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GENETICS

Effects of the Dominant Lethal Yellow Mutation on Reproduction, Growth, Feed Consumption, Body Temperature, and Body Composition of the Japanese Quail

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ABSTRACT Wild-type Japanese quail were compared with full-sibs with a yellow plumage color determined by an autosomal dominant mutation (*Y*), which is lethal when homozygous. These quail have wheat-straw yellow-colored feathers. Early growth was slower in yellow quail that had 2.4% lower BW than wild-type quail (149.3 g vs. 153.0 g) at 28 d of age. The BW, however, was similar for yellow and wild-type males at 35 d, and it remained so throughout the last part of the growth of the quail monitored until the age of 120 d, as indicated by the very close parameters of the monomolecular growth curve [BW= $A - B\exp(-kt)$] obtained for the 2 groups. Yellow plumage color was also associated with a more difficult adaptation to housing (measured by temporary BW loss) in individual cages and to a significantly 0.2°C lower body temperature at 42 d, but feed consumption and residual feed intake were similar for the 2 plumage color phenotypes. Breast and liver weights were similar in the 2 groups, but abdominal fat was 24% higher (4.66 vs. 3.76 g) in yellow quail. There is some association between the correlated effects of the *Y* gene in quail and those of the lethal mutation A^y at the agouti locus in the mouse.

Key words: Japanese quail, agouti, yellow, plumage color, abdominal fat

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INTRODUCTION

Correlated effects of Japanese quail plumage color genetic variants on performance traits have only been studied for a few mutations, such as the roux mutation, which can be used for auto-sexing at 1 d of age (Minvielle et al., 1999); the recessive white gene (Petek et al., 2004); or the curly mutation, which is associated with increased BW (Minvielle et al., 2005a). Plumage color variants have also been used for tagging a line, such as the white-breasted and albino mutations (Minvielle, 1998), and for biomedical studies, such as the albino mutation with associated glaucoma (Dkhissi et al., 1994) and the black-at-hatch gene (Minezawa and Wakasugi, 1977) with associated developmental defects in blood vessels (Shiojiri et al., 1997). Finally, similarities of plumage colors in quail and chicken have been used to search for homology of the albino (Silversides and Mérat, 1991) and lavender (Minvielle et al., 2002) genes in these 2 species of the Phasianidae family.

Heredity of the yellow plumage was described by Homma et al. (1967). These quail have wheat-straw yellow-colored feathers, and they are heterozygous for a dominant lethal mutation (*Y*). A similar phenotype with the same genetic determinism was studied by Roberts and Fulton (1980), and the Manchurian Gold stock developed with the *Y* mutation (Somes, 1988) seems to have been used at one time as commercial stock for quail production in North America (Poultry Pages, 2007). So far, this mutation has not been reported in the chicken. Little is known, however, on the associated effects of the Y mutation on performance traits in Japanese quail. The gene has recently been located on a quail linkage group homologous to GGA20 in the chicken (Miwa et al., 2005; Kayang et al., 2006) that also contains the expressed sequence tag homologous to the agouti-signaling protein (**ASIP**) (Miwa et al., 2005). In the mouse, there are several mutations at the locus for ASIP, and 1 of them (A^y), first described by Cuénot (1905), is a dominant lethal and induces a yellow coat color and adult obesity. The probable common location of the *Y* and *ASIP* loci on CJA20 in quail and the similarities of both the mode of inheritance and the phenotype of the yellow variants in the mouse and the quail raise the question of the relatedness between the 2 loci. Therefore, it was important to obtain the first data ever on the growth, feed intake (**FI**), and body com-

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Table 1. Effects of type of cross on the reproductive performance of yellow Japanese quail

Type of cross (sire × dam)	Number of single-pair matings	Number of eggs			Phenotyped progeny[1] (sex ratio at 4 wk)		
		Incubated	Fertilized	Hatched	Yellow	Wild type	χ^2
Wild-type × yellow	17	216	182	164	89 (0.97)	89 (1.00)	0
Yellow × wild-type	20	264	221	206	93 (1.00)	126 (1.07)	4.97*

[1] Feathered, unhatched embryos and hatched progeny.

*$P < 0.05$.

position of the yellow quail, because nonagouti alleles in the mouse are variably associated with several other traits, especially body fat content (Miltenberger et al., 1997; Chen and Garg, 1999). This was the objective of the present study. From a production standpoint, this gene may be of some interest to help identify a commercial line visually.

