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The Influence of the Naked Neck Gene (*Na*) on Growth, Pterylosis, and Egg Production of Egg-Type Local-Exotic Crossbred Chickens

Amexo, V.E., *Adomako, K., Hamidu, J.A., Gakpetor, G. and Olympio, O.S.
Department of Animal Science, Faculty of Agriculture,
College of Agriculture and Natural Resources,
Kwame Nkrumah University of Science and Technology,
Kumasi, Ashanti Region, Ghana
**Corresponding Author:* adomakokwaku5@gmail.com

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ABSTRACT

The study was conducted to assess the influence of the naked neck gene on the growth, egg production, and pterylosis of egg-type chickens. Two hundred and forty (240) birds (120 males and 120 females with 60 birds per line and 30 from each phenotype) were used for the growth studies. Three hundred (300) birds; 150 birds per line (brown and white) and 75 birds per phenotype (normal feathered and naked neck) per line were used for the egg production studies. Forty birds (36 weeks old) comprising 20 males and 20 females with 10 normal feathered birds and 10 naked neck birds within each sex were sampled for the pterylosis study. Data collected included body weight and rate of lay as well as the following data on pterylosis: capital, dorsal cervical, dorsal ventrical, pectoral, sternal, abdominal, cloacal circlet, ventral caudal, upper marginal coverts of prepatagium, dorsal caudal, dorsopelvic, interscapular, humeral, wing, lateral body, femoral and cural. ANOVA was performed using Genstat 11.1E at p<0.05. Males grew faster (p<0.05) than females. There was no difference (p>0.05) between the naked neck and normal feathered birds in terms of weight gain and egg production. The white layer line laid more eggs (p<0.05) than their brown layer counterparts. Naked neck birds recorded lower follicle numbers (P<0.05) than the normal feathered birds at the capital, ventral cervical, pectoral, sternal, abdominal, femoral, interscapular, humeral, dorsopelvic, upper marginal coverts of prepatagium and crural tracts. The naked neck birds did not have any follicles in the lateral body, dorsal cervical, and cloacal circlet tracts. In conclusion, white layers lay more eggs than brown eggs. Males generally recorded higher follicle numbers than females. The naked neck allele did not influence body weight and egg production, but it reduced follicle numbers by 30.8% in males and 37.4% in females in its heterozygote state. This deviates from the 20-30% published many years ago.

Keywords: *Pterylosis, Feather Follicles, Feather Tracts, Naked neck, Normal feathered.*

INTRODUCTION

Local chicken breeds are usually endowed with major genes (naked neck, frizzle, dwarfism etc.) that confer adaptability, and disease resistance, and also boost immunocompetence and/or performance under hot conditions which gives them an advantage over normal feathered local birds as well as exotic breeds (Mahrous *et al*., 2008; Mwacharo *et al.,* 2007; Fayeye *et al*., 2006; Islam and Nishibori, 2009).

Birds carrying the naked neck gene are characterized by the absence of feathers in the neck area or by only a tuft of feathers at the base of the neck for the homozygous and heterozygous phenotypes respectively. Rauen *et al*. (1986)

observed that reduced feathering intensity (up to 40% in the homozygotes and 20-30% in the heterozygotes) and modified feather structure led to increased heat dissipation, which indirectly boosted feed efficiency and increased productivity. High environmental temperature normally results in the accumulation of body heat and this heat load, leads to rise in body temperature and its associated adverse effects (Cooper and Washburn, 1998).

A number of strategies have been employed to study the naked neck trait in chickens. Pterylosis comes to play as one of such strategies. The science behind pterylosis is to ascertain the arrangement and number of feathers or feather follicles on birds. The naked neck gene has the potential to reduce feather coverage by 30-40% in the homozygous state and 20-30% in the heterozygous state (Merat, 1986). The naked neck gene has been introduced into different breeds and strains of chickens with different surface areas and feather densities (Adomako *et al.*, 2014). However, the percentage of feather reduction by the naked neck gene has not been studied extensively. This study was designed to assess the effects of the naked neck gene on some economic traits and the pterylosis of local-exotic crossbred egg-type chickens.

