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The "Naked neck" gene and the adaptability of the native chicken to heat stress on station in Cameroon

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Abstract

The rational use of the native chicken genetic resource is seen a viable option for sustainably improving poultry meat production in Cameroon. This study aimed at assessing the potential of the Na gene for resilience under acute heat stress. The study was done in two trials. Firstly, a total of 180 young roosters reared in similar management conditions from the 1st to the 8th week of age were randomly distributed per genotype according to a 3 x 2 factorial design including two treatments (acute and moderate ambient temperatures) of 90 birds each and three genotypes (Na*Na, na*na and Na*na) of 30 birds per treatment. Treatments consisted of moderate and acute ambient temperatures of 25-27°C and 39 - 42°C respectively for 5 hours/day from 8 to 12 weeks of age. The genotypes within and between the treatments were compared for body weight (BW), average daily weight gain (ADG), water consumption (WC), feed consumption (FC), and feed conversion ratio (FCR). Results showed that the na*na and Na*na were statistically comparable but superior to the Na*Na genotype under moderate temperature. The three genotypes were significantly affected (P<0.05) by the heat stress. However, the Na*na was less affected and maintained the highest ADG and lowest FCR. For the second trial, 90 birds including 30 birds randomly sampled per genotype were compared for the feathering intensity and five carcass characteristics and giblets at 24-week-old. The results revealed an association of the "Na" gene with 21 to 50 % feather reduction in heterozygote and homozygote respectively whereas heterozygote naked neck had greater body and carcass weight as well as giblet and head weights (P<0.05). The animal model equation could clearly quantify the genotype effect. The phenotypic advantage evidenced for the Na gene is confirmed as an adaptation to heat stress whereas the significant superiority of heterozygote Na*na for most of the traits opens a window for the valorisation of potential overdominance effects for poultry breeding in hot climates.

Keywords: Cameroon, native chicken, feathering intensity, growth, heat tolerance, Na-gene

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INTRODUCTION

According to 2017 and 2018 national statistics (INS, 2019), poultry contributes to 37.15% of total livestock meat production and is by far the main animal protein supplier in terms of meat (152 207 tons/year) and eggs (75 205 204 tons/year) in Cameroon. *Gallus gallus* species

represents 80% of the national poultry flock. However, despite the most significant contribution of poultry meat and eggs to food security and poverty alleviation, the national production is highly dependent on imported commercial strains of chickens. The dependence of national poultry production on imported breeds and commercial strains of birds is a serious threat to the conservation and sustainable use of native chicken resources. There has been a rapid increase in the importation of poultry meat from 100 000 tons to 10 100 000 tons between 1990 and 2000 (INS, 2019). The importation of exotic breeds as the main driver of the intensive poultry production sector brings to jeopardy the preservation of genetic resources of the native chicken. Native poultry constitutes 80% of backyard poultry production. It is a source of identity as well as a cultural legacy for the local communities (Mwacharo *et al.,* 2013). The native chicken population of Cameroon exhibits important genetic diversity despite its slow growth rate and low laying performance which is a serious constrain for national productivity (Keambou *et al.,* 2009; Hako *et al.,* 2015). Whereas restrictions in movement and trade as a result of the current COVID-19 crisis has exposed the fragility of the national livestock sector which is highly dependent on imported genetic resources. There is therefore a pressing need to address this trend by valorising native chicken genetic resources for a more resilient livestock sector. In this light, major genes with significant importance on adaptability to tropical environmental conditions were previously identified. These include among other genes, the feathered shank gene (Pti) that evidenced beneficial effect on growth but a less favourable effect on early chicken mortality (Hako *et al*., 2012); the Frizzle feathered gene (F) and the dwarf gene (dW) that improved heat stress tolerance and viability of the subjects but reduced growth rate and finally the naked neck gene (Na) that positively affected egg production and feed efficiency (Hako *et al*, 2009; Fotsa *et al*., 2011; Setegn *et al*., 2021 and Fathi *et al*., 2022). The naked neck gene has been recommended as a superior genotype for tropical poultry breeding with improved feed efficiency (Fathi *et al*. 2008 and 2022; Patra *et al*., 2002). Besides, Galal and Fathi (2001) reported that it improves the live weight of the chicken. In most cases, the beneficial effects of the naked neck gene were attributed to feather reduction thus enhancing its ability to dissipate heat and adapt to high ambient temperatures while maintaining some acceptable level of food intake as well. There is therefore a need to assess and quantify the effect of the naked neck gene on feathering reduction and adaptability to heat stress on native chickens in Cameroon in order to generate enough reliable information for breeding and conservation purpose. To this effect, a performance comparison is commonly used to discriminate among different phenotypes of native chickens in low input production systems. This study aims at estimating the Naked neck gene effect on adaptability to heat stress using the animal equation model.

MATERIALS AND METHODS

The animal material used in this study was not subjected to any restriction and was approved by the scientific committee (DZOO/CE/01322) of the Department of Animal Science of the University of Dschang.