MATERIALS AND METHODS

Birds and Husbandry

Reciprocal single-pair matings were carried out between yellow quail (20 males and 17 females) of a line obtained from S. Ito and maintained at the Experimental Unit Génétique Factorielle Avicole in Nouzilly, France, and wild-type birds (17 males and 20 females) of an advanced generation of a QTL detection experiment (Minvielle et al., 2005b).

Eggs were collected for 2 wk and incubated in a single lot, but eggs from different families were separated in the incubator to prevent intermingling. Chicks (n = 224) were wing-tagged at hatching and placed for 10 d in 2 large group cages where the temperature was maintained at 35 to 37°C. They were then transferred to other group cages at 30°C and finally at 25°C, where they remained until sexing, at 28 d of age. At 35 d, yellow (n = 55) and wild-type male (n = 56) sibs born from 32 single-pair matings were randomly sampled within each family and placed in individual cages at 22°C, where they remained under a 14 h/d artificial lighting regimen until the end of the experiment, at the age of 120 d.

Feed and water were provided ad libitum throughout the experiment. Chicks received a mash starter diet (2,901 kcal of ME/kg, 11.5% moisture, 7% ash, 27% total protein, 8% fat, and 4% crude fiber) ad libitum. Adults received a commercial diet (2,709 kcal of ME/kg, 11.5% moisture, 12% ash, 20% total protein, 4% fat, and 4% crude fiber).

Traits

The numbers of eggs set, candled, and hatched were obtained for each single-pair mating. At hatching, plumage color (yellow or wild-type) was recorded for all chicks and on unhatched eggs with feathered embryos. The BW was measured at hatching and weekly until 28 d of age on all quail and also at 35, 42, 63, and 120 d on the males caged individually. Rectal body temperature (**RT**) was measured on males at 35 d. At 42 d of age, a 21-d feed trial was started on the males. Weight change between the 1-wk adaptation period to the individual cages, BW gain (**BWG**), average BW, and individual FI during the feed trial were obtained. All males were slaughtered at the age of 120 d. The carcasses were weighed and left overnight at 4°C. Then, the right pectoralis major and pectoralis minor were excised from the carcass, weighed together, and recorded as fillet weight. Abdominal adipose tissue and liver were also collected and weighed.

Statistical Analysis

Half the quail produced for the experiment were expected to have a yellow plumage. The goodness-of-fit of the observed frequencies was tested by using the logarithm-likelihood ratio test and comparing the observed number of the statistic with a χ^2 distribution with 1 df (Sokal and Rohlf, 1981). Analyses of variance of the BW data from hatching until 28 d of age were run with plumage color, sex, type of reciprocal cross, and family (nested within the type of reciprocal cross) as main effects. Prelim-

Table 2. Effects of the type of reciprocal cross, family, sex, and plumage color on early growth (mean ± SD) of yellow and wild-type Japanese quail

Trait	Plumage color		Significance of interactions	Significance of main effects				R^2
	Yellow	Wild type		Type	Family	Sex	Plumage color	
BW at hatching (g)	8.01 ± 0.77	7.95 ± 0.71	NS	NS	***	NS	NS	0.84
1-wk BW (g)	34.3 ± 2.9	35.6 ± 2.8	NS	NS	***	*	***	0.69
2-wk BW (g)	74.9 ± 5.2	77.5 ± 6.2	NS	***	***	***	***	0.70
3-wk BW (g)	115.4 ± 7.4	119.5 ± 9.0	NS	**	***	***	***	0.67
4-wk BW (g)	149.3 ± 10.8	153.0 ± 13.0	NS	NS	***	***	*	0.60

*$P \leq 0.05$; **$P \leq 0.01$; ***$P \leq 0.001$.

Table 3. Parameters (±SE) and coefficient of determination of the growth curves[1] for yellow and wild-type males and the effects of family and plumage color on the parameters of the individual curves

	Plumage color		Significance of main effects		
Parameter	Yellow	Wild type	Family	Plumage color	R^2
A	180.3 ± 1.92	181.7 ± 1.65	**	NS	0.53
B	192.0 ± 2.70	193.6 ± 2.34	**	NS	0.55
k	0.0512 ± 0.00167	0.0520 ± 0.00146	*	NS	0.48
Coefficient of determination	0.987	0.986	—	—	—

[1] Using the monomolecular model: $A - B \exp(-kt)$, where A = the asymptotic BW; B = the range of BW from hatching to asymptotic BW; k = the relative rate of growth; and t = the age in days (from 1 to 120 d).

*$P \leq 0.05$; **$P \leq 0.01$.

inary analyses of traits measured later in life on males only (feed trial and dissection) demonstrated (data not shown) that the effect of the type of reciprocal cross was not significant at the 5% level. Therefore, the linear models for the ANOVA of those traits included the phenotype and the family as fixed main effects but not the type of reciprocal cross. Dissection traits were analyzed by an ANOVA including the effect of the technician (n = 3) and with the slaughter weight as a covariable.