MATERIALS AND METHODS

Experimental location and birds

The experiment was conducted at the Department of Animal Science (KNUST), Kumasi, Ghana (Altitude 261.4 MSL, Latitude 06° 41'N and Longitude 01°33'W).

The birds used for the study were obtained from the Department of Animal Science (KNUST). These birds were local-exotic naked-neck and normal feathered crossbred layers, which were offspring of a seventh-generation cross of exotic layers and local naked-neck males. The crossbreeding programme was conducted by Animal Breeders at the Department of Animal Science (KNUST), and it involved indigenous heterozygous naked neck (*Nana*) males from Ghana and normal feathered (*nana*) exotic commercial females (Lohmann Brown Classic) to develop two lines of both naked neck and normal feathered birds (white and brown), (see Plates 1-4).

Management: The handling and care of the



Plate 1: White naked neck birds



Plate 2: White normal feathered birds



Plate 3: Brown naked neck birds



Plate 4: Brown normal feathered birds

animals were implemented with the intention of maintaining their welfare and causing minimal stress, according to International Guidelines for Research involving Animals (Directive 2010/63/EU). On the day of the hatch, all chicks were given free access to feed and water. All birds were fed *ad libitum* with a diet containing 18% crude protein and 2800 Kcal ME/Kg feed, 3.5 % calcium, and 0.5% available phosphorus during the egg production period. Floor space per bird was 0.25 m^2.

Body weight: Two hundred and forty (240) birds were randomly sampled for this assessment. The sample comprised of 120 males and 120 females with 60 birds per line (brown and white) per sex, and 30 birds per phenotype (normal feathered and naked neck) per line. Body weights were measured at week 22 (onset of lay) and at week 36, just before the pterylosis study.

Pterylosis: Forty birds were randomly selected from both lines for this experiment. The forty birds comprised of 20 males and 20 females with 10 normal feathered birds and 10 naked neck birds within each sex. The males had an average weight of 2.5±0.2 kg and the females had an average weight of 1.5±0.2kg. The birds were thirty-six (36) weeks old at the time of this experiment.

Egg production: Three hundred (300) birds; 150 birds per line (brown and white) and 75 birds per phenotype (normal feathered and naked neck) per line were used in the egg production studies.

Experimental procedure

Body weight and Egg Production: Body weight was assessed at point of lay (week 22) and at week 36 (during peak production) in kilograms (kg) using a digital scale. All the eggs laid were recorded daily for five successive months. The total number of eggs produced under both factors (i.e., lines and phenotypes) were recorded weekly for the evaluation of egg production performance.

Pterylosis: The birds were slaughtered and were defeathered carefully without scalding, to avoid stretching of the skin which would have made the feather follicles difficult to see and count. Contour feather tracts, which were now visible, were demarcated according to the demarcation of feather tracts as described by Lucas and Stettenheim (1972) [see Plates 5-20]. Feather follicles in each tract were then identified, counted and recorded. The feather tracts were grouped into three regions for easy discussion. These regions with their tracts were:

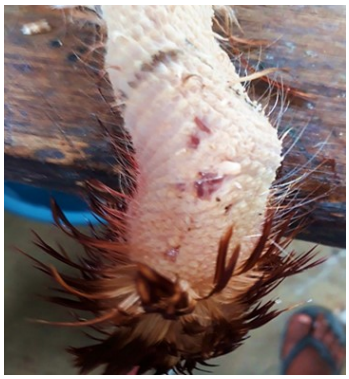


Plate 5: Capital tract



Plate 6: Dorsal cervical tract



Plate 7: Interscapular tract



Plate 8: Humeral tract



Plate 9: UMCP tract



Plate 10: Dorsopelvic tract



Plate 11: Dorsal caudal tract



Plate 12: Ventral cervical tract



Plate 13: Pectoral tract



Plate 14: Sternal tract



Plate 15: Ventral caudal tract



Plate 16: Abdominal tract

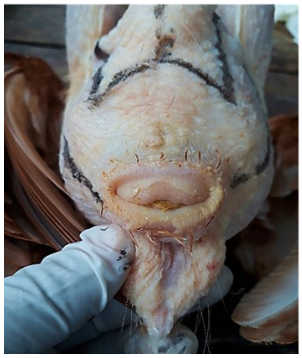


Plate 17: Cloacal circlet



Plate 18: Crural tract



Plate 19: Lateral body



Plate 20: Femoral tract

- **Dorsal region:** capital, dorsal cervical, interscapular, humeral, upper marginal coverts of prepatagium (UMCP), dorsopelvic and dorsal caudal tracts,
- **Ventral region:** ventral cervical, pectoral, sternal, abdominal, cloacal circlet and ventral caudal tracts, and
- **Lateral region:** crural, lateral body, and femoral tracts.

