

Effect of the slow (K) or rapid (k^+) feathering gene on body and feather growth and fatness according to ambient temperature in a Leghorn \times brown egg type cross

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Abstract – Chicks of both sexes issued from the cross of heterozygous K/k^+ cocks for the slow-feathering sex linked K allele with k^+ (rapid feathering) hens, were compared from the age of 4 to 10 weeks at two ambient temperatures. In individual cages, 30 male chicks of each genotype (K/k^+ and k^+/k^+) were raised at 21 °C, and 60 others, distributed in the same way, were raised at 31 °C. 71 K/W females and 69 k^+/W females were raised in a floor pen at 31 °C till 10 weeks of age. In the males, the body weight, feed consumption and feed efficiency at different ages were influenced only by temperature (lower growth rate and feed intake at 31 °C); no significant effects of the genotype at locus K nor genotype \times temperature interaction were observed. In females, all at 31 °C, the genotype (K/W or k^+/W) had no significant effect on growth rate. Plumage weight and weight of abdominal fat (absolute or related to body weight) were measured on half of the males of each group in individual cages, at 10 weeks of age. Moreover, on 36 males and 48 females of the two genotypes, in a group battery at 31 °C, the absolute and relative weight of plumage were measured on a sample every two weeks between 4 and 10 weeks. In the first case, no significant effect of genotype appeared. In the second case, an interaction between age and genotype was suggested from plumage weight: its growth, especially in male chicks, appears to be temporarily and unexpectedly faster from 4 to 6 weeks of age for the K/k^+ and K/W genotypes

slow-feathering alleles / rapid-feathering alleles / growth rate / feed consumption / feather growth / abdominal fat deposition

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1. INTRODUCTION

The sex-linked slow-feathering (K) or rapid-feathering (k^+) genes, described by Serebrovsky [16] and Warren [19], are responsible for the speed of feathering in birds, especially concerning remiges and rectrices. At one day of age, the primary and secondary feathers are like coverts in a slow feathering chick, and at eight days they do not have tails. Owing to the considerable power of thermal insulation of the plumage, this phenomenon may favour heat dissipation towards the environment and thus have an influence on traits of economic importance: food intake, growth rate, fatness. The purpose of the present work was to research a possible relation between the K or k^+ alleles and body growth, food intake and several body measurements at ambient temperature.

2. MATERIALS AND METHODS

2.1. Animals

A total of 371 chicks were used. Half of them were rapid-feathering (k^+) and half were slow-feathering (K). All were issued from a cross between a heterozygous K/k^+ medium-size sire and k^+/W females from a white Leghorn line. The chicks were vent sexed at hatching and were raised in floor pens till the age of 3 weeks. Each experimental group included chicks of both genotypes (slow and fast feathering) in each sire family.

2.2. Experiments and conditions

1. After being kept for 3 weeks on the floor, two groups of 60 male chicks (30 K/k^+ , 30 k^+/k^+ per group) were placed in individual cages in two rooms maintained respectively at 21 °C and 31 °C. Each room was lighted 10 h per day (from 8 to 18 h). Temperatures were continuously recorded. The feed contained 2 800 Kcal/Kg ME and 20% crude protein. Food and water were given *ad lib*.
2. Another group including 140 female chicks (71 K/W and 69 k^+/W) was raised in the floor pen. The room temperature was maintained at 31 °C on average till the age of 10 weeks. Water and food were given *ad lib*. Light was given 10 h per day.
3. Finally 36 males and 48 females, half of the rapid feathering genotype (k^+/k^+ or k^+/W) and half of the slow feathering (K/k^+ or K/W) were kept in two group batteries and samples were slaughtered every 2 weeks for measurement of plumage growth.

2.3. Measurements

Body weight was measured for all birds every two weeks from the age of 4 weeks to 10 weeks when the birds were slaughtered. The same took place for individual food intake of males in individual cages. For them, body measurements were done at slaughter age (10 weeks). At that age, 60 of them, 30 of each genotype, were fasted during 20 h, then slaughtered, bled, weighted and dry feathered. Feather weight was estimated as the difference between body weight before and after plucking.

Finally carcasses were kept at 0 °C for 48 h. They were dissected weighing fat of the abdominal cavity and around gizzard and ventricle. Fat was in order to weighed to the nearest 0.1 g and expressed as per cent of slaughtered weight.

In addition, in each of the two group batteries, at the ages of 4, 6, 8 and 10 weeks, six pairs of female birds (K/W and k^+/W) were slaughtered in order to measure plumage weight. In males, similar measurements were taken at 4, 6, and 8 weeks of age.