Study site and animal material

The study was carried out on station at the Research and Application Farm of the University of Dschang (FAR/UDs), located in the Western Highlands of Cameroon between latitude 5^{o} and 7^{o} N and longitude 8^{o} and 20^{o} East. The experiment was conducted on native chickens of the region. All the birds were uniformly barred feathered with a characteristic white skin and shanks, the only discriminating factor being the presence or absence of the “Na” gene. The three genotypes studied were the Homozygous naked neck chicken (Na*Na), the normally feathered chicken (na*na) and their crossbred (Na*na).

Experimental design

To achieve the objectives of this study, two trials were conducted. For the first trial,
a total of 180 young roosters reared on litter in similar management conditions in 18 pens of 3 m^{2} for 10 birds each. Birds were randomly distributed into the pens according to their genotype. Before the trial (1st to 8th week of age), the effects of the pens as replicates were not significant (P>0.05) and therefore were not considered for the statistical design. As from the 8th week of age, each pen was equipped with a *Simple Deluxe 150W Ceramic Heat Emitter bulb* as the heat source and adapted with a thermostat for temperature control. A 3 x 2 factorial design including two treatments (acute and moderate ambient temperatures) of 90 birds each and three genotypes (Na*Na, na*na and Na*na) of 30 birds per treatment was implemented. The treatments consisted of moderate and acute ambient temperatures of 25 – 27°C and 39 – 42°C respectively for 5

hours/day (i.e., from 11:00 am to 4:00 pm) from 8 to 12 weeks of age. The genotypes within and between the treatments were compared for body weight (BW), average daily weight gain (ADG), water consumption (WC), feed consumption (FC), and feed conversion ratio (FCR). Water and feed were served *at libitum* and the quantities consumed were evaluated by computing the difference between the total quantity distributed and the residues. The parameters studied included the body weight (BW) and variation in body weight (ΔBW), the average daily gain (ADG), feed and water consumption (FC and WC), and feed conversion ratio (FCR). Following the protocol of Hako *et al.* (2009), the ADG and FCR ratio were estimated using the following formula:

$$ADG = \frac{Final\ weight\ (in\ grams) - Intitial\ weight\ (in\ grams)}{time\ period\ (1\ day)}$$

$$FCR = \frac{Quantity\ of\ feed\ consumed\ in\ grams}{Average\ daily\ weight\ gain\ in\ grams}$$

In the second trial, 90 birds including 30 birds randomly sampled within each genotype from the first trial were used at 24 weeks of age for the estimation of carcass characteristics and the feathering intensity. The sampled birds were weight and then, slaughtered, plucked, gutted and dismembered. The weighing was done using a digital scale (3000g max, ± 1g) for the carcass and the different organs including the head, shanks, and giblets (gizzards, heart, lung, liver, pancreas, spleen, intestine, and testes). The carcass percentage of the weighed organs was estimated and compared according to the three genotypes. For the feathering intensity on each carcass, the breast and the thigh were delineated in triangles meanwhile the leg was delineated in a trapeze as represented in Figure 1. A calliper (200mm max ± 0,01mm) was used for the linear measurements as delineated. The number of pores on the skin of each delineated organ was counted and the surface area estimated using the appropriate formula for the triangles (breast and thigh) and trapeze (leg). The feathering intensity (FI) was then estimated as the number of pores over the surface area of the skin in cm^2 for the considered organ.

Data analysis

Data collected was subjected to a generalised linear model of Analysis of Variance (ANOVA) with two factors for trial 1 and one factor for trial 2 in order to determine the relationship between the dependent variable (performance) and the independent variables (genotype and temperature). When ANOVA revealed a significant difference in performance between the different genotypes considered, a Duncan's test at 5% and 1% thresholds was used post hoc to separate the means. The statistical equation employed was adapted from the models cited by Iguodala *et al.* (2016) and Chen *et al.* (2009).

The two factorial general linear ANOVA model used for the first trial is summarised as follows:

$$Y_{ijk} = \mu + g_i + t_j + gt_{ij} + e_{ijk}$$ where;

Y_{ijk} = Performance (BW / ADG / FCR) of individual *k* of genotype *i* subjected to temperature *j*
μ = Population mean
g_i = Fixed effect of genotype i; i varying from 1 to 3
t_j = Fixed effect of temperature t; t varying from 1 to 2
gt_{ij} = Interaction between genotype and temperature
e_{ijk} = Residual effect of observations

For the second trial, the following one-factor general linear ANOVA model was used:

$$Y_{ij} = \mu + g_i + e_{ij}$$, where;

Y_{ij} = Performance (feathering intensity /carcass trait) of individual *j* of genotype *i*
μ = Population mean
g_i = Fixed effect of genotype i; i varying from 1 to 3
ei_j = residual effect of individual j of genotype i.