Statistical analysis

Data collected were subjected to a two-way analysis of variance (2 feather phenotypes x 2 sexes for the pterylosis study, and 2 feather phenotypes x 2 feather colour lines for growth and egg production studies) using Genstat Edition 11.1 at $p<0.05$. The mixed models (model 1 for growth and egg production data and model 2 for the pterylosis data) as presented below were used for the data analysis.

$$Y_{ijk} = \mu + a_i + \beta_j + \lambda_k + \alpha_i\beta_j + \varepsilon_{ijkl} \quad \text{Model 1}$$

$$Y_{ijk} = \mu + \alpha_i + \tau_j + \lambda_k + \alpha_i I_j + \varepsilon_{ijkl} \quad \text{Model 2}$$

Where;

Y_{ijk} = *effect measured;*
μ = *overall means*
α = *main effect of feathering type*
β_j = *main effect of sex*
I_j = *main effect of feather-colour line*
λ_K = *random effect due to either number of Birds or number of times the experiment was replicated*
$\alpha_i\beta_j$ = *interaction of feathering-type and sex*
$\alpha_0 I_j$ = *interaction of feathering-type and feather colour line*
$\mathcal{E}ijkl$ = *residual error term*

Ethics Approval
The experimental procedure on animal use was approved by the Animal Research Ethics Committee (AREC) of the Kwame Nkrumah University of Science and Technology.

RESULTS AND DISCUSSION

Growth and Egg Production Performance of the Birds

Body Weight (BW)

Males were heavier ($p<0.001$) than females at 22 weeks of age (Table 1). Kgwatalala and Segokgo (2013) reported similar findings in their work with Australorp x Tswana crossbred chickens and purebred indigenous Tswana chickens. The crossbred males were significantly heavier ($p<0.05$) than females from 10 weeks of age. This has been established as sexual dimorphism in BW. Kgwatalala and Segokgo (2013) stated that the presence of sexual dimorphism in BW at 10 weeks of age indicates early enhanced growth in crossbred males than females probably as a result of enhanced secretion of male sex hormones that promote rapid growth. Hence crossbred males thus had more pronounced effects of heterosis on growth or early enhanced growth compared to their female counterparts because of effective male growth hormones compared with female hormones (Adomako and Asamoah, 2025; Asumah et al., 2022; Adomako et al., 2014b; Singh *et al*., 1982; Nwenya *et al*., 2017).

No significant differences ($p>0.05$) were recorded in BW between the two phenotypes even though naked neck birds are noted for their superiority over their normal feathered counterparts in most production parameters under moderate to high ambient temperature (Adomako *et al*., 2014b), but this advantage was not exhibited in this study (Table 1).

At 36 weeks (Table 1), males recorded higher body weights than females ($p<0.05$). No significant differences ($p>0.05$) were recorded between the two phenotypes. At 36 weeks (Table 1), there was a significant ($p<0.05$) phenotype x sex interaction.

Table 1: Effect of sex, feather colour and naked neck gene on body weight of layers (at 22 and 36 weeks)

Factor	Body weight	
	22 weeks	36 weeks
SEX (S)		
Male	2.083[a]	2.437[a]
Female	1.440[b]	1.862[b]
s.e.d.	0.029	0.022
LINE (L)		
White	1.807[a]	2.130
Brown	1.717[b]	2.168
s.e.d.	0.029	0.022
PHENOTYPE (P)		
Normal feathered	1.755	2.133
Naked neck	1.768	2.165
s.e.d.	0.029	0.022
P. VALUES		
Sex	<.001	<.001
Line	0.002	0.085
Phenotype	0.649	0.154
SxL	0.733	0.006
SxP	0.570	0.002
LxP	0.032	<.001
SxLxP	0.003	0.006

[a,b]Means within the same column under each factor with different superscripts are significantly different (P<0.05). Means with the same column under each factor with no superscripts are not significantly different (P>0.05).

