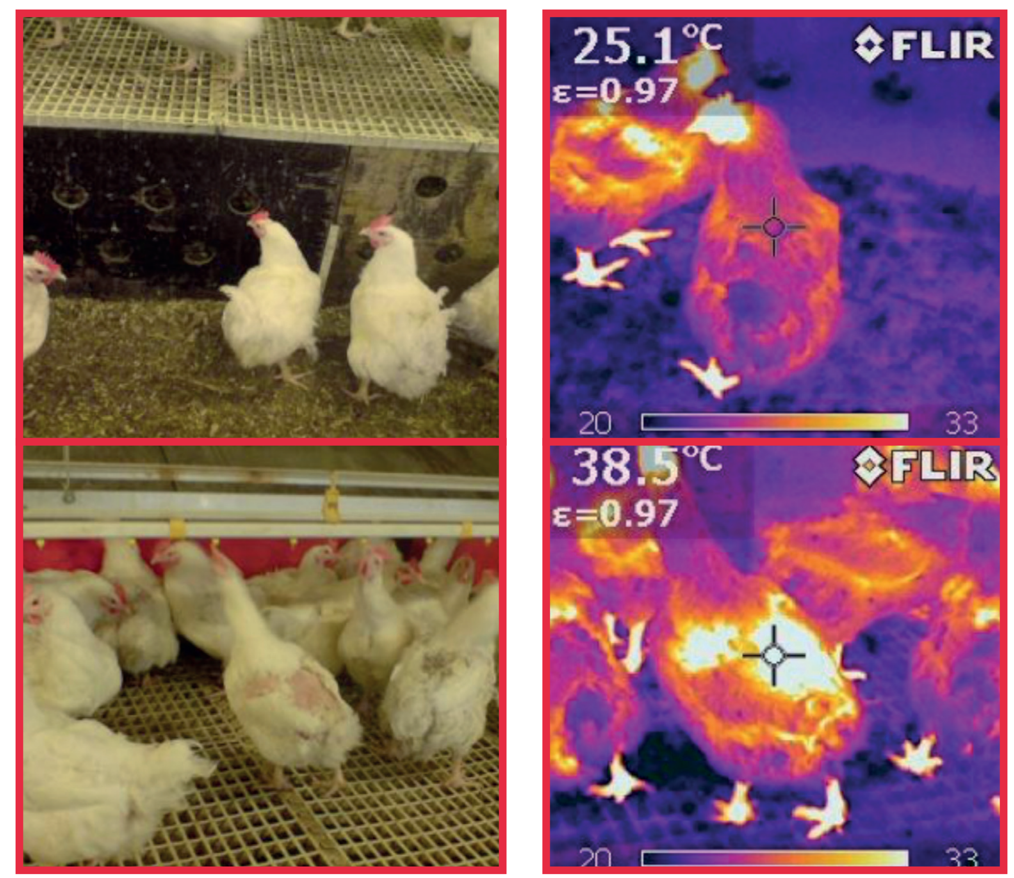
FEATHER GROWTH AND NUTRITION

ADJUSTING FEEDING PROGRAMS FOR FEATHER LOSS

The effect of feather cover on energy loss and efficiency is an area which has received widespread attention in poultry research. Some single genes influence feather cover, such as naked neck (Na) and featherless or scaleless (sc) and these have been considered for commercial application in hot climates. The feather cover of birds has a major role in thermoregulation. This is an adaptive mechanism since muscles at the base of each follicle can modify the orientation of the feather and change the amount of trapped air. Heat loss is obviously increased if the feathers are absent or damaged (**Figure 14**).

This increased heat loss can be both an advantage at high temperatures and a disadvantage at low temperatures. Within a practical range, say from 15-25℃ (59-77℉), differences in feather cover will have measurable effects on feed intake and energy utilization. If the feed intake of broiler breeders is carefully controlled to meet body-weight targets then feather cover will be one of the many factors that influence feeding levels. If a fixed feeding program is used then environmental temperature and quality of feathering will be two of the factors that need to be taken into account.

Figure 14. Photographs and thermographs of well-feathered and poorly-feathered hens. The light areas on the thermographs show the higher skin temperature, in the de-feathered areas. This leads to increased heat loss.