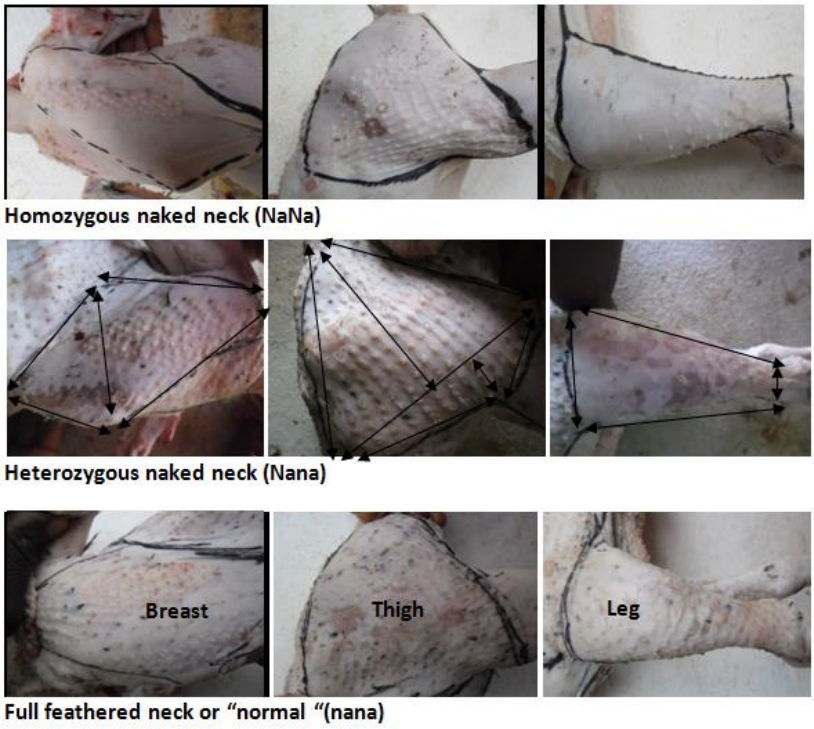

Figure 1: Estimation of feathering intensity (FI) as the number of pores per unit area (in cm^2) of skin of homozygous NaNa (top), heterozygous Nana (middle), and "normal" nana (bottom). From left to right, parts of the body on which FI were estimated including the breast, the thigh and the leg. In Nana (middle), the delineation of triangles (brisket and thigh) and a trapeze (leg) facilitated the application of the appropriate formula for FI.

RESULTS

Effect of Na gene on growth, FCR and acute heat stress

A linear mixed model (or animal model) as described in Setegn *et al.,* (2021) and Aggrey and Cheng (1994) was used to estimate the random effect of the direct additive genetic value of each genotype on the performance at different ages in both trials. This included the mean breeding temperature as a fixed environmental effect. Likewise, the mean temperature effect on bird performance was equally evaluated by fitting the genotype as a fixed effect in the model. The model was manually fitted into Excel and applied to the data. The general model employed can be summarised thus:

The effect of the naked neck on the evolution of the live body weight of the local chicken is presented in Table 1.

$$Y = X\beta + Za + e \text{ (trial 1), and}$$
$$Y = Za + e \text{ (trial 2).}$$

Where Y is the vector of performances (BW, ADG, and FCR for trial 1 and FI and Carcass trait for trial 2), β the vector of the effects of the external factors (here, the means for temperature $T1$ and $T2$), a the vector of genetic values ($Na, Na * na,$ and na), e the vector of residual or individual effects, X and Z the incidence matrix of the external and genetic values so that for an individual from each of the experimental unit:

$$\begin{bmatrix} y_{Na1} \\ y_{Na2} \\ y_{Nana1} \\ y_{Nana2} \\ y_{na1} \\ y_{na2} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \mu_{1Na1} \\ \mu_{1Na2} \\ \mu_{1Nana1} \\ \mu_{2Nana2} \\ \mu_{1na1} \\ \mu_{2na2} \end{bmatrix} + \begin{bmatrix} 1 & 0 & 0 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} a_{Na} \\ a_{Na} \\ a_{Nana} \\ a_{Nana} \\ a_{na} \\ a_{na} \end{bmatrix} + \begin{bmatrix} e_{Na1} \\ e_{Na2} \\ e_{Nana1} \\ e_{Nana2} \\ e_{na1} \\ e_{na2} \end{bmatrix} \text{ (trial 1)}$$

$$\begin{bmatrix} \mu_{Na} \\ \mu_{Nana} \\ \mu_{na} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \mu_1 \\ \mu_2 \\ \mu_3 \end{bmatrix} + \begin{bmatrix} a_{Na} \\ a_{Nana} \\ a_{na} \end{bmatrix} \quad \text{(trial 2)}$$

The genotype and breeding temperature significantly influenced (P <0.05) the live weight of the birds from the 9th week of age. Irrespective of ambient temperature, the highest body weight is observed for the normal feathered genotype (na*na) whereas a dose-effect is observed for the Na gene in terms of body temperature reduction from the 9th to the 12th week of age. The acute heat stress had an unfavourable effect on the evolution of the bodyweight irrespective of the genotype (P<0.05).