Egg production

Results of the weekly egg production performance show that the average number of eggs laid per week increased as the bird's age increased up to peak production (Table 2). There was no significant difference ($p > 0.05$) between the lines during the first four weeks of egg production (Wk. 16 to Wk. 20), however from the 22nd week to the 32nd week, the white line laid significantly ($p < 0.05$) more eggs than the brown layer line (Table 2).

There were no significant differences ($p > 0.05$) between the naked neck (*Nana*) and the normal feathered (*nana*) layers in the number of eggs produced (Table 2).

Capital tract

Males recorded higher follicle numbers than females in this tract ($p<0.05$). This tract is locat-

ed at the head region (Table 3). Due to sexual dimorphism, males naturally tend to have larger heads than females and as a result, have a larger surface area and hence recorded more follicle numbers. Aboagye Poku *et al*. (2017) in a similar work done on normal feathered and frizzle birds, had males recording higher follicle numbers than females in this tract. Normal feathered birds had higher follicle numbers ($p<0.05$) than the naked neck birds. The extent of follicle reduction in this tract for the naked neck bird was quite pronounced. The lower follicle numbers recorded

Table 2: Egg production performance of the experimental hens

Effect	Age of layer hens (Weeks)								
	16	18	20	22	24	26	28	30	32
Lines									
White	4.00	25.40	58.00	91.4[a]	136.20[a]	151.80[a]	142.40[a]	127.20[a]	129.20[a]
Brown	3.50	20.83	41.17	62.00[b]	76.33[b]	100.83[b]	96.33[b]	84.50[b]	97.67[b]
Phenotypes									
Naked neck	3.50	25.33	46.50	77.67	107.67	124.67	119.33	102.50	113.83
Normal feathered	4.00	20.00	51.60	72.60	98.60	123.20	114.80	105.60	109.80
P-Values									
Lines (L)	0.97	0.68	0.14	0.01	< 0.002	0.004	0.002	0.001	0.008
Phenotypes (P)	0.97	0.43	0.69	0.5	0.07	0.74	0.58	0.70	0.55
L x P	0.87	0.61	0.19	0.09	0.03	0.81	0.98	0.98	0.44

[a,b]Means within the same column under each factor with different superscripts are significantly different (P<0.05). Means with the same column under each factor with no superscripts are not significantly different (P>0.05).

Table 3: Feather distribution in the dorsal region of normal feathered and naked neck birds

Factor	TRACT						
	Capital	Dorsal cervical	Interscapular	Humeral	*UMCP	Dorso pelvic	Dorsal caudal
SEX (S)							
Male	520.0[a]	216.0[a]	97.2	129.3	499.0	491.7[a]	103.2
Female	459.0[b]	135.0[b]	94.8	125.1	488.0	442.6[b]	92.8
SED	23.5	32.0	8.6	10.1	27.7	12.1	10.7
PHENOTYPE (P)							
Normal feathered	597.0[a]	351.0[a]	118.6[a]	153.8[a]	538.0[a]	485.4[a]	102.3
Naked neck	382.0[b]	0.00[b]	73.5[b]	100.6[b]	449.0[b]	448.0[b]	93.6
SED	23.5	32.0	8.6	10.1	27.7	12.1	10.7
P. VALUES							
Sex	0.013	0.016	0.783	0.676	0.690	<.001	0.338
Phenotype	<.001	<.001	<.001	<.001	0.003	0.005	0.417
SxP	0.414	0.016	0.582	0.087	0.939	0.465	0.455

*[a,b]Means within the same column under each factor with different superscripts are significantly different (P<0.05). Means with the same column under each factor with no superscripts are not significantly different (P>0.05). *UMCP= Upper marginal coverts of prepatagium.*

here for naked neck birds can be attributed to the effect of the naked neck gene, it is known to be a feather reducing gene. No significant sex x phenotype interaction was recorded ($p>0.05$) for the capital tracts.