AMINO ACID NUTRITION AND FEATHER GROWTH

The amino acid composition of feather protein differs considerably from that of the feather-free carcass protein. The main differences are in lysine and histidine, which are lower in feather protein and the sulphur-containing amino acid, cystine, which is lower in carcass protein. Because of the large difference in lysine content the amino acid balance, expressed relative to lysine, is very different in the two tissues. The overall levels of essential (EAA) and non-essential (NEAA) are very similar.

When feather growth is considered in the calculation of nutrient requirements, an allowance must be made for feathers which have grown but been lost over the period under consideration. This might be considered as "feather maintenance" and it could account for a considerable additional output in nutritional terms. The extent of feather loss is difficult to quantify, and the only reported data are from Fisher et al., (1981) who studied male and female broilers up to 49 days of age. Calculations from these data (**Table 2**) illustrate how feather loss occurs when expressed as a percentage of average feather weight over successive 7-day periods. Feather loss is seen to increase with age over this period in broilers and to be much higher in females compared to males.

Determining the composition of feathers is complicated by variations in the amount of feather pulp as opposed to the mature ramus and barbules. The total feathering is a mixture of feathers at different and changing stages of maturity; the dry matter content of this mixture in particular will vary with age and stage of development as will the protein content to a smaller degree. Existing data do not allow these variations to be well described. Smith (1994) has argued that the contribution of pulp is significantly underestimated when calculating nutrient needs from the average weight and composition of feathers.

Table 2. Mean feather weight (g (lb)/bird) and daily feather loss (% mean feather weight) in male and female broilers over 7-day periods. From Fisher et al. (1981).

	Mean feather wt. g (lb)	% loss per day	Mean feather wt. g (lb)	% loss per day
Age (days)	Males		Females	
28-35	24.8 (0.05)	0.05	13.8 (0.03)	0.34
35-42	35.8 (0.08)	0.12	37.6 (0.08)	0.48
42-49	52.3 (0.12)	0.32	47.1 (0.10)	1.51

