

Growth Traits, Breast Meat Yield and Quality of Broiler Genotypes under Hot Conditions

Research Article

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ABSTRACT

The study evaluated the body weight during growth (BWG), body weight at slaughter (BWS), breast meat yield (BMYg), percent breast meat yield (BMY) and breast meat quality (colour and drip loss) of genetically featherless (*scsc*) broilers compared to their feathered sibs under hot conditions. Two hundred featherless chicks and 200 feathered sibs were reared under hot conditions in two rooms (average temperature 29 to 33 °C) divided into pens by genotypes and diets (control diet and 10%, 15% and 20% protein and energy reduction) for 50 days. Fattening traits (BWG and BWS), breast meat quantity traits (BMYg and BMY %) and breast meat quality traits [(colour: lightness(L*), redness (a*), and drip losses at 24 hours (h) and 72 hours (h) postmortem (PM)] were measured or calculated on 56 featherless and 39 feathered sibs. Results confirmed statistically significant improvements ($P < 0.05$) in favour of the *scsc*. On day 50, average values of body weight during growth (BWG), body weight at slaughter (BWS), breast meat yield (BMYg) and breast meat yield (BMY) in *scsc* vs. feathered sibs were: 2299 g vs. 1950 g, 2150 g vs. 1847 g, 390 g vs. 264 g, 18% vs. 14%, respectively. Breast meat colour at 24 h and 72 h PM was better in *scsc* with lower L* values (52.8 vs. 54.4 and 53.2 vs. 55.6) and higher a* values (3.2 vs. 2.5 and 4.2 vs. 3.2). Drip losses were lower in featherless birds compared to their feathered sibs at 72 h and 96 h PM (1.27% vs. 1.83% and 1.9% vs. 2.6%). Mortality on day 45 due to a heat wave of 38 °C and low relative humidity (25%) led to the mortality of 2 out of 100 featherless birds (2%) and 30 out of 72 feathered sibs (42%). Thus, reduction in BWG, BWS, BMYg and BMY %, survival and breast meat quality of fast growing normally feathered birds under hot conditions can be counteracted by the introduction of the featherless (*scsc*) gene for cost effective commercial production in hot climate.

KEY WORDS breast meat quality, breast meat yield, featherless broilers, hot temperature, scale-less gene.

INTRODUCTION

Heat stress due to high ambient temperature (AT) has been reckoned with as one of the major environmental factors hindering broiler production in hot tropical climates (Daghir, 2008). The reported negative effects of high AT on broilers are: low growth rate, high mortality, low feed intake and meat yield (Yalcin *et al.* 2001; Cahaner *et al.* 2003) as well as low meat quality (Aksit *et al.* 2006; Bianchi *et al.* 2007). Consumers' satisfaction and acceptance of

poultry meat in any culture are strongly related to the meat quality. Among other factors, genetics, rearing conditions and nutrition have been considered to affect poultry meat quality (Berri, 2000; Fletcher, 2002). However, increased sensitivity of broilers to high AT (heat stress) may be due to continuous selection for increased growth rate (Cahaner *et al.* 1995) since fast growing birds need a high feed consumption rate and, in turn, this generates metabolic heat which these large fast-growing birds find difficult to dissipate rapidly enough following meals (Daghir, 2008). Thus,

adapting the environment to the demands of fast growing broilers by means of high cost cooling and ventilation system are feasible, but in many cases are not economical in developing countries where energy and water are not in constant supply. The problem of heat stress on broilers (low growth rate, reduced meat yield and quality as well as high mortality) and the non-sustainable management practices used in combating it can be alleviated by introducing the featherless (*scsc*) gene (genotype and environment interaction). The *sc* gene form which featherless broilers were derived is an autosomal recessive mutation which was found among New Hampshire chicks from the University of California flock at Davis in the autumn of 1954; with one male and four females being scaleless, all sired by the same male as reported by [Abbot and Asmundson \(1957\)](#), were characterized by lower growth rate and body weight than the then meat type chicken. Due to their low growth rate the original scaleless (featherless) mutants were not considered for practical purpose.