The study of the variation in the BW (Figure 2) and feed conversion ratio (Figure3) of the different genotypes under acute heat stress reveals a general variable trend depending on the genotype of the chicken. The least variation in the body temperatures of the local chickens was recorded for the naked neck (Na*Na) chickens which could explain why the latter was less affected by the rise in ambient temperature in comparison to the normally feathered (na*na) and crossbred (Na*na) chickens. Hyperthermia induced between the 8th to the 12th week led to a drop in weight gain by -5.78%, -7.57% and -14.74% for the naked neck, naked neck x normal and normal genotypes respectively. The effect of the induced heat stress on weight gain of the naked neck chicken was fairly steady from the 9th to the 10th week as well as between the 11th and the 12th week. The results of the random effects of the genotype and environment on the body weight are summarised in Tables 2 and 3 respectively. The variation of body weight evidenced is explained by both the genotype and the temperature increases with clear evidence of the dose-effect of the Na gene from -26 to -70 grams of body weight from the homozygote dominant Na*Na to the recessive na*na with -36 grams for the heterozygote at 12 weeks (Table 2). Carriers of the Na gene carriers become are gradually less affected by the 5°C increase of temperature from 8 to 12 weeks (Table 3) with -26 to +6.5 grams body weight gain in Na*Na, +16 to 28 grams in Na*na and +10 to -34 grams in nana.

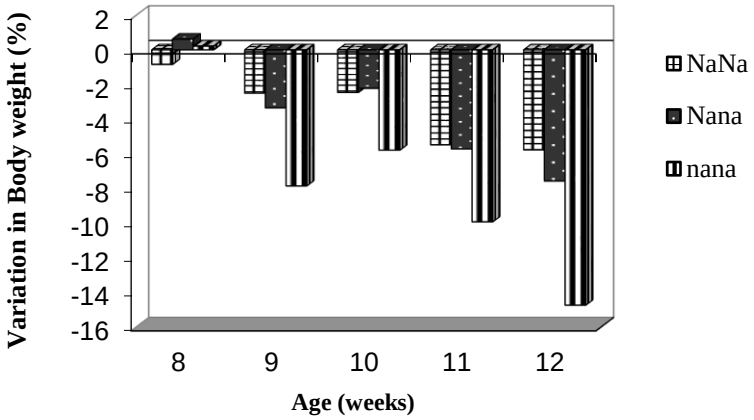

Figure 2: Variation in body weight according to genotype under acute heat stress.

Table 1: Evolution in body weight (in grams) of Cameroon local chickens according to genotype and breeding temperature

Genotype (G)/ temperature (T)	Age of birds in weeks				
	8	9	10	11	12
Na*Na					
25-27°C	498.35±48.78	584.00±36.10**b**	658.30±29.52**c**	755.40±34.53**b**	899.10±30.72**b**
39-42°C	494.15±48.82	569.40±37.72**c**	639.10±28.91**c**	713.95±38.15**c**	847.15±33.32**c**
Na*na					
25-27°C	532.60±31.39	610.85±32.05**ab**	695.20±30.59**ab**	793.55±25.80**a**	939.35±24.67**a**
39-42°C	535.90±30.63	590.40±26.22**b**	679.75±28.8**b**	748.15±30.88**b**	868.20±34.88**c**
na*na					
25-27°C	528.95±30.70	626.75±25.29**ab**	706.95±35.00**a**	794.10±30.07**a**	946.15±33.46**a**
39-42°C	530.10±27.45	577.50±34.01**b**	666.00±29.74**b**	715.25±37.43**c**	806.65±29.39**d**
P-value (G)	n.s	<0.01	<0.01	<0.01	<0.01
P-value(T)	n.s	<0.01	<0.01	<0.05	<0.05
P-value	n.s	<0.01	<0.01	<0.01	<0.01

Key: ^{abc} on the same column and between rows; the means assigned to the different letters are significantly different (P<0.05). ns=not significant, Na*Na= homozygote naked neck, Na*na=heterozygote naked neck, na*na= normal feathered neck

Table 2: Effect of the naked neck gene (Na) on the evolution of body weight (in grams) in the Cameroon local chicken according to breeding temperature

Genotype / Temperature	Age in weeks				
	8	9	10	11	12
Na*Na					
25-27°C	2.10	7.30	8.10	20.73	25.98
39-42°C	-2.10	-7.30	-8.10	-20.73	-25.98
Na*na					
25-27°C	-1.65	10.23	7.73	22.70	35.57
39-42°C	1.65	-10.23	-7.73	-22.70	-35.57
na*na					
25-27°C	0.58	24.63	20.48	39.43	69.75
39-42°C	-0.58	-24.63	-20.48	-39.43	-69.75

Na*Na= homozygote naked neck, Na*na=heterozygote naked neck, na*na= normal feathered neck

Table 3: Effect of the breeding temperature on the evolution of body weight (in grams) in the Cameroon local chicken according to genotype

Temperature / Genotype	Age in weeks				
	8	9	10	11	12
25-27°C					
Na*Na	-21.62	-23.20	-28.52	-25.62	-29.10
Na*na	12.63	3.62	8.38	12.53	11.5
na*na	8.98	19.55	20.13	13.08	17.95
39-42°C					
Na*Na	-25.90	-9.70	-20.52	-11.83	6.48
Na*na	15.85	11.30	-17.13	22.37	27.53
na*na	10.05	-1.60	3.38	-10.53	-34.02

Na*Na= homozygote naked neck, Na*na=heterozygote naked neck, na*na= normal feathered neck

The feed conversion ratio of the three genotypes according to the breeding temperature is presented in Figure 3.