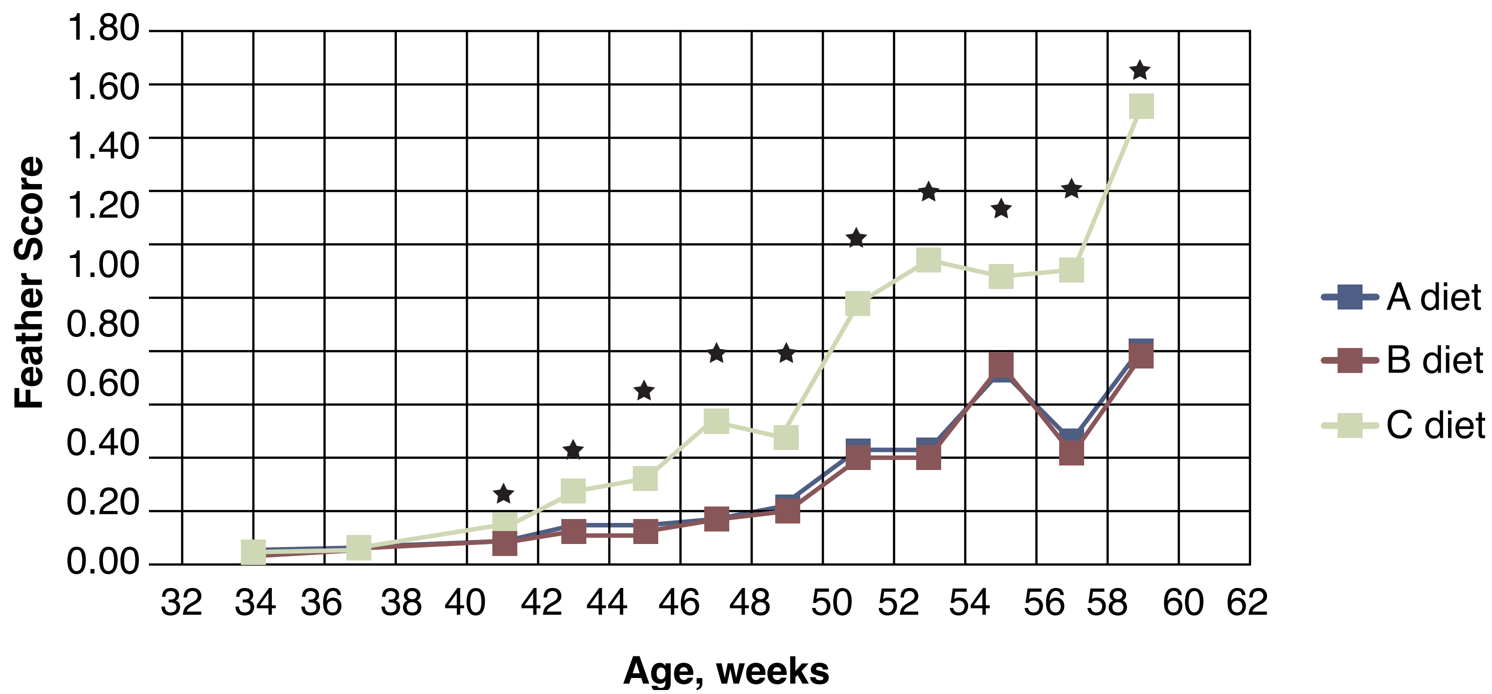
INTERNAL STUDIES

INTERNAL STUDY 1: A trial evaluating amino acid levels for breeders.

The feathers on the back (dorsal) tract of Ross® 708 breeder hens were scored during a trial in which different amino acid levels were fed from 25 to 60 weeks of age. The results indicate that amino acid supply is important for feathering during this period and also helps to indicate when feather growth is taking place.
Three diets were fed, as large crumbles, in Breeder 1 and Breeder 2 stages. Diet A had amino acid levels per Ross Parent Stock Nutrition Specifications. Diet B had 10% additional amino acids. Diet C was formulated according to a calculation model but in effect contained less amino acids than Diet A (ranging from 7 to 12% less for different amino acids – except for methionine and cystine). Other nutrients were similar in all three diets and a common feeding program was followed.

Feather scoring started at 34 weeks of age when all birds still had a zero score (zero score = no feather loss up to score 5 = significant feather loss). By 41 weeks the scores on Diet C were worse and they continued to deteriorate in all groups up to 59 weeks of age **(Figure 15)** when the birds on Diet C were poorer than Diets A and B. The average feathering scores at 59 weeks of age were 0.75, 0.66 and a.49 for Diets A, B and C respectively. The big difference was in the number of birds with very poor feathering (scores 4 and 5) which totaled 5, 4 and 21% of the flock on Diets A, B and C. The feathering effect in Diet C was not due to methionine or methionine+cystine, as the levels were similar to Diet A.

Figure 15. Feather scores on three diets differing in amino acid levels. Significant differences within age shown by ★.



INTERNAL STUDY 2: The importance of feeding and nutrition to maintenance of feathering in adult hens.

Continuous feather losses were observed in some flocks after 28-30 weeks (feather score 1 to 2) progressing to more serious loss at later stages. No significant regrowth of the feathers was observed unless causative factors were identified and corrected. Some of the managers involved attribute this early feather loss to male aggression. However, feather loss is not necessarily a good indicator of mating activity. It was observed that in a majority of cases the hens presented one or more of the following features:

- Body-weight gain above the standard
- Low fat reserves
- Rapid increase in peak egg production
- Peak feed given after 70% egg production (i.e. too late)
- Insufficient daily energy allowances
- Rapid reduction in feed allowance after peak
- Cold environment

In addition to feather loss, such flocks are likely to exhibit poor persistency of egg production even when uniformity and peak egg production have been good.

Some data from one such flock are shown in **Figures 16** and **17**. The back feathering scores **(Figure 16)** show that even at 28 weeks of age only 20% of the birds had perfect feathering (score 0). A further 25% showed some ruffled feathers on the back (score 1) and more than 50% of the flock show clear evidence of feather loss (scores 2-4). Feathering then progressively deteriorates as the flock ages such that 30% of the birds show the most severe feather loss (score 5) by 53 weeks of age. Average feather scores were 1.36, 2.33, 2.41, 2.43 and 4.04 at 28, 35, 40, 47 and 53 weeks respectively.