However, the development of fast-growing featherless broilers was initiated in the year 2000 by crossing original scaleless mutants with contemporary fast-growing broilers, followed by a series of backcrossings accompanied by intensive selection on body weight ([Cahaner and Deed, 2004](#)).

The *sc* gene improves adaptation to hot conditions by eliminating feathers ([Somes and Johnson, 1982](#); [Azoulay et al. 2011](#)). Previous studies on the *sc* gene indicated that the relative weight of the breast was increased in featherless (*scsc*) birds ([Yadgary et al. 2006](#); [Cahaner et al. 2008](#)). The aim of the present study is to test whether the introduction of *scsc* broilers improves survival, weight gain during growth and meat yield as well as meat quality under hot conditions (heat stress) in broiler production in the hot tropics.

MATERIALS AND METHODS

Experimental birds (parental lines)

Two genetic groups (normally feathered and featherless), progeny of the same + / *sc* heterozygous females (carriers of the *sc* allele) crossed with featherless homozygous (*scsc*) males, were used in a controlled trial at the experimental station and laboratories of the faculty of Agricultural, Food and Environmental Quality Sciences in Rehovot. Two hundred *scsc* chicks and 200 feathered sibs were used for the experiment from the mixed sperm of 20 *scsc* cocks which was used to artificially inseminate 80 + / *sc* hens (feathered carriers of *sc*). The chicks were reared under hot conditions in two rooms (average temperature from 29-33 °C) divided into pens by genotype and diets (control diet and 10%, 15% and 20% protein and energy reduction).

Fattening traits and Survival

The body weight during growth (BWG) was assessed as birds were weighed twice weekly throughout the experiment using an electronic precision (0.1 g) balance (Sartorius bP 6100) attached to a bar code scanner and portable data terminal (Symbol PDT 3100). The body weight day 0 (BW 0 d) was the weight of the chicks measured at the day of hatch.

Body weight at slaughter (BWS) on day 50 (after 10 hours (h) of feed withdrawal) was measured on 56 featherless and 39 feathered sibs using the same electronic precision balance.

One of the mortality incidence reckoned as an indication of survival which was on day 45 was due to a heat wave of 38°C and very low relative humidity (about 25%).

Post-mortem breast meat quantity traits

The breast meat yield in grams (BMG) of the birds at 24 h PM was measured on 56 featherless and 39 feathered sibs. The percent breast meat yield (BMG %) at 24 h PM was calculated and this was expressed as percent of BWS.

Post-mortem breast meat quality traits

The birds were mechanically plucked and eviscerated, and the washed carcasses were hanged at +1 °C in the chilling room.

On the following day, 24 hours post-mortem (PM), the breast meat was deboned from each carcass. Breast meat colour was measured at 24 h and 72 h PM on 56 featherless and 39 feathered sibs using Minolta CR-200 Chroma meter having a trichromatic system as lightness (L*), redness (a*) and yellowness (b*) values at both the upper and lower parts of the bone facing side of the Pectorialis major muscle.

The drip loss at 72 h and 96 h PM was assessed from the breast meat of 56 featherless and 39 feathered sibs packaged in a transparent polythene bag and stored in a chilling room of +5 °C for 48h, after which the excess moisture was removed from the bag and the surfaces of samples and thereafter the breast samples were weighed (at 72 h PM) and the drip loss % (24-72 h PM) was calculated as percentage of breast meat yield in grams measured at 24 h PM. The same procedure was repeated 24 h later at (96 h PM).

Statistical analysis

The full model (three-way ANOVA using GLM procedure of SAS Institute Inc., Cary, NC), which was reduced accordingly for each dependent variable examined in this study, is as shown below:

$$Y_{ijklm} = \mu + G_i + R_j + D_k + S_l + (GR)_{ij} + (GD)_{ik} + (GS)_{ij} + (RD)_{jk} + (RS)_{jk} + (DS)_{kl} + (GRD)_{ijk} + E_{ijklm}$$

Where:

μ : the overall mean.

