The effect of the Frizzle (*F*) gene on egg production traits under standard and high ambient temperature

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INTRODUCTION

High ambient temperature (AT) has a negative effect on growth rate and egg production of commercial chickens due to the difficulty of dissipating metabolic heat, which leads to an increase in body temperature that can be lethal in extreme cases. The reduction of feather coverage has proved to increase heat dissipation, allowing a greater rate of irradiation of body heat and a better thermoregulation (Eberhart and Washburn (1993)). Some major genes have been described as affecting feather mass. The naked neck gene (Na) reduces the number of feathers by limiting the feathered body surface in chickens, and the frizzle gene (*F*) has a feather curling effect and causes feather mass reduction. Although the adaptive effect of the naked neck gene at high environmental temperatures has been extensively studied (Bordas and Mérat (1984), Deeb and Cahaner (1999), Chen et al. (2004)), the effect of the frizzle gene has been investigated mostly in its heterozygous form (Bordas and Mérat (1990)) and often in association with the naked neck (*Na*) gene (Yunis and Cahaner (1999), the dwarf gene (*dw*) (Missohou et al. (2003)) or both (Garcês, Casey and Horst (2001)), and the results are rather contrasted. The purpose of this study was to analyse the effect of the frizzle gene on thermotolerance in frizzle homozygous (*FF*), heterozygous (Ff^+), and normally feathered homozygous (f^+f^+) laying hens, by comparing egg productivity and egg quality traits under standard temperature conditions and artificially induced long-term heat stress.

MATERIAL AND METHODS

Genetic background and husbandry. The frizzle gene was introduced into our animal stock in 1981 with 6 cocks of the Lyonnaise breed. Since then, the gene has been kept in the heterozygous form by successive crossing with normally feathered brown-egg layers. Six heterozygous males (Ff^+) were pedigree-mated to a total of 48 dams of the same genotype (1 cock and 8 hens per family), producing progeny of the three genotypes: homozygous for the mutation (*FF*), heterozygous (Ff^+) and normally feathered homozygous (f^+f^+). Only female chicks were kept and were reared in floor pens, under standard conditions. At 17 wk of age, between 83 and 91 pullets per genotype were sampled equally from the six parental families and transferred at random into individual cages, with the genotypes being equally distributed among 6 temperature-controlled chambers. AT was kept at 22°C until 22 wk of age, and then, the temperature was increased rapidly to 32°C for 3 chambers, while for the other 3 it was kept at 22°C. Relative humidity could not be controlled but was continuously monitored. The light regime was 14L:10D and food and water were *ad libitum*. The layer mash contained 16.4% crude protein and 11.2 MJ ME/kg.

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Measurement and Statistical Analysis. Egg production traits were recorded daily for each hen from the first egg to 44 wk of age. Average egg weight was calculated from a laying period of two weeks between 32 and 33 weeks of age, and body weight was the average between the weight measured at 31 and 34 weeks of age. Data from each experiment were analysed, using the GLM procedure (SAS (1995)), by a 2-way ANOVA, with genotypes (G) and ambient temperature (T) as the main effects; their interactions (GxT) were also analysed.

RESULTS AND DISCUSSION

Effects of ambient temperature, genotype and interaction. The means of all traits and the significance of the main effects and of the GxT interaction are given in Table 1. Mortality was overall low and not significantly different for the two temperatures. Corresponding data were discarded from the analyses.

The genotype by temperature interaction significantly affected several egg production traits: egg number, laying rate (n of eggs laid/n of days recorded from the first egg) and days of pause (egg laying pause of two consecutive days or more/n of days recorded). It also affected egg weight, shell thickness and average body weight. The high AT significantly affected all traits except the rate of shell-less egg and the age at first egg, which was expected because oviposition started before the increase of temperature.

Table 1: Performance of the three Frizzle genotypes at two different ambient temperatures and significance of genotype, ambient temperature and interaction

	32°C			22°C			Significance		
Genotypes	*FF*	*Ff*$^{+}$	*f*$^{+}$*f*$^{+}$	*FF*	*Ff*$^{+}$	*f*$^{+}$*f*$^{+}$	G	T	GxT
n of animals	(40)	(44)	(45)	(43)	(45)	(46)			
Egg production traits									
Age at first egg, d	148.4	147.7	147	147.6	147.4	146.5			
Egg number	130.2^{a}	97.2^{b}	94.9^{b}	139.3	135.5	135.7	***	***	***
Laying rate,%	72.8^{a}	54.2^{b}	52.8^{b}	77.4	75.6	75.3	***	***	***
Clutch length, d	4.91^{a}	3.13^{b}	3.09^{b}	6.85^{a}	5.07^{b}	5.9^{ab}	***	***	
Days of pause,%	13.82^{a}	32.63^{b}	34.47^{b}	12.86	12.13	11.6	***	***	***
Cracked eggs, %	6.1	8.95	7.3	6.9	4.82	3.27		*	
Shell-less eggs %	1.05^{ab}	1.88^{a}	1.0^{b}	1.49^{a}	1.25^{ab}	0.53^{b}	*		
Egg composition traits									
Egg wt., g	49.98^{a}	46.1^{b}	44.98^{b}	50.79^{a}	50.21^{ab}	48.98^{b}	***	***	**
Shell thickness, mm	0.358^{a}	0.338^{b}	0.325^{b}	0.364	0.362	0.357	***	***	*
Mean body weight, g	1807	1724	1734	1866	2018	1937		***	**