Dorsal cervical tract

Lucas and Stettenheim (1972), established that the dorsal cervical tract begins as a continuation of the capital tract and covers the lateral and dorsal surfaces of the neck in the anterior region (Table 3). Males recorded higher follicle numbers ($p<0.05$) than females in this tract. This is the neck region of the bird and due to sexual dimorphism (Owens and Short, 1995), males have longer necks than females. This contributed to the males having a larger surface area for this region and hence the higher follicle numbers ($p<0.05$). Comparing the phenotypes, normal feathered birds had follicles on this tract ($p<0.05$) whereas the naked neck birds had no follicles since this is a region of bareness on their neck. Unlike other tracts where there were reduced follicle numbers, the effect of the naked neck gene is very pronounced in the dorsal cervical tract, making it completely bare without feather follicles hence its associated name, *naked neck or bare neck*. A similar work done by Adomako *et al.* (2014a) and Dunga *et al. (*2025) on normal feathered, frizzle and naked neck birds showed similar results for this tract.

The interaction between sex and phenotype was significant for this trait ($p<0.05$); the normal feathered males recorded higher follicle numbers ($p<0.05$) than normal feathered females but the naked neck males and the naked neck females had the same values (no follicles).

Interscapular tract

This tract constitutes a group of follicles and feathers distinct from the anteriorly located dorsal cervical tract (Lucas and Stettenheim (1972). No significant differences were recorded between sexes ($p>0.05$). Normal feathered birds recorded higher follicle numbers ($p<0.05$) than the naked neck phenotype. Naked neck birds had no feathers at the dorsal cervical tract and this tract somewhat merges with the interscapular tract. The resultant bareness on their necks extends a little into this tract hence the reduced follicle numbers. This is in agreement with the findings of Dunga *et al.* (2025) and Adomako *et al*. (2014a) who also recorded similar results for this tract when they studied the pterylosis of naked neck, frizzle and normal feathered birds. No significant interactions were recorded for this tract ($p>0.05$).

Humeral tract

Lucas and Stettenheim (1972), described the humeral tract as a tract having well-defined boundaries. The tract forms a band that extends from the anterior edge of the shoulder and the posterior corner of the prepatagium. According to the same authors, the humeral tract may be joined at its anterior end by one or two rows of feathers of the ventral cervical tract in chickens. It was observed to be so for the normal feathered birds whereas the separation was quite distinct for the naked neck birds.

No significant differences ($p>0.05$) existed between the sexes. Higher follicle numbers were recorded for normal feathered birds than their naked neck counterparts in this tract ($p<0.05$). The influence of the naked neck gene was also evident in this tract showing reduced follicle numbers for the naked neck birds. The interaction between phenotype and sex was not significant ($p>0.05$).

Upper Marginal Coverts of Prepatagium

Lucas and Stettenheim (1972), described the feathers on the ventral side of the tract to be often smaller and less numerous than those on the dorsal side. This was also observed for both groups of birds in this study. There was no significant difference ($p>0.05$) between follicle numbers of males and females. This tract is located on the wing. Normal feathered birds had more follicles for this tract as compared to naked neck birds ($p<0.05$). Lower follicle numbers recorded in the naked neck birds is associated with the feather reducing effect of the naked neck gene. Phenotype by sex interaction was not significant ($p>0.05$) for this tract.

Dorsopelvic tract

This tract is caudal to the interscapular tract. Technically, there is a dorsal and pelvic tract but due to the broad continuity in both tracts for chickens, it is categorized as one, Dorsopelvic (Lucas and Stettenheim, 1972).

Males recorded higher numbers ($p<0.05$) than females. The size of the males as a result of sexual dimorphism contributed to this result (Owens and Short, 1995). As previously established, bigger size correlates to a larger surface area and hence, the higher follicle numbers recorded in males. Aboagye Poku *et al*. (2017) also recorded higher follicle numbers in males than females. Between phenotypes, as a result of the feather reducing nature of the naked neck gene, normal feathered birds had more follicles than naked neck birds in this tract ($p<0.05$). The findings of this study agree with the findings of Aboagye Poku *et a*l. (2017), but not with those of Dunga *et al*. (2025) and Adomako *et al*. (2014a) who recorded higher follicle numbers for naked neck birds per this tract. This could be as a result of differences in feather densities and surface areas among various breeds of chicken.