G_i : the fixed effect of the i -th genetic group (featherless and their feathered sibs).

R_j : the fixed effect of the j -th room (#1 and #2).

D_k : the fixed effect of the k -th diet (standard diet as control, and three experimental diets with protein and energy reduced by 10%, 15% and 20%).

S_l : the fixed effect of the l -th sex (males and females).

$(GR)_{ij}$: the interaction between the i -th genetic group and the j -th room.

$(GD)_{ik}$: the interaction between the i -th genetic group and the k -th diet.

$(GS)_{il}$: the interaction between the i -th genetic group and the l -th sex.

$(RD)_{jk}$: interaction between the j -th room and the k -th diet.

$(RS)_{jl}$: the interaction between the j -th room and the l -th sex.

$(DS)_{kl}$: the interaction between the k -th diets and the l -th sex.

$(GRD)_{ijk}$: the interaction between the i -th genetic group, the j -th ambient temperature, and the k -th diet.

E_{ijklm} : the error term.

The data was unbalanced as such the LS means (Least square means) were used and the Type III SS was accepted. Pair-wise comparisons of means for the diets (Control, Low, Medium and High) significant effect of ANOVA were performed by Scheffé test using the LSmeans statement of the GLM procedure (Table 1).

RESULTS AND DISCUSSION

Body weight during growth (BWG)

The body weight (BW) of feathered broilers increased from day 0 (BW 0 d) till day 34 (BW 34 d) was similar to that of the featherless broilers. Then, from 38d to 50d the featherless still showed a steady increase of growth rate while the growth rate of their feathered sibs already plummeted (Figure 1).

The mean BW 38d of the featherless and their feathered sibs was the same (1462 g). Conversely, the mean BW at 41 d and 50 d of the featherless were significantly higher (1688 g vs. 1588 g, $P=0.0059$; 2299 g vs. 1950 g, $P<0.0001$, respectively) than the BW of their feathered sibs.

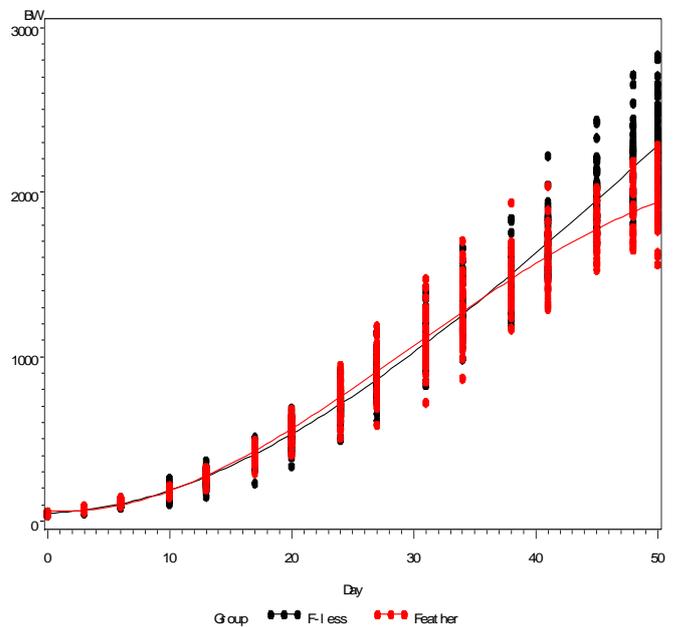


Figure 1 Growth curves of broilers of the two genotypes averaged over sex and diets

Mortality due to heat wave

Heat wave (38 °C) and a low relative humidity (25%) on day 45 led to the mortality of 2 out of 100 featherless birds (2%) and 30 out of 72 feathered sibs (42%).

Post-mortem meat quantity traits

The BWS, breast meat yield in grams (BMYG) and in percent (BMY %) were significantly different ($P<0.0001$) between the genetic groups (Table 2) in favour of the featherless broilers. Thus the significant difference in BWS and body composition led to a disproportionately lower breast meat yield in the feathered broilers under the hot conditions of the experiment.