The growth of males was studied using the nonlinear monomolecular model: BW = $A - B \exp(-kt)$, where A = the asymptotic BW; B = the range of BW from hatching to asymptotic BW; k = the relative rate of growth; and t = the age in days (France et al., 1996).

For each quail, the residual FI (**RFI**) was the residual of the multiple regression of FI on $BW^{0.75}$ and BWG fitted to all the feed trial data. The equation ($R^2 = 0.48$) used to calculate RFI was FI = 18.90 + 7.27 $BW^{0.75}$ + 1.65 BWG. All analyses were carried out with the GLM and NLIN procedures of the SAS program library (SAS Institute, 1999).

RESULTS

Reproduction

The number and type of progeny obtained from the 2 reciprocal crosses are given in Table 1. None of the reproductive performances evaluated from egg number traits throughout the incubation period were significantly affected by the plumage color phenotype of the progeny (data not shown). The cross between yellow sires and wild-type dams produced significantly ($P \leq 0.05$) more wild-type individuals than yellow ones, and to a similar extent in both sexes (data not shown), but the other reciprocal cross yielded equal numbers of wild-type and yellow progeny.

Growth

The BW of yellow and wild-type quail during their early growth are listed in Table 2. There were no significant interactions during that period. Sexual dimorphism was already significant ($P \leq 0.05$) at 1 wk of age, and the difference between female and male BW ($P \leq 0.001$) reached 7.7 g, or 5% of mean BW (data not shown), at 4 wk. From 1 wk of age onwards, BW of yellow quail was lower than that of wild-type birds, but the mean difference never exceeded 4 g.

Parameters of the monomolecular growth curves fitted to yellow and wild-type male BW are given in Table 3. The high coefficients of determination (0.987 and 0.986, respectively) indicated that the fit was satisfactory and similar for both plumage color phenotypes. The 3 parameters of the individual curves adjusted to each quail were not affected significantly by the plumage color, but there was a significant family effect ($P \leq 0.05$ and $P \leq 0.01$).

Feed Trial

Measures and traits analyzed during the feed trial are in Table 4. The difference in BW between yellow and wild-type males was not significant at the start of the feed trial. In yellow quail, however, the body temperature was 0.18°C lower ($P \leq 0.05$), and the BW loss during the adaptation period to individual cages was higher ($P \leq 0.05$) than in wild-type males. The interaction between the plumage color and the family was significant ($P \leq 0.05$) for FI. The RFI was not affected by the plumage color, and BWG on test was not significantly different in yellow and wild-type quail.

Gross Carcass Dissection

Results of the gross dissection of the males at the age of 120 d are shown in Table 5. The model with the slaughter weight as a covariable explained most of the variation ($R^2 \geq 0.96$). No significant interaction was found for any of the 4 traits, but there was a significant effect of the technician who carried out the dissection on the weights of the breast muscles and the liver. On an equal slaughter-weight basis, plumage color had a significant effect ($P \leq 0.05$) on the amount of abdominal adipose tissue, which was 0.9 g (24%) heavier in yellow quail.

DISCUSSION

Reproductive performances did not depend on the reciprocal cross that was done, and hatching rates of eggs from wild-type and yellow dams were similar and rather

Table 4. Effects of the plumage color on BW traits, feed consumption, and body composition (mean ± SD) of 5-wk-old Japanese quail

	Plumage color			Significance of main effects		
Trait	Yellow	Wild type	Significance of interaction	Family	Plumage color	R^2
5-wk BW (g)	146.4 ± 9.9	148.4 ± 11.8	NS	***	NS	0.56
Body temperature[1] (°C)	40.95 ± 0.38	41.13 ± 0.36	NS	*	*	0.78
Adaptation period BW loss (g)	20.1 ± 21.6	11.6 ± 14.3	NS	NS	*	0.60
Daily feed intake (g)	17.86 ± 2.61	17.09 ± 2.15	*	*	NS	0.68
21-d residual feed intake (g)	5.91 ± 41.3	–5.91 ± 30.4	NS	NS	NS	0.59
BW gain on feed test (g)	19.4 ± 22.1	13.1 ± 15.8	NS	NS	NS	0.57

[1] Five-week BW was used as a covariable for the analysis of body temperature.