Dorsal caudal tract

No significant differences were recorded across all factors ($p>0.05$), (Table 4). Dunga *et al*., (2025) however, recorded higher follicle numbers for normal feathered birds for this tract than naked neck birds. Again this could be as a result of differences among breeds as stated earlier.

Pterylosis of normal feathered and naked neck birds

Dorsal region

The dorsal region is made up of the capital, dorsal cervical, interscapular, humeral, upper marginal coverts of prepatagium (UMCP), dorsopelvic and dorsal caudal tracts. Table 3 and Plates 5 -11 show the pterylae for these tracts.

Ventral region

This region comprises the ventral cervical, pectoral, sternal, abdominal, cloacal circlet and ventral caudal tracts. The results obtained are summarized in Table 4 and Plates 12-17.

Ventral cervical tract

No significant difference was recorded between the sexes ($p>0.05$). Normal feathered birds had more follicles ($p<0.05$) in this tract than their naked neck counterparts. The ventral cervical tract is on the ventral side of a bird's neck. This tract generally divides to form two branches on each side of the midline. Lucas and Stettenheim (1972), stated that in chickens, the tracts have a complete continuity with the pectoral tracts and an arbitrary line of separation is situated at the anterior end of the shoulder. For naked neck chickens however, even in this study, the folli-

Table 4: Feather distribution in the ventral region of normal feathered and naked neck birds

Factor	Tract					
	Ventral Cervical	Pectoral	Sternal	Abdominal	Circlet	Ventral Caudal
SEX (S)						
Male	254.0	267.5[a]	246.5	116.6	16.3[b]	40.6
Female	225.0	227.1[b]	254.6	121.0	24.2[a]	43.0
SED	20.4	15.0	15.1	13.9	3.7	4.0
PHENOTYPE (P)						
Normal feathered	328.0[a]	292.3[a]	309.1[a]	164.4[a]	40.5[a]	45.2
Naked neck	151.0[b]	202.3[b]	192.0[b]	73.4[b]	0.00[b]	38.5
SED.	20.4	15.0	15.1	13.9	3.7	4.0
P. VALUES						
Sex	0.162	0.010	0.594	0.754	0.037	0.553
Phenotype	<.001	<.001	<.001	<.001	<.001	0.103
SxP	0.375	0.780	0.018	0.233	0.037	0.656

[a,b]Means within the same column under each factor with different superscripts are significantly different (P<0.05). Means with the same column under each factor with no superscripts are not significantly different (P>0.05).

cles within the tracts are not continuous as there is a break or apterium in the mid region of the tract.

The bareness on the neck of the naked neck bird due to the presence of the naked neck gene, extends into this tract and is the reason for the huge margin of difference between follicle numbers of the normal feathered and the naked neck birds (328.0 and 151.0). This agrees with the results of Aboagye Poku *et al*. (2017), Dunga *et al*. (2025) and Adomako *et al*. (2014a).

Pectoral tract

The pectoral tract overlies the rib cage and sternum, and is ventral to the pectoral muscles (Lucas and Stettenheim, 1972). In this study, the pectoral tracts were not confluent with the sternal tracts, which is often the case for some species of birds as reported by Lucas and Stettenheim (1972). The pectoral apterium separated the tracts.

As shown in Table 4, males recorded higher follicle numbers ($p<0.05$) than females for this tract. Aboagye *et al*. (2017) however had females recording higher follicle numbers for this tract than males. Between the phenotypes, normal feathered birds had more follicles ($p<0.05$) in this tract as compared to their naked neck counterparts. However, the interaction between feathering-type and sex was not significant ($p>0.05$). The reduced follicle numbers recorded by the naked neck birds is as a result of the naked neck gene. The results reported here agree with those of Dunga *et al*., (2025) and Adomako *et al*., (2014a).

Sternal tract

There were no significant differences ($p>0.05$) in follicle numbers for male and female birds. This tract is located at the breast region of the bird. This tract lies on each side of the keel; it is sometimes close to it or far laterally (Lucas and Stettenheim, 1972). It was narrow and relatively close to the keel in this study. Naked neck birds recorded significantly lower ($p<0.05$) follicle numbers in this tract than the normal feathered birds. The extent of reduction was quite high, reflecting a more pronounced effect of the naked neck gene on this tract. This agrees with results of Dunga *et al.* (2025) and Adomako *et al*. (2014a) who had similar findings. Aboagye Poku *et al*. (2017) however, had frizzle birds recording higher numbers than normal feathered birds for this tract.