* p<0.05; ** p<0.01; *** p<0.001

[a, b, c] Different superscripts indicate significant difference at the same ambient temperature

The heterozygous frizzle and the homozygous normally feathered birds were equally penalised by the heat, showing the typical signs: deterioration of egg quantity and quality, loss of body weight, and the decrease of food intake (data not shown). The egg laying rate dropped by 30% compared to their performances at 22°C, clutch length was reduced by 38% and 48% respectively and the days of pause almost tripled. At 32°C, the egg weight decreased by 8% in both genotypes, shell was 7% and 9% thinner respectively, the number of cracked eggs doubled and body weight dropped by 15 and 10% respectively. On the contrary, the frizzle homozygous hens performed well at high AT. The egg laying rate decreased by only 5.9% at 32°C and showed a homogeneous performance throughout the whole experiment, comparable to that registered at 22°C for the three genotypes (Figure 1). The days of pause increased by only 1% and the egg weight and shell thickness decreased by 1.6% and 1.7% respectively. The mean body weight did not change significantly at 32°C in spite of a decrease in food intake (data not shown), probably reflecting a lower need to devote part of food intake to maintain body temperature.

At high AT, the frizzle heterozygous hens had a deterioration of egg productivity and quality comparable to that of normally feathered animals, suggesting that the frizzle gene in the heterozygous form has no adaptive effect on heat stress. One reason could be that the overall feather mass of heterozygous animals is not significantly reduced when compared to their normally feathered sibs (data not shown). Similar results were obtained earlier by Bordas and Merat (1990) and by Yunis and Cahaner (1999), while Haaren-Kiso et al. (1994) reported a 40% decrease in feather intensity in frizzle heterozygous hens. It is not clear why there is such a large difference among studies. Perhaps the phenotypic effect of the frizzle gene was not the same among different chicken breeds, or, more simply, the degree of feather damage, which is known to increase with the age of the animal, was not the same between studies.

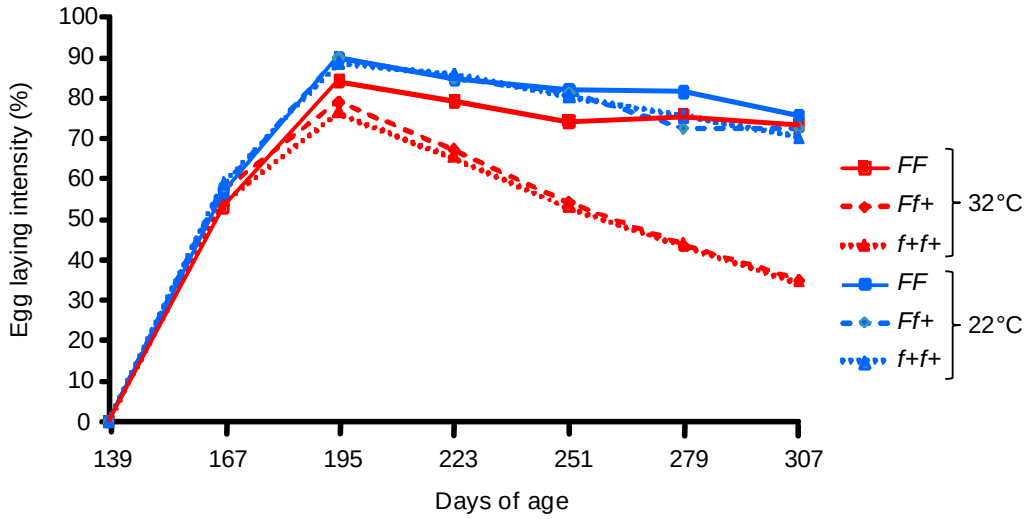

Figure 1: Laying intensity at 22°C and 32°C for frizzle homozygous (*FF*), frizzle heterozygous (*Ff*$^{+}$) and normally feathered homozygous (*f*$^{+}$*f*$^{+}$) hens

Egg productivity and quality of frizzle homozygous hens were only slightly affected by the heat, reflecting a higher capacity to dissipate endogenous heat due to an increased effective surface of dissipation. Although the *F* allele does not affect the number of feathers, frizzled feathers tend to break, especially in *FF* animals; hence, their number also decreases as the birds get older leading to a reduced feather mass as high as 60% (Haaren-Kiso et al. (1992)). It has been proposed that the beneficial effect of the *F* gene on broiler reared at high AT is less than that of the *Na* gene (Yunis and Cahaner (1999)). For layers, however, frizzle homozygous hens appear superior to heterozygous *Na/na*, and comparable to homozygous *Na/Na*, that have little commercially value because of their poor hatchability (Mérat (1986)).

CONCLUSION

The adaptive effect to heat of the frizzle gene has been underestimated because it has mainly been studied in its heterozygous form. In this paper, we have shown that the frizzle mutation in laying hens has a positive effect on adaptation to high temperatures, but this effect is detectable only when it is present in the homozygous form (*FF*). Therefore, chicken breeds fixed for the *F* allele should be more suited for poultry production in hot countries.

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