Figure 16. Back feather scores at different ages in a flock of breeding hens.

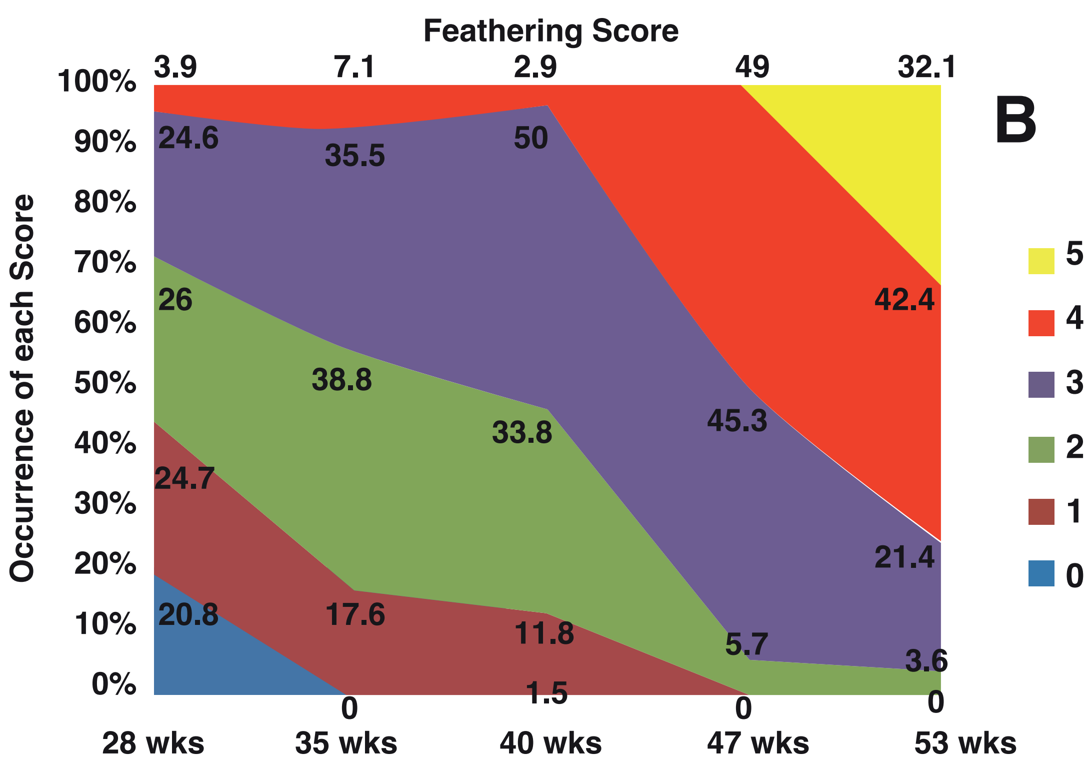
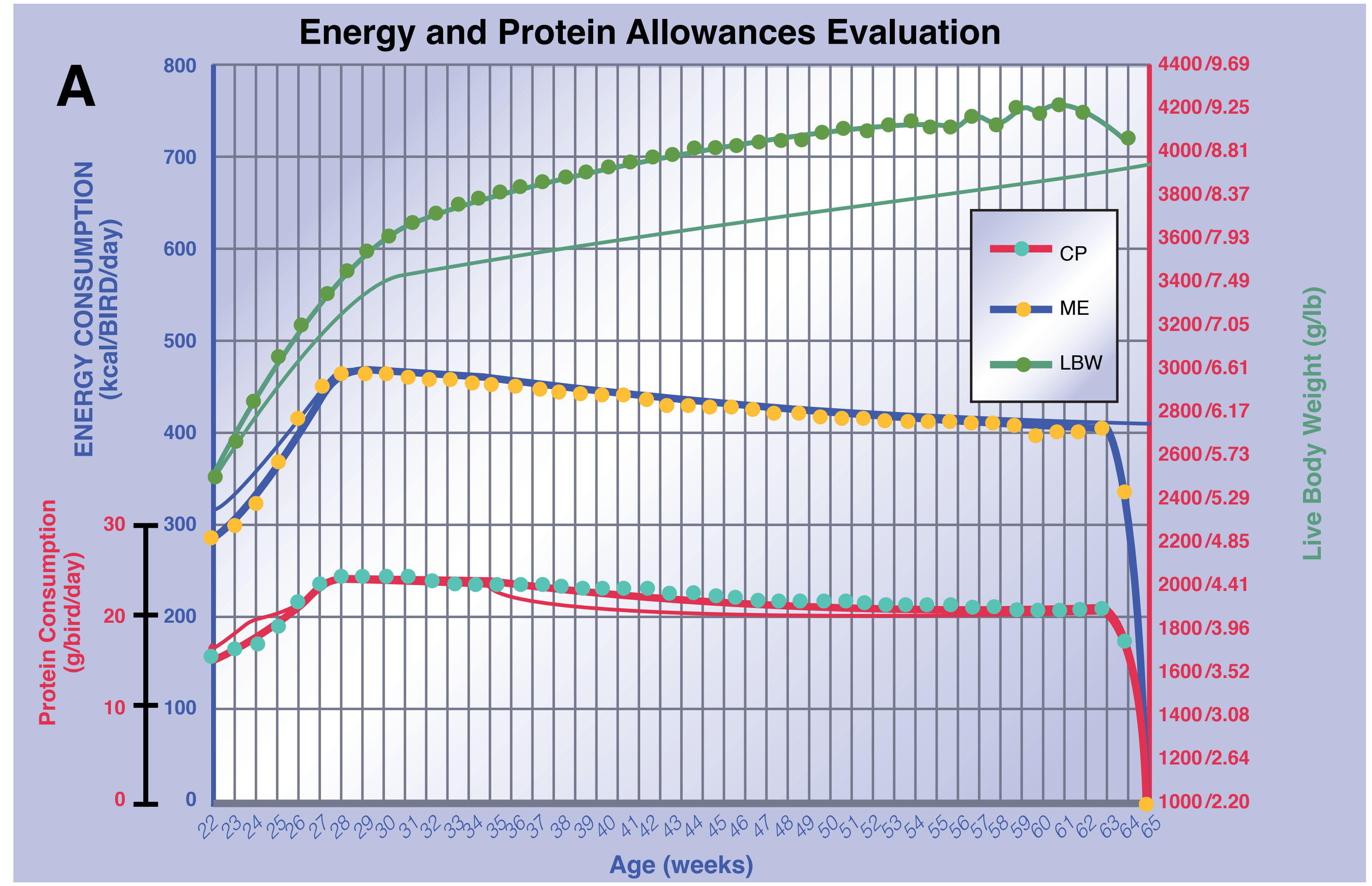