$^*P \leq 0.05$; $^{***}P \leq 0.001$.

high (77 and 75%, respectively). This may be partially due to heterotic effects in this F_1 obtained from crossing 2 small experimental lines from different origins. The deficit of yellow progeny sired by yellow males crossed to wild-type females indicates that sperm carrying the *Y* mutation might have less success in fertilizing the ovum. After extensive studies on the chicken, Mérat (1970) also reported an abnormal segregation associated with heterozygous sires for the naked neck and white skin major genes. Since his report, however, no further work on the possible mechanisms for such selective fertilization has been published.

The sexual dimorphism observed in the present work was not affected by the plumage color, because the interaction between sex and plumage color was not significant at any age. Its moderate relative value (5%) was similar to that obtained previously in commercial and experimental quail lines (Okamoto et al., 1989; Marks and Washburn, 1991; Minvielle et al., 1999). The *Y* mutation was associated with lower early growth, but the 4-g difference observed at 4 wk of age did not persist later on, because the asymptotic BW was similar for the 2 plumage color phenotypes. Similar (Minvielle et al., 1999, 2005b) and stronger (Mérat et al., 1981) associated effects of plumage color on early BW were found previously for roux, rusty, and albino quail, and it seems that no plumage color mutation with a favorable effect on BW has been reported so far. Yet, another plumage mutation, curly (Minvielle et al., 2005a), which has a transient frizzling effect on the feather, has a positive effect on BW.

The RT differences have been reported between quail lines (Minvielle et al., 2002) but not between plumage color variants or other major genes. In the present study, lower RT of yellow quail was not associated with markedly different FI or body composition, except for the amount of adipose tissue, which was 23% larger in these birds. Direct associations between plumage color variants and RT have not been reported before in quail or in chickens. In yellow quail, the association might be the consequence of the causal relationship between lipogenesis and basal metabolism rate, with lower RT induced by increased lipogenesis, observed as abdominal adipose tissue in the present work.

The increased fatness in yellow quail was not accompanied by marked hyperphagia or strongly altered BW, and these quail appeared to be storing part of their consumed calories as fat rather than using them to maintain higher body temperature. The same observations and reasoning were made by Miltenberger et al. (1997) in their review on the agouti gene in mice and its role in the obese syndrome. Of course, yellow quail in the present experiment were simply fatter and not obese, but the addition of the present zootechnical and physiological results to the previous knowledge on the heredity of the color trait in both species and the probable localization of the *Y* mutation and the *ASIP* gene on the same microchromosome in the quail (Kayang et al., 2006) make this plumage color mutation a candidate for an avian nonagouti-like gene yet to be identified at the molecular level.

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Table 5. Effects of the plumage color on gross body composition (mean ± SD) of 120-d-old male Japanese quail

	Plumage color			Significance of main effects			
Trait	Yellow	Wild type	Significance of interaction	Technician	Family	Plumage color	R^2
Slaughter weight (g)	178.4 ± 16.4	179.6 ± 17.7	NS	—	NS	NS	0.72
Abdominal adipose tissue[1] (g)	4.66 ± 3.02	3.76 ± 3.14	NS	NS	**	*	0.98
Fillet weight[1,2] (g)	17.5 ± 1.9	17.9 ± 1.9	NS	**	**	NS	0.98
Liver weight[1] (g)	4.00 ± 0.79	4.22 ± 0.82	NS	*	*	NS	0.96

[1] Slaughter weight was used as a covariable for the analyses of abdominal adipose tissue, fillet weight, and liver weight.

[2] Fillet weight is the total weight of the right pectoralis major and pectoralis minor muscles.

$^*P \leq 0.05$; $^{**}P \leq 0.01$.

REFERENCES

Chen, D., and A. Garg. 1999. Monogenic disorders of obesity and body fat distribution. J. Lipid Res. 40:1735–1746.

Cuénot, L. 1905. Les races pures et leurs combinaisons chez les souris. Pages 123–132 in Archives de Zoologie Expérimentale et Générale. 4th ed. G. Pruvot and E. G. Racovitza, ed. Notes Rev., Paris, France.

Dkhissi, O., N. Dalil-Thiney, and F. Minvielle. 1994. Retinal distribution of tyrosine hydroxylase immunoreactive cells in two strains of quails *Coturnix coturnix japonica.* J. Brain Res. 35:263–268.

France, J., J. Dijkstra, and M. S. Dhanoa. 1996. Growth functions and their application in animal science. Ann. Zootech. 45S:165–174.

Homma, K., S. Shumiya, and M. Jinno. 1967. Yellow-feathered Japanese quail (*Coturnix coturnix japonica*). Jpn. J. Zootech. Sci. 38:163–166.