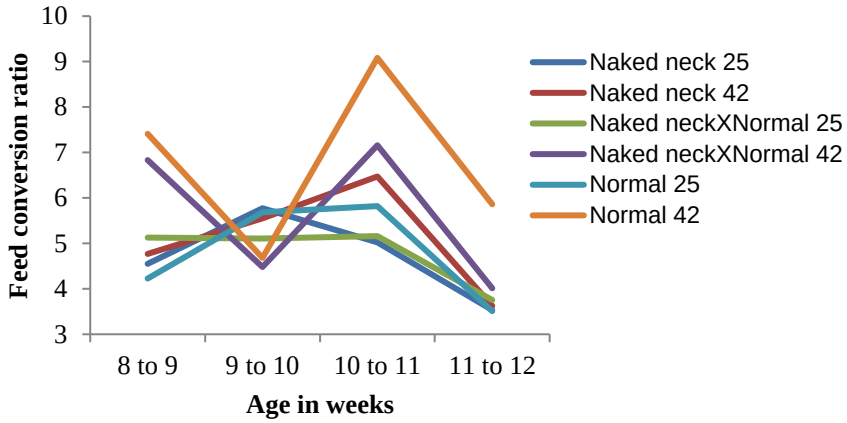

Figure 3**:** evolution of feed conversion ratio according to genotype under accute heat stress

At a breeding temperature of 25-27^{o}C, the crossbred (Na*na) had a steady feed conversion ratio (5.13 to 5.16) from the 8th to the 10th week in contrast to the normally feathered and naked neck chickens which presented a jigsaw evolution. When the birds were subjected to acute heat stress (39-42 ^{o}C), a general rise in the FCR of the local chickens was observed between the 9th and the 10th week. The drop in the feed conversion ratio after the age of 10 weeks indicates that the local chickens waste less food with age.

The water and feed consumption of the local chickens varied according to genotype and breeding temperature (Figures 4 and 5 respectively). Irrespective of the breeding temperatures and genotype, we observed a general increase in feed and water consumption with age. Nevertheless, the induction of acute heat stress brought about an overall drop in feed intake with a corresponding increase in water consumption. Analysis reveals that irrespective of the breeding temperature, the normally feathered chickens consumed more feed and water than the naked neck and normal x naked neck crossbred chickens although the difference was not significant at the threshold tested (0.05). However, the variations between the same parameters (genotype, feed and water consumption) were significant (P <0.05) for the 5 hours of acute heat stress (Figures 6 and 7).

Effect of Na gene on feathering intensity and carcass

Table 4 presents the distribution of the feathering intensity with respect to genotype and body part. Results reveal that regardless of the body part, the presence of the naked neck gene reduced the feathering intensity by approximately 21% to 50% in the heterozygote (Na*na) and homozygous (Na*Na) respectively. The result from the analysis of the effect of genotype on bodyweight, carcass, and offal weights and yields as well as their respective summarised in table 5. Overall, and irrespective of treatments (temperature), the normally feathered genotypes (na*na) presented a insignificant but superior performance to carriers of the Na gene, with exceptions in the case of carcass yield, intestinal, and testes weights. However, a significantly superior mean carcass yield (1062.55g ± 78.49g) and proportion can be observed in the heterozygous naked neck chicken. The contribution of the carcass and offal to the body weight of the live birds was equally measured (Table 6). Irrespective of temperature, this highest carcass-to-body weight ratio was equally observed for the heterozygous naked neck chicken (80.14%). This further. The greatest proportion of the giblets (i.e., the feet, head, gizzard, heart, liver, lungs, pancreas, intestine and testes) was found in the homozygote naked neck chickens (Na/Na).

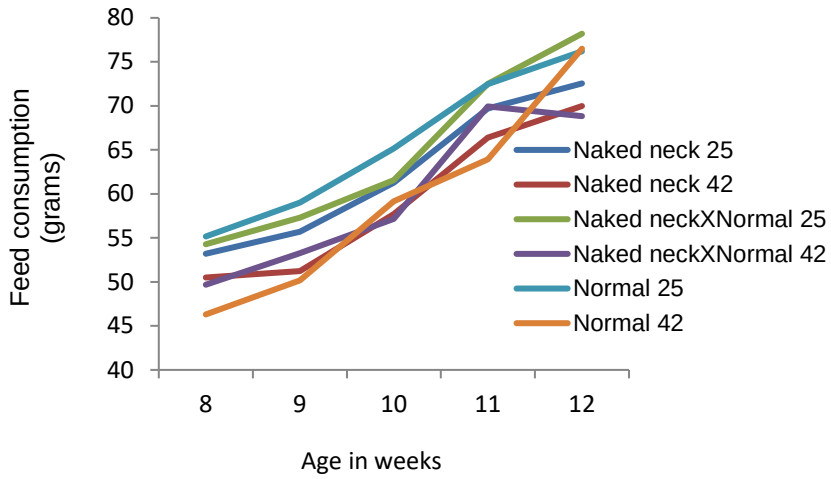

Figure 4: Effet of naked neck gene on the evolution of daily feed consumption in the local chicken under acute heat stress.