Figure 17 shows the energy and protein inputs to these birds and their body weight. After 24 weeks of age failure to adjust the feeding program led to a progressive increase in body weight above the standard.

Figure 17. Body weight of the hens suffering from feather loss with energy and protein intakes



Energy supply was kept quite close to, but also slightly below, the standard while crude protein intake, while also close to the standard, was in slight excess. Other details of this particular flock are not known but it is proposed that a combination of higher maintenance requirements, reduced energy supply and excess protein (perhaps also other stressors as listed above) led to an energy shortage and resulting feather loss. In other flocks where these circumstances have been detected an increase in energy supply has reduced the deterioration in feathering or encouraged regrowth of feathers.

A fully-tested hypothesis as to why feather loss occurs under conditions of mis-feeding is not available. However, the frequency of these observations and success in preventing or reversing feather loss by avoiding or correcting the indicators listed above give strong support for the hypothesis. The nutritional imbalance may trigger a cascade of neuroendocrine effects which alter the pattern of hormone release with consequent reduction of fat reserves, catabolism of muscle tissue for sustaining yolk precursors, involution of the reproductive tract and drop of feathers.

CONCLUSIONS

As with many conditions relating to broiler breeders, feathering is an area which needs a significant amount of research for the mechanisms, management, and resolutions to be understood more completely. Nutritional requirements, managing birds to a correct body weight, monitoring behavior and an understanding of the biology of feather development play key roles in the development and persistency of feather cover. By gaining insight into the feathering status of the flock, managers can monitor feather loss and determine its effects on fertility and chick production.

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