The normal feathered birds recorded significantly higher follicle numbers ($p<0.05$) in the sternal tract than the naked neck birds.

Abdominal tract

The abdominal tract is continuous with the sternal tract; only separated by the posterior margin of the sternum; positioned at about the level where the two arms of the sternal tract unite (Lucas and Stettenheim, 1972). This observation was same for both groups of birds in this study although the feather distribution was sparse in the naked neck birds.

Normal feathered birds had more follicles than naked neck birds for the abdominal tract ($p<0.05$). The effect of the naked neck gene was pronounced here as well, with the normal feathered birds having more than twice the follicle numbers of the naked neck birds. Adomako *et al.* (2014a) also recorded similar results but Aboagye Poku *et al*. (2017) recorded no significant differences here with respect to frizzle and normal feathered birds. No significant differences were recorded for sex in this tract ($p>0.05$) and the phenotype x sex interaction was not significant ($p>0.05$).

Cloacal circlet

This tract is usually characterized by a single row of small feathers surrounding the vent. The cloacal circlets studied here were distinct from the abdominal tracts on both the anterior and posterior surfaces of the vent. Females recorded higher follicle numbers ($P<0.05$) than males. Aboagye Poku *et al*. (2017) on the contrary, recorded more follicle numbers for males than females. Naked neck birds did not have any follicles on this tract. The bareness of this tract for the naked neck birds could be explained as a result of the action of the naked neck gene (Adomako and Asamoah, 2025). Adomako *et al*. (2014a) also reported similar results when they studied naked neck, frizzle and normal feathered birds.

Ventral caudal tract

This tract is limited to a few rows of small, irregularly scattered feathers adjacent to the under

- tail coverts. An apterium separates the right and left halves of the ventral caudal tract; its continuation along the margin of the dorsal vent creates a natural distinction between the abdominal and ventral caudal tracts (Lucas and Stettenheim, 1972). This distinction was observed as well in this study.

No significant differences were recorded for all factors for this tract ($p>0.05$). No significant interaction was also recorded ($p>0.05$). The naked neck gene and sex did not significantly influence feather development within this tract. The comparative studies between the feathering-types and sex on this tract in this study was novel, as all the authors quoted earlier (Adomako *et al* 2014; Dunga *et al*., 2013 and Aboagye Poku *et al*., 2017) did not study this tract.

Lateral region

The lateral region comprises the lateral body, femoral and crural tracts, and the results obtained for these tracts are shown in Table 5 and Plates 18-20.

Table 5: Feather distribution in the lateral region of normal feathered and naked neck birds

Factor	Tract		
	Lateral body	Femoral	Crural
SEX (S)			
Male	26.80	581.0	548.0
Female	25.10	550.0	544.0
S.E.D.	1.7	22.5	29.0
PHENOTYPE (P)			
Normal feathered	51.90[a]	641.0[a]	604.0[a]
Naked neck	0.00[b]	490.0[b]	488.0[b]
S.E.D.	1.7	22.5	29.0
P. VALUES			
Sex	0.321	0.182	0.880
Phenotype	<.001	<.001	<.001
SxP	0.321	0.133	0.246

[a,b]Means within the same column under each factor with different superscripts are significantly different ($p<0.05$). Means with the same column under each factor with no superscripts are not significantly different ($p>0.05$).

Lateral body tract

This is found on the lateral body surface. The feathers here are covered by the folded wing. No significant difference was recorded between the sexes ($p>0.05$). The naked neck birds did not have any follicles present in their lateral body tract but the normal feathered birds had follicles present in this tract. The interaction between sex and phenotype was also not significant ($p>0.05$). This tract is also another region of bareness on the naked neck bird and it is as well associated with the action of the naked neck gene. These results collaborate the earlier findings of Dunga *et al*. (2013) and Adomako *et al.* (2014a).