Table 1 Reduced model (ANOVA using the GLM procedure) for the dependent variables measured on body weight slaughter and breast meat

Dependent variables	Main and interaction effects used in the model										
	G_i	R_j	D_k	S_l	$(GR)_{ij}$	$(GD)_{ik}$	$(GS)_{il}$	$(RD)_{jk}$	$(RS)_{jl}$	$(DS)_{kl}$	$(GRD)_{ijk}$
Body weight (BW)-slaughter	+		+	+		+	+				
Breast 24 h PM	+		+	+		+	+				
% breast 24 h PM	+		+	+		+	+				
Colour 24 h PM											
L* (lightness)	+		+			+					
a* (redness)	+	+	+	+		+					
Colour 72 h PM											
L* (lightness)	+	+	+								
a* (redness)	+	+	+	+		+	+		+	+	
Drip loss (24-72 h) PM	+										
Drip loss (24-96 h) PM	+										

For definition of the main and interaction effects see the model structure in the statistical analysis section.

Table 2 Effect of genotype, diet, sex and their interactions on body weight at slaughter and breast meat yield at 24 h postmortem

Main effects	Body weight (BW) (g) slaughter		Breast (g)		Breast (%)	
	LSM	SE	LSM	SE	LSM	SE
Genotype						
Featherless	2150.02 ^a	27.69	389.71 ^a	8.03	18.12 ^a	0.24
Feathered	1847.32 ^b	29.07	263.59 ^b	8.44	14.21 ^b	0.25
Sex						
Male	2099.68 ^a	24.21	341.01 ^a	7.03	15.98 ^a	0.21
Female	1897.66 ^b	33.99	312.30 ^b	9.86	16.35 ^a	0.29
Diet						
Control	2066.82 ^A	37.87	347.55 ^A	10.99	16.61 ^A	0.33
Low	2021.37 ^A	35.80	333.20 ^A	10.39	16.38 ^A	0.31
Medium	1914.27 ^B	42.15	302.27 ^B	12.23	15.45 ^A	0.37
High	1992.22 ^{AB}	39.02	323.58 ^{AB}	11.32	16.23 ^A	0.34
P-values						
Genotype	< 0.0001		< 0.0001		< 0.0001	
Sex	< 0.0001		0.0247		0.3182	
Diet	0.0651		0.0564		0.1135	
Genotype *sex	0.0595		0.1185		0.7971	
Genotype *diet	0.0608		0.0311		0.0068	

SE: standard error and LSM: least square means.

^{a, b}: the means within the same column with different letter, are significantly different (P<0.05).^{A, B}: the means within the same column with different letter, are significantly different (P<0.0001).

Post-mortem meat quality traits

The breast meat quality traits colour [(lightness (L*) and redness (a*)], and drip losses were significantly different between the genetic groups (Table 3) in favour of the featherless broilers.

Table 3 Effect of genotype on breast meat quality traits measured and calculated at postmortem (PM)

Dependent variables	Genotype				P-value
	Featherless		Feathered		
	LSM	SE	LSM	SE	
Lightness (L*) at 24 h PM	52.8 ^a	0.4	54.4 ^b	0.4	0.0055
Lightness (L*) at 72 h PM	53.2 ^a	0.4	55.6 ^b	0.4	< 0.0001
Redness (a*) at 24 h PM	3.2 ^a	0.2	2.5 ^b	0.2	0.0093
Redness (a*) at 72 h PM	4.2 ^a	0.2	3.2 ^b	0.2	0.0024
Drip loss at 24-72 h PM (%)	1.3 ^a	0.1	1.8 ^b	0.1	0.0003
Drip loss at 24-96 h PM (%)	1.9 ^a	0.1	2.6 ^b	0.2	0.0003

SE: standard error and LSM: least square means.

The means within the same row with at least one common letter, do not have significant difference (P>0.05).