Plumage weight was calculated as an absolute value and per cent of body weight, as for males in individual cages.

2.4. Statistical analysis

Analysis of variance with unequal subclass numbers [18] was used. In the case of males in individual cages, this analysis included two sources of variation (genotype and temperature) with two genotypes (K/k^+ and k^+/k^+) and two temperatures (31 °C vs. 21 °C). The model was as follows:

$$x_{ijl} = \mu + a_i + \beta_j + (a\beta)_{ij} + e_{ijl}$$

with

- μ = population mean
- a_i = mean effect of genotype
- β_j = mean effect of environment (temperature)
- $(a\beta)_{ij}$ = interaction effect (genotype \times temperature)
- e_{ijl} = random individual deviation.

For females in the floor pen, there was only one temperature (31 °C). However, a “sire family” effect was introduced, with nine families. The model was:

$$y_{ij'l} = \mu + a + \beta'_j + e_{ij'l}$$

with

- μ and a_i having the same meanings as before
- β'_j = mean effect of sire family
- $e_{ij'l}$ = random individual deviation.

Finally for male and female birds in group batteries, the data concerning plumage weight were submitted to variance analysis with three sources of variation: sex, age (three levels) with different birds represented at each age and genotype (two levels) corresponding to the model:

$$y_{abmq} = \mu + a_{\alpha} + b_{\beta} + m_T + (ab)_{\alpha\beta} + (bm)_{\beta T} + (am)_{\alpha T} + (abm)_{\alpha\beta T} + e_{\alpha\beta Tq}$$

with

- μ = population mean
- a_{α} = mean effect of sex
- b_{β} = mean effect of age (4, 6, 8 weeks)
- m_T = mean effect of genes (K and k^+)
- $(ab)_{\alpha\beta}$, $(bm)_{\beta T}$, $(am)_{\alpha T}$ = two-way interaction effects
- $(abm)_{\alpha\beta T}$ = three-way interaction effect
- $e_{\alpha\beta Tq}$ = individual random deviation.

The analysis was done for absolute values although variances were heterogeneous according to age.

3. RESULTS AND DISCUSSION

3.1. Body growth rate

3.1.1. Females in floor pen

Analysis of variance and means (Tab. I) for body weight and body weight gains in females reared at 31 °C showed that the two genotypes (K/W and k^+/W) did not differ significantly.

The absence of a significant influence associated with the K gene on body growth rate at high ambient temperature suggests that birds of the two genotypes did not differ considerably for heat insulation of their plumage, or that, if such a difference took place, it was compensated by another mechanism.

3.1.2. Growth rate of males in individual cages

The performances of cockerels kept (Tab. II) at high (31 °C) or moderate (21 °C) temperature showed that body weight and body weight gains did not differ significantly according to genotype from 4 to 10 weeks. Concerning the temperature, highly significant differences ($P < 0.001$) were observed at 10 weeks and for the whole experimental period (4 to 10 weeks), body weight being higher at the lower temperature.

These results were in agreement with those of Mérat [12] and Lowe and Merkley [10] but differed from those of Warren and Payne [20], Plumart and Mueler [14], Mc Donald [11], Lowe and Garwood [9], Goodman and Murin [5],

Table I. Females in a floor pen at 31 °C: Growth performances till the age of 10 weeks.

Genotypes and number of observations	Average body weights (g) per age (weeks)				
	4	6	8	10	
<i>K/W</i> ($n = 62$)	210 ± 36	340 ± 59	503 ± 85	681 ± 106	
<i>k⁺/W</i> ($n = 67$)	204 ± 31	329 ± 57	478 ± 94	664 ± 125	
Analysis of variance per age: Significance					
Source of variation	d.f.	4 w.	6 w.	8 w.	10 w.
Genotype	1	NS	NS	NS	NS
Families (sires)	8	**	*	**	***
Interaction	8	NS	NS	*	NS
Residual	111				

NS: not significant; * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$.

Mérat [13], Bacon *et al.* [1], Dunnington and Siegel [2], for whom the k^+ genotype exhibited a slightly faster growth rate, and from those of Hays [8], Godfrey and Farnsworth [4], Sheridan and Mc Donald [17], who observed a slight difference in the opposite direction. On the contrary, it should be noted that the identical response of the two genotypes in heated (31 °C) and temperate (21 °C) environments do not suggest that the *K* gene (slow feathering) is a genetic factor for adaptation to heat in our conditions.