Femoral tract

This tract is on the integument covering the thigh and is spread over most of the surface of the thigh. No significant differences were recorded between the sexes and the sex by phenotype interaction ($p>0.05$) was not significant. Normal feathered birds had more follicles present in this tract than the naked neck birds ($p<0.05$). The reduced feathering effect of the naked neck gene was evident in this tract. The reduction was relatively high. Aboagye Poku *et al*. (2017) and Dunga *et al*. (2025) reported similar findings. Adomako *et al.* (2014a) however, reported that there were no significant differences ($p>0.05$) in follicle numbers between the naked neck and normal feathered for this tract.

Crural tract

The crural tract encircles the lower leg from the knee to the ankle joint. Observations made in this study agree with Lucas and Stettenheim (1972) descriptions for this tract. The plumage is described to be relatively far apart and as such, do not form a dense plumage. The feathers on the inner surface are less than those on the external surface and tend to be downier.

No significant difference was recorded in follicle numbers between the sexes ($p>0.05$). The normal feathered birds had significantly higher follicle numbers ($p<0.05$) here than the naked neck birds. This is as a result of the feather reducing properties of the naked neck gene. Aboagye Poku *et al.* (2017) reported that frizzle birds had more follicles in this tract than normal feathered birds.

Feathering intensity in normal feathered and naked neck birds

Birds possessing the naked neck gene have bare necks and reduced feather coverage throughout the body and these account for 20-30% feather reduction in heterozygotes and 30-40% in homozygotes (Fernandes et al., 2023; Desta, 2021; Cai et al., 2025).

In this study, only the heterozygous naked neck was studied and the average reduction of feather coverage in naked neck males was 30.8% (Table 6) which was close to the upper limit of what had been published (20% - 30%) earlier. However, the naked neck females had their feather coverage reduced by 37.4% (Table 6) which was much higher than what had been published in the literature (20-30%). The naked neck gene is a single incompletely dominant gene which could be introgressed into any breed or strain of chicken. The variation between the results of this study and what had been published earlier (Desta, 2021; Fernandes et al., 2023; Adomako & Asamoah, 2025). could be due to differences in breeds or strains. The variation could also be due to fact that the naked neck gene had mutated and is now able to reduce feather coverage in chicken to a larger extent than before (Loewe, 2008). The extent of feather reduction was higher in females than males because females had smaller body sizes and therefore recorded significantly smaller follicle numbers ($p<0.05$) compared to males in almost all the tracts.

It was observed in this study that the difference in contour feather numbers between males and females was 303.6 corresponding to 7.3% less feathers for the female population. The difference in feather numbers between normal feathered males and normal feathered females was 174.5, which was 3.6% less feathers for the normal feathered female population. The difference in feather numbers between naked neck males and naked neck females was 432.7 corresponding to 12.7% less feathers for the population of female naked neck birds. These findings clearly show that the reduction of feather coverage caused by the naked neck gene is more pronounced in females than males.

CONCLUSIONS

The naked neck gene did not have any influence on body weight gain at 22 weeks (sexual maturity) and 36 weeks (peak production) as well as rate of lay in this experiment. Males had higher follicle numbers than females in the following tracts due to their larger body size which provided a larger surface area for a greater number of follicles to develop. Females had higher follicle numbers in the cloacal circlet tract than males. Naked neck birds had lower follicle numbers in almost all feather tracts. The naked neck gene reduced follicle numbers in birds by 30.8% in males and 37.4% in females in its heterozygote state. This slightly deviates from what had been published already in literature for feather reduction in heterozygotes (20-30%). Feather follicles in the dorsal caudal tract within the dorsal region and the ventral caudal tract within the ventral region were not influenced by the naked neck gene.

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Table 6: Effect of the naked neck gene (*Na*) on the feathering intensity of the two sexes

		FACTOR			
SEX	**Phenotype**	**Number of feathers for each sex**	**Average feathers for each phenotype under the two sexes**	**Differences between phenotypes under the two sexes**	**% of reduced feathering in naked necks**
Male	Normal feathered	4153.95	4909.4	1510.9	30.8%
	Naked neck		3398.5		
Female	Normal feathered	3850.35	4734.9	1769.1	37.4%
	Naked neck		2965.8		

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