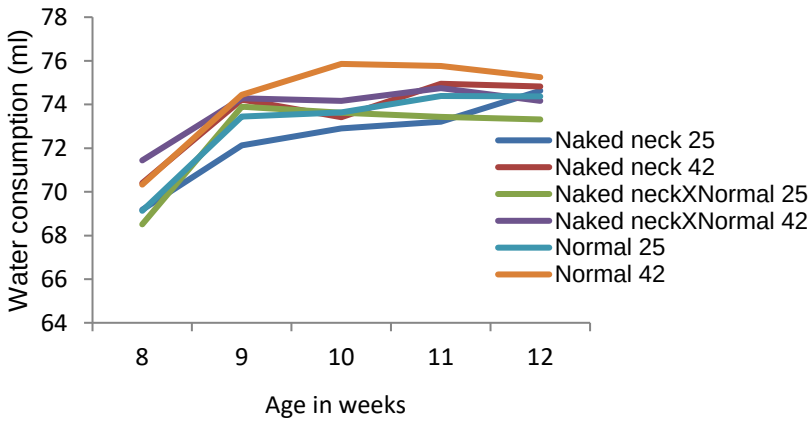

Figure 5: Effect of naked neck gene on the evolution of daily water consumption in the local chicken under acute heat stress.

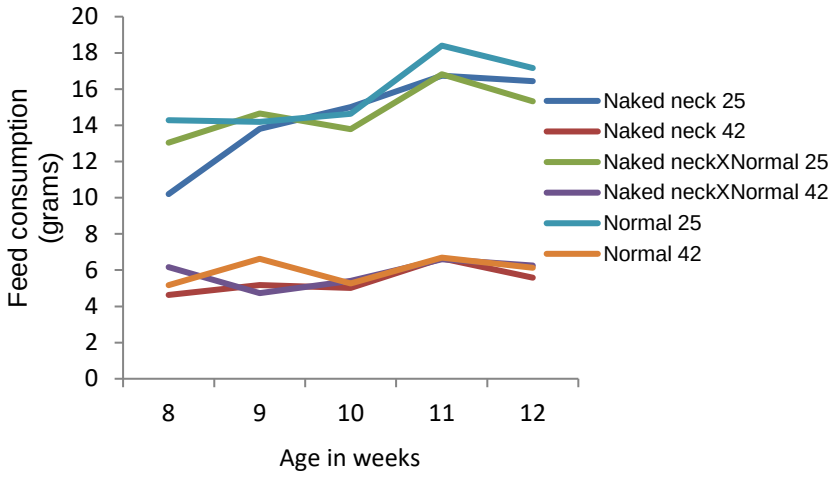

Figure 6: Effect naked neck gene on the evolution of feed consumption during 5 hrs of heat stress

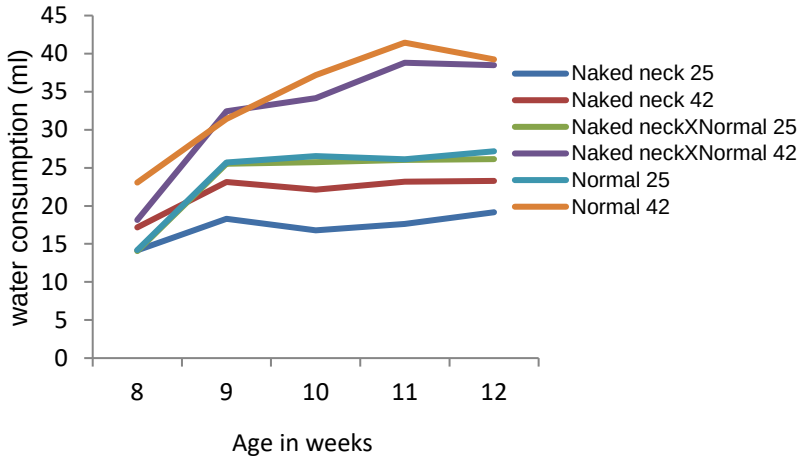

Figure 7: Effect of naked neck gene on the evolution of water consumption during 5 hrs of heat stress

Effect of Na gene on feathering intensity and carcass

Table 4 presents the distribution of the feathering intensity with respect to genotype and body part. Results reveal that regardless of the body part, the presence of the naked neck gene reduced the feathering intensity by approximately 21% to 50% in the heterozygote (Na*na) and homozygous (Na*Na) respectively.

The result from the analysis of the effect of genotype on bodyweight, carcass, and offal weights and yields as well as their respective summarised in table 5. Overall, and irrespective of treatments (temperature), the normally feathered genotypes (na*na) presented a insignificant but superior performance to carriers of the Na gene, with exceptions in the case of carcass yield, intestinal, and testes weights. However, a significantly superior mean carcass yield (1062.55g ± 78.49g) and proportion can be observed in the heterozygous naked neck chicken.

The contribution of the carcass and offal to the body weight of the live birds was equally measured (Table 6). Irrespective of temperature, this highest carcass-to-body weight ratio was equally observed for the heterozygous naked neck chicken (80.14%). This further. The greatest proportion of the giblets (i.e., the feet, head, gizzard, heart, liver, lungs, pancreas, intestine and testes) was found in the homozygote naked neck chickens (Na/Na).