The mean BW at day 41 and 50 were significantly higher in the *scsc* than in their feathered sibs indicating that under heat stress (≈ 32 °C) the steady growth of the *scsc* broilers was increasing at an increasing rate while that of their feathered sibs was increasing at a diminishing rate; being consistent with the results obtained by Cahaner *et al.* (2008) and Yadgary *et al.* (2006). The significant lower mortality (2% vs. 42%) due to heat wave of 38 °C in favour of the *scsc* broilers is a proof that feather coverage in fast growing

broiler has a negative effect on thermoregulation in hot climates leading to high mortality under hot conditions in agreement with the findings of Yunis and Cahaner (1999) and Azoulay *et al.* (2011). Therefore, in practise the welfare of *scsc* broiler is less or not dependent on costly cooling systems. The average BWS of the *scsc* broilers was 2150 g and thus 303g heavier than the 1847 g of their feathered sibs indicating the superiority of the *scsc* broilers in meat yield under hot condition. Consequently, the BMY (g) of the *scsc* was 126 g heavier than the 264 g of their feathered sibs, representing an increase of almost 50% which is very relevant economically for broiler production delivering markets with a preference for breast meat in the hot climate. The BMY (%) was 18 versus 14% in the *scsc* and feathered broilers, representing an increase of 4% points which was consistent with the result obtained by Cahaner *et al.* (2003) and this increase was irrespective of the diet (Control, Low, Medium and High) fed under the heat stress condition.

This shows that the meat yield of the *scsc* broilers under heat stress condition is largely due to genotype by environment interaction rather than genotype by diet; since this is the case the broiler meat producers in the hot tropics could save cost on feed and energy required for cooling down the microenvironment of the *scsc* broilers. Thus, the combined advantages of the welfare (less or not dependent on costly cooling) and high meat yield of *scsc* broilers under hot conditions are incentives aimed at low cost of broiler production in the hot climate.

A higher L* value is associated with paleness and a tendency towards PSE (pale, soft, exudative) meat characteristics (Galobart *et al.* 2004) where PSE stands for three negative characteristics of meat. Applying the classification

used by Qiao *et al.* (2001) on breast meat lightness (L^*) values, namely lighter than normal (light, $L^* > 53$), normal ($48 < L^* < 53$), and darker than normal (dark, $L^* < 46$); it was indicated that the *scsc* broilers had a normal breast meat lightness (L^*) while that of their feathered sibs was lighter than normal (pale). Moreover, the *scsc* broilers had higher a^* values than their feathered sibs (3.2 vs. 2.5) at 24 h PM and (4.2 vs. 3.2) at 72 h PM. A higher a^* value is associated with lower L^* value and hence better meat quality (this was true for the *scsc* broilers). The tendency of the breast meat of the feathered broilers to show a lower redness (a^*) when lightness (L^*) increases observed in this study agrees with previous findings (Van Laack *et al.* 2000; Qiao *et al.* 2001; Yadgary *et al.* 2006; Bianchi *et al.* 2007) and especially under heat stress condition (Petracci *et al.* 2001). The effect of the genetic group on the drip loss from the breast meat was significant at both 24-72 h PM and at 24-96 h PM. The result obtained with the *scsc* broilers having a 56% and 73% lower drip loss than their feathered sibs at 24-72h and 24-96 h PM was in line with Yadgary *et al.* (2006). Reports from Bianchi *et al.* (2007) and Lu *et al.* (2007) showed that under heat stress condition the water holding capacity (WHC) properties deteriorate and this was true for the feathered broilers used in this study too but the *scsc* broilers had a better WHC property (drip losses) under heat stress conditions. Thus, broiler production with the *scsc* birds in hot climates is able to benefit the producer while securing the meat quality in preference to consumers' satisfaction.

CONCLUSION

Reduction in body weight during growth (BWG), body weight at slaughter (BWS), survival, meat yield and quality of fast growing normally feathered birds under hot conditions can be counteracted by the introduction of the scaleless (*sc*) gene for efficient and cost effective large scale commercial production of high yield and quality broiler meat while minimizing mortality of birds due to heat stress in the hot climate.

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