3.2. Food intake and food efficiency (males in individual cages)

3.2.1. Food intake

Highly significant differences ($P < 0.001$) were observed for food consumption of cockerels in individual cages due to ambient temperature (higher food intake at 21 °C as expected) but no effect associated with *K/k⁺* or *k⁺/k⁺* genotypes (Tab. II). Concerning the latter, our results agree with those of Lowe and Merkle [10] and Guillaume [7] although the latter results concerned chicks aged between 0 and 20 days. Our results also agree with those of Dunnington *et al.* [3]. The excess of food intake at 21 °C as compared to 31 °C was respectively 17.3 per cent for the slow feathering genotype and 19.9 per cent for fast feathering birds from 4 to 10 weeks of age.

In the literature we did not find data related to the relation between genotypes *K/k⁺* and *k⁺/k⁺* genotypes and food intake at ambient temperature.

3.2.2. Food efficiency

Food efficiency was not significantly different between genotypes (Tab. II) over the whole experimental period, nor within each environment. It may

Table II. Males in individual cages: growth performances till 10 weeks of age according to genotype (K/k^+ versus k^+/k^+) and temperature.*(continued on the next page)*

		Mean values (\pm standard deviations)					
Temperature	Variable	Genotype	Age				4 to 10 weeks
			4 weeks	6 weeks or 4 to 6 w.	8 weeks or 6 to 8 w.	10 weeks or 8 to 10 w.	
31 °C	Body weight (BW) (g)	K/k^+ (a)	232 \pm 18	418 \pm 73	617 \pm 112	831 \pm 156	–
		k^+/k^+ (b)	228 \pm 34	407 \pm 71	608 \pm 120	825 \pm 163	–
	Change of body weight ΔW (g)	K/k^+	–	185 \pm 40	199 \pm 51	215 \pm 79	599 \pm 140
		k^+/k^+	–	176 \pm 47	202 \pm 53	217 \pm 65	594 \pm 141
	Feed intake (FI) (g)	K/k^+	–	549 \pm 82	658 \pm 101	787 \pm 167	1994 \pm 303
		k^+/k^+	–	521 \pm 84	629 \pm 114	772 \pm 162	1921 \pm 338
Feed conversion (FI/ ΔW)	K/k^+	–	3.01 \pm 0.3	3.28 \pm 0.2	3.66 \pm 0.7	3.41 \pm 0.5	
	k^+/k^+	–	3.13 \pm 0.9	3.24 \pm 0.8	3.61 \pm 0.5	3.32 \pm 0.5	

Analysis of variance							
Variable	Source of variation	d.f.	Significance per age (weeks)				
			4	6	8	10	4–10
BW	Temperature (T)	1	NS	NS	NS	***	–
	Genotype (G)	1	NS	NS	NS	NS	–
	$T \times G$	1	NS	NS	NS	NS	–
	Residual	117					
ΔW	T	1	–	NS	NS	***	***
	G	1	–	NS	NS	NS	NS
	$T \times G$	1	–	NS	NS	NS	NS
	Residual	117					

be noticed that the K/k^+ cockerels had slightly lower food efficiency than the k^+/k^+ cockerels at 8 weeks of age, the difference being in the reverse direction at 10 weeks. Our study also showed that the two temperatures had very significant effects ($P < 0.01$) on food efficiency: with the exception of the 6th week, the values of the intake/weight gain ratio were higher at 21 °C

Table II. *continued.*

		Mean values (\pm standard deviations)					
Temperature	Variable	Genotype	Age				4 to 10 weeks
			4 weeks	6 weeks or 4 to 6 w.	8 weeks or 6 to 8 w.	10 weeks or 8 to 10 w.	
21 °C	Body weight (<i>BW</i>) (g)	<i>K/k</i> ^(c)	227 \pm 30	420 \pm 64	638 \pm 10.3	955 \pm 136	–
		<i>k</i> ⁺ / <i>k</i> ⁺ ^(d)	219 \pm 32	414 \pm 64	633 \pm 9.4	943 \pm 123	–
	Change of body weight ΔW (g)	<i>K/k</i> ⁺	–	193 \pm 41	218 \pm 50	316 \pm 120	707 \pm 116
		<i>k</i> ⁺ / <i>k</i> ⁺	–	195 \pm 38	219 \pm 42	310 \pm 41	724 \pm 123
	Feed intake (<i>FI</i>) (g)	<i>K/k</i> ⁺	–	592 \pm 79	770 \pm 119	1 051 \pm 120	2 412 \pm 301
		<i>k</i> ⁺ / <i>k</i> ⁺	–	570 \pm 64	755 \pm 96	1 074 \pm 114	2 399 \pm 251
	Feed conversion (<i>FI</i> / ΔW)	<i>K/k</i> ⁺	–	3.14 \pm 0.8	3.63 \pm 0.5	3.35 \pm 0.3	3.34 \pm 0.2
		<i>k</i> ⁺ / <i>k</i> ⁺	–	2.99 \pm 0.4	3.51 \pm 0.5	3.49 \pm 0.3	3.34 \pm 0.3