Kayang, B. B., V. Fillon, M. Inoue-Murayama, M. Miwa, S. Leroux, K. Fève, J. L. Monvoisin, F. Pitel, M. Vignoles, C. Mouilhayrat, C. Beaumont, S. Ito, F. Minvielle, and A. Vignal. 2006. Integrated maps in quail (*Coturnix japonica*) confirm the high degree of synteny conservation with chicken (*Gallus gallus*) despite 35 million years of divergence. BMC Genomics 7:101.

Marks, H. L., and K. W. Washburn. 1991. Body, abdominal fat, and testes weights, and line by sex interactions in Japanese quail divergently selected for plasma cholesterol response to adrenocorticotropin. Poult. Sci. 70:2395–2401.

Mérat, P. 1970. Proportions mendéliennes anormales limitées à un sexe chez la poule. Ann. Genet. Sel. Anim. 2:139–144.

Mérat, P., A. Bordas, F. Jonon, and A. Perramon. 1981. Effets quantitatifs associés au gène albinos lié au sexe chez la caille japonaise. Ann. Genet. Sel. Anim. 13:75–91.

Miltenberger, R. J., R. L. Mynatt, J. E. Wilkinson, and R. P. Woychik. 1997. The role of the agouti gene in the yellow obese syndrome. J. Nutr. 127:1902S–1907S.

Minezawa, M., and N. Wakasugi. 1977. Studies on a plumage mutant (black at hatch) in the Japanese quail. Jpn. J. Genet. 52:183–195.

Minvielle, F. 1998. Genetics and breeding of Japanese quail for production around the world. Pages 122–127 in Proc. 6th Asian Pac. Poult. Congr., World's Poult. Sci. Assoc., Japan Branch, Nagoya.

Minvielle, F., D. Gourichon, and J. L. Monvoisin. 2002. Testing homology of loci for two plumage colors, "lavender" and "recessive white," with chicken and Japanese quail hybrids. J. Hered. 93:73–76.

Minvielle, F., D. Gourichon, and C. Moussu. 2005a. Two new plumage mutations in the Japanese quail: "curly" feather and "rusty" plumage. BMC Genet. 6:14.

Minvielle, F., E. Hirigoyen, and M. Boulay. 1999. Associated effects of the roux plumage color mutation on growth, carcass traits, egg production, and reproduction of Japanese quail. Poult. Sci. 78:1479–1484.

Minvielle, F., B. B. Kayang, M. Inoue-Murayama, M. Miwa, A. Vignal, D. Gourichon, A. Neau, J. L. Monvoisin, and S. Ito. 2005b. Microsatellite mapping of QTL affecting growth, feed consumption, egg production, tonic immobility and body temperature of Japanese quail. BMC Genomics 6:87.

Miwa, M., M. Inoue-Murayama, B. B. Kayang, A. Vignal, F. Minvielle, J. L. Monvoisin, H. Takahashi, and S. Ito. 2005. Mapping of plumage colour and blood protein loci on the microsatellite linkage map of the Japanese quail. Anim. Genet. 36:396–400.

Okamoto, S., S. Kobayashi, and T. Matsuo. 1989. Feed conversion to body weight gain and egg production in large and small Japanese quail lines selected for 6-week body weight. Jpn. Poult. Sci. 26:227–234.

Petek, M., Y. Ozen, and E. Karakas. 2004. Effects of recessive white plumage colour mutation on hatchability and growth of quail hatched from breeders of different ages. Br. Poult. Sci. 45:769–774.

Poultry Pages. 2007. Subject: Keeping quail. http://www.poultry.allotment.org.uk/Poultry/Keeping_Quail/quail_keeping_coturnix.php

Roberts, C. W., and J. E. Fulton. 1980. Yellow: A mutant plumage color, segregating independently from brown, in Japanese quail. Can. J. Genet. Cytol. 22:411–416.

SAS Institute. 1999. SAS User's Guide. Version 6.12. SAS Inst. Inc., Cary, NC.

Shiojiri, N., H. Satoh, and A. Nakamura. 1997. *Bh* (black at hatch) gene appears to cause hemorrhage in the homozygous quail embryo lung. Zool. Sci. 14:321–326.

Silversides, F. G., and P. Mérat. 1991. Homology of the s^+ locus in the chicken with Al^+ in the Japanese quail. J. Hered. 82:245–247.

Sokal, R. R., and F. J. Rohlf. 1981. Biometry. W. H. Freeman and Co., San Francisco, CA.

Somes, R. G., Jr. 1988. International Registry of Poultry Genetic Stocks. Storrs Agric. Exp. Stn., Univ. Connecticut, Storrs.