Table 4: Mean (±SD) Feathering Intensity*, percentage of reduction in feathering in the naked neck type in comparison to the normal type

Genotype	Feathering intensity number/cm^2				percentage to the normal type	
	Brisket	Thight	Leg	Total	Feathering	Feathering reduction
Na*Na	1.00±0.08	1.36±0.08	0.85±0.12	1.09±0.05	50.37	49.63
Na*na	1.58±0.20	1.98±0.18	1.58±0.11	1.72±0.12	79.35	20.65
na*na	1.98±0.15	2.64±0.27	1.85±0.09	2.18±0.13	100.00	00.00

Na*Na= homozygote naked neck, Na*na=heterozygote naked neck, na*na= normal feathered neck

Table 5: Mean (±SD) body weight, carcass weight and offal weight (all in grams) according to genotype

Genotype	Body weight	Carcass	Giblets	shanks	Head
Na*Na	1278.00±52.61^{c}	955.25±34.68^{c}	248.85±10.05^{a}	53.25±4.93	57.40±3.14^{a}
Na*na	1325.80±91.50^{b}	1062.55±78.49^{b}	240.55±10.79 ^{ab}	52.50±4.50	55.15±5.39^{ab}
na*na	1360.40±109.89^{a}	1053.50±67.52^{a}	234.20±6.36^{b}	49.25±3.30	52.30±2.76^{b}
P-value	<0.01	<0.01	<0.05	n.s	<0.05
	Gizzards	Heart	Liver	Lungs	Pancreas
Na*Na	31.55±5.39	9.00±0.95	26.60±1.66	17.95±2.16	1.65±0.48
Na*na	30.90±3.39	6.55±0.59	25.70±2.37	16.70±1.19	1.35±0.48
na*na	32.10±3.11	6.70±0.56	26.05±2.09	15.60±1.36	1.20±0.40
P-value	n.s	n.s	n.s	n.s	n.s
	Intestines	Spleen	Testes		
Na*Na	47.40±3.50	2.25±0.54	1.80±0.68		
Na*na	47.65±3.88	1.65±0.79	2.40±0.58		
na*na	47.20±3.20	1.30±0.46	2.50±0.50		
P-value	n.s	n.s	n.s		

^{abc} on the same column and between rows; the means assigned to the different letters are significantly different (P<0.05). ns=not significant; Na*Na= homozygote naked neck, Na*na=heterozygote naked neck, na*na= normal feathered neck

Table 6: Carcass yield and proportion of offal according to percentage body weight of the studied genotypes

Genotype	% Body weight					
	Carcass	Gibblet	Feet	Head	Gizzards	Heart
Na*Na	74.75	17.89	4.17	4.49	2.47	0.70
Na*na	80.14	17.29	3.96	4.16	2.33	0.49
na*na	77.44	16.84	3.62	3.84	2.36	0.49
	Liver	Lungs	Pancreas	Intestines	Spleen	Testicles
Na*Na	2.08	1.40	0.13	3.41	0.16	0.13
Na*na	1.94	1.26	0.10	3.43	0.12	0.17
na*na	1.91	1.15	0.09	3.39	0.09	0.18

Na*Na= homozygote naked neck, Na*na=heterozygote naked neck, na*na= normal feathered neck

DISCUSSION

Despite the valuable contribution of native chicken genotypes to the livelihoods of rural households, very little efforts are furnished to preserve them (Manyelo *et al.,* 2020). The native chicken possesses a vast genetic diversity which confers them the capacity to easily adapt to extreme local climatic conditions better than imported breeds (van Marle-Köster *et al.,* 2009). A higher body weight registered in favour of the normally feathered chickens over the naked neck types under room temperatures (25-27^{o}C) but the reverse under high ambient temperatures is in phase with the observations of Rajkumar *et al*. (2011), Sharifi *et al*. (2010), Hanzl and Somes (1983) and Bordas *et al*. (1978). The present study reveals a significantly higher body weight for the heterozygote naked neck (Na*Na) chicken over the homozygote naked neck (Na*na) and the normally feathered chickens respectively under acute heat stress. This, therefore, suggests a favourable effect of the naked neck gene (Na) on the growth performance of chickens under high ambient temperatures. This is consistent with the findings of Rajkumar *et al*. (2011 and 2010), Sharifi *et al*. (2010), Fathi *et al*. (2008 and 2022), Mahrous *et al*. (2008), Lin *et al*. (2006), Patra *et al*. (2002), Galal and Fathi (2001), Deeb and Cahaner (1999) who reported a superior performance for the naked neck chickens over their normally feathered counterparts. Fathi *et al.* (2022) and Reddy *et al.* (2015) equally reported a higher body weight for the naked neck genotypes under high temperatures. Hanzl and Somes (1983) further indicate that the heterozygous (Na*Na) had the greatest live weight under high ambient temperatures. Nonetheless, N'dri *et al*. (2007) obtained a non-significant but greater live weight for the homozygous naked neck chicken, a difference which could be attributed to the genetic diversity of the strains studied. Nonetheless, Almeida and Zuber (2010) registered a higher performance for the normally feathered chicken in a hot climate. The performance of chickens is generally influenced by so many factors including the genetic type, sex, age, production system and ambient temperature (Haoua *et al*., 2015; Khobondo *et al*., 2015; Keambou *et al*., 2013; Magala *et al*., 2012). The naked neck gene has a favourable effect in chicken under high ambient temperatures as it limits the negative impact of heat stress on growth and feed efficiency (Fathi *et al*., 2013; Rajkumar *et al*., 2011; Lin *et al*., 2006; Patra *et al*., 2002; Deeb and Cahaner, 2001; Merat, 1986). The least variation in the body temperature, weight gain and feed efficiency (Figure 3) of the chickens under acute heat stress recorded in this study in favour of the naked neck genotype (Na*Na) simply corroborate this fact.