Analysis of variance							
Variable	Source of variation	<i>df.</i>	Significance per age (weeks)				
			4	6	8	10	4–10
<i>FI</i>	<i>T</i>	1	–	***	***	***	***
	<i>G</i>	1	–	NS	NS	NS	NS
	<i>T</i> \times <i>G</i>	1	–	NS	NS	NS	NS
	Residual	117					
<i>FI</i> / ΔW	<i>T</i>	1	–	NS	**	**	NS
	<i>G</i>	1	–	NS	NS	NS	NS
	<i>T</i> \times <i>G</i>	1	–	NS	NS	NS	NS
	Residual	117					

^(a) $n = 30$; ^(b) $n = 29$; ^(c) $n = 28$; ^(d) $n = 30$; NS: not significant;

** $P < 0.01$; *** $P < 0.001$.

than at 31 °C, as a consequence of the effect of temperature on body weight gain and food consumption. Considering the whole period (4–10 weeks), the intake/weight gain ratio was slightly better at 21 °C than at 31 °C, even if the difference was not statistically significant.

According to some authors, especially Guillaume [7], a favourable effect associated with the k^+/k^+ genotype is not observed with food efficiency. The results of Lowe and Merkle [10] showed that body weight gains/food consumption ratios tended to favour the K/k^+ genotype, which our results suggest at 10 weeks, although not significantly. The effects of the k^+ gene observed by Pym *et al.* [15] seem to agree with our observations.

3.3. Plumage weight

3.3.1. Cockerels in individual cages

The analysis of variance (Tab. III) and means of absolute values of plumage weight and per cent related to body weight did not show any significant effect of temperature on these variables at 10 weeks. These results show on the contrary that the genotype had no effect on the weight of feathers, neither in absolute terms nor in per cent of body weight. These observations are in agreement with the conclusion of Dunnington and Siegel [2]. However, in spite of the absence of significant differences between K/k^+ and k^+/k^+ birds, it appears that the latter exhibit absolute or per cent values slightly superior to those of slow feathering birds and that the temperature of 21 °C gave only a slight advantage in absolute value to the birds of all genotypes as compared to 31 °C.

According to these results, it seems that K/k^+ as well as k^+/k^+ birds are sufficiently insulated to maintain a constant body temperature so as not to influence their performances; moreover the absence of significant effect of temperature and interaction with genotype suggests that the environment acts similarly on the expression of the genotype at 10 weeks of age.

3.3.2. Cockerels and pullets in group cages

It appears that concerning the absolute plumage weight (Tab. IV), the effect of age was highly significant ($P < 0.001$) in each sex and in both sexes together; the effects associated with the feathering genotype were not significant in any sex; however, the genotype \times age interaction was significant ($P < 0.05$) in males and in both sexes combined.

We also observed that any other interaction concerning the plumage weight was not significant. The differences of plumage growth due to age (Tab. IV) showed that the K/K or K/k^+ genotype was superior to k^+/k^+ at the 6th week only whereas afterwards the tendency was reversed. These observations are difficult to explain at present. In this respect, one may recall the conclusions of Sheridan and Mc Donald [17] according to whom the body and feathers of the chick at 6 weeks of age are in competition for arginin and cystein, of which the requirement is more important during the synthesis of feathers.

Table III. Males in individual cages: Body measurements at 10 weeks of age according to genotype and temperature.

Temperature	Variable	Mean values	
		Genotype	
		<i>K/k</i> ⁺ (<i>n</i> = 17)	<i>k</i> ⁺ / <i>k</i> ⁺ (<i>n</i> = 13)
31 °C	Weight of feathers (g)	93.0 ± 26.0	95.5 ± 21.0
	% feathers	10.9 ± 2.0	11.9 ± 0.9
	Weight of abdominal fat (g)	9.2 ± 5.8	10.6 ± 6.1
	% abdominal fat	1.4 ± 1.4	1.2 ± 0.5
		<i>K/k</i> ⁺ (<i>n</i> = 15)	<i>k</i> ⁺ / <i>k</i> ⁺ (<i>n</i> = 15)
21 °C	Weight of feathers (g)	102.4 ± 16.9	108.0 ± 19.3
	% feathers	10.8 ± 0.9	11.1 ± 0.9
	Weight of abdominal fat (g)	9.8 ± 6.4	10.9 ± 9.1
	% abdominal fat	1.0 ± 0.6	1.1 ± 0.8

Analysis of variance

Source of variation	Significance per variable				
	<i>d.f.</i>	Weight of feathers	% feathers	Weight of AF ^(a)	% AF
Temperature (<i>T</i>)	1	NS	NS	NS	NS
Genotype (<i>G</i>)	1	NS	NS	NS	NS
<i>T</i> × <i>G</i>	1	NS	NS	NS	NS
Residual	56				

^(a) AF: Abdominal Fat.