Birds have many behavioural ways for maintaining thermoregulation and homeostasis when subjected to high environmental temperatures including a significant reduction in feed intake and activity as well as an increase in water intake (Wasti *et al*., 2020; He *et al*., 2018; Kumari and Nath, 2018). Irrespective of the genotype studied, the induction of the local chickens to high ambient temperatures of 39-42^{o}C brought about an overall drop in feed intake with a corresponding increase in water intake. These results were consistent with the findings of Hanzl and Somes (1983). A non-significant but higher feed consumption for the normally feathered chicken over the homozygous and heterozygous naked neck chickens contrasts the findings of Patra *et al*. (2002) who reported a higher feed consumption for the naked neck chickens under normal temperatures. No

scientific work has of yet elucidated the significantly (P<0.05) higher feed consumption for the normally feathered chickens over their naked neck counterparts within the exact time frame of exposure to acute heat stress. However, the higher feed consumption for the normally feathered chicken at the end of the trial is probably due to the phenomenon of compensatory effect characterized by an increase in the consumption of water and feed once the stress factor (high temperature) is removed.

A reduction in the feathering intensity slightly above 20% in the heterozygote naked neck chickens obtained in this study is consistent with the findings of several authors (Rajkumat *et al*., 2010a; Fathi *et al*., 2008; Lin *et al*., 2006, Singh *et al*., 2001; Deeb and Cahaner, 1999). However, a reduction in the feather mass to approximately 50% in the homozygote is considerably higher than the observations of the same authors who reported a 30 to 40% decrease in feathering intensity. This difference simply highlights the genetic diversity that exists within the naked neck genotype or the genotype*environment interaction. Feather reduction in Na gene carriers increases the uncovered surface area of the skin, easily dissipates heat and thus favours a better thermoregulatory efficiency and heat tolerance compared to their normally feathered counterparts (Patra *et al*., 2002; Rajkumar *et al*., 2011). This ability to easily dissipate heat is equally responsible for the relatively high productive performance of indigenous naked neck chickens reared in the tropics (Ariyadi *et al*., 2015).

The significantly (P<0.05) superior live weight and carcass weight recorded for the normally feathered chicken (na*na) under normal breeding temperatures (25-27^{o}C) are not coherent with the observations of Bineadeo *et al.* (2022), Fathi *et al.* (2022) and Rajkumat *et al*. (2011) who reported an overall better performance of the naked neck genotype with respect to its live weight and carcass yield. Patra *et al*. (2002) on the other hand recorded no significant difference in the dressing percentage of homozygote naked neck, heterozygous naked neck and normally feathered chickens. The difference in the age at slaughter in the different studies could be at the deviation in performance thereby suggesting that the interaction between genotype and age significantly influences the bodyweight of local chickens (Hako *et al*., 2009a; Keambou *et al*., 2013). A higher dressing yield for the heterozygous naked neck chicken probably reflects the phenomenon of overdominance. A significantly superior giblet weight obtained for the naked neck chickens is consistent with the findings of Bineadeo *et al.* (2022) and Rajkumat *et al*. (2011). This could suggest increased activity of the liver and heart in a bid to meet up with the metabolic rates needed to combat heat stress. This pronounced development of the gibl*et al*so reflects a better development of the digestive tract and could explain the better feed efficiency (lower feed conversion ratio) observed in the naked neck genotype.

CONCLUSIONS

Our previous studies revealed an effect of the naked neck gene on the growth, the feed conversion ration, the carcass yield and chronic heat stress as compared to other chicken genotypes including the normally feathered (na*na), feathered shanks (Pti*Pti and Pti*pt+) and crested (Cr*Cr and Cr*cr+) chickens under tropical conditions. This current research successfully quantified the effect of the naked neck on the same parameters under acute heat stress with evidence of the overdominance effect of Na*na combination on improving the live weight, the carcass yield, the feed conversion ration and resilience to acute heat stress. The interest of the naked neck gene for the genetic improvement of the local chicken under harsh and challenging tropical conditions is enhanced and reliable quantitative information for modelling and predictive breeding is provided. The present study only considered growth and carcass characteristics in the Cameroon local chicken. Further assessment is required to assess the mean effect of the naked neck gene on the reproductive and egg laying performance of the native chicken under acute heat stress.

Declaration of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest. All authors read and approved the manuscript.

Author contribution

HTBA designed the project and supervised the work. YSN drafted the paper and contributed to data collection and analysis. All the authors read and approved the final manuscript.

Ethics approval and consent to participate

The animal material used in this research is not subject to any restriction. The procedures and

protocols applied during this research are ethically clean and approved by the scientific committee of the University of Dschang (DZOO/CE/01317).

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