The fact that feather weight does not show significant differences associated to the *K/k*⁺ or *k*⁺/*k*⁺ genotypes is in agreement with Dunnington and Siegel's [2] results.

For absolute and per cent plumage weight, age and genotype showed no significant interaction effect in males. In females, conversely, we observed a highly significant influence ($P < 0.001$) of age on this parameter. In both sexes confounded, the highly significant effects were that of age ($P < 0.001$) and the effect of sex ($P < 0.001$) with the percentage of plumage being at

Table IV. Numbers of birds and mean values of feathers weight (absolute values and per cent) of birds in group cages.

Variables and sex		Periods (weeks) and genotypes							
		4 w.		6 w.		8 w.		10 w.	
		<i>K/k⁺</i>	<i>k⁺/k⁺</i>	<i>K/k⁺</i>	<i>k⁺/k⁺</i>	<i>K/k⁺</i>	<i>k⁺/k⁺</i>	<i>K/k⁺</i>	<i>k⁺/k⁺</i>
Males	<i>n</i>	7	5	6	6	6	6	6	6
weight of feathers (g)	<i>x ± σ</i>	12 ± 2.4	17 ± 3.2	31 ± 9.6	23 ± 6.6	33.8 ± 10.2	43.8 ± 9.9	—	—
% of feathers	<i>n</i>	7	5	6	6	6	6	—	—
<i>x ± σ</i>		5.4 ± 0.69	6.7 ± 0.67	8.16 ± 2.21	6.14 ± 1.9	7.10 ± 1.27	7.52 ± 0.49	—	—
Females	<i>n</i>	6	6	6	6	6	6	6	6
weight of feathers (g)	<i>x ± σ</i>	14 ± 2.53	14.17 ± 3.06	34.67 ± 10.71	28 ± 8.65	45.67 ± 12.96	44.33 ± 2.5	54.5 ± 5.54	59.7 ± 6.8
% of feathers	<i>n</i>	6	6	6	6	6	6	6	6
<i>x ± σ</i>		6.32 ± 0.88	6.43 ± 0.69	10.24 ± 1.24	7.36 ± 2.53	8.22 ± 1.89	8.73 ± 0.60	8.61 ± 0.64	9.04 ± 0.43

Analysis of variance

Source of variation	<i>df.</i>	Significance per variable	
		weight of feathers	% of feathers
1 - Sex	1	NS	***
2 - Age (4 to 8 weeks)	2	***	***
3 - Genotype	1	NS	NS
Interaction 1 × 2	2	NS	*
“ 1 × 3	1	NS	NS
“ 2 × 3	2	*	*
“ 1 × 2 × 3	2	NS	*
Residual	60	—	—

* *P* < 0.05; *** *P* < 0.001.

the advantage of females (Tab. IV); in addition, age \times sex and age \times sex \times genotype interactions were significant ($P < 0.05$).

3.4. Weight of abdominal fat

The effects of genotype and environmental temperature on abdominal fat deposition in cockerels at 10 weeks were not significant (Tab. III). Our results are in accordance with those of Lowe and Merkley [10] for each environment and each sex. On the whole, birds used in this study, of a laying type, had a rather low adiposity.

4. CONCLUSION

In conclusion keeping chicks at 31 °C (heated environment) causes an important growth depression, in particular after the 6th week, and a reduction of food intake over the whole assay period. This is reflected by the observations done on the cockerels, as compared to the ambient temperature of 21 °C. On the contrary, observations show that the sex-linked feathering genes did not influence growth rate, food intake and food efficiency in each sex. The *K* gene did not appear as an adaptation factor to heat, at least in light or median-size lines.

We also observed that the sex-linked feathering genes did not influence the abdominal fat deposition in males nor the growth of plumage in both sexes. There was an effect of age in both sexes on the total weight of feathers (absolute and per cent of body weight) and an effect of sex on per cent of feathers. On the contrary, the age \times genotype interaction in both sexes for the two same traits showed that the two genotypes have not had the same expression at all ages. This fact is not explained to date. It would be interesting to study the effects of the *K* gene at ages from 3 to 7 weeks and at temperatures above 31 °C in combination with other feathering genes known to favour adaptation of poultry to hot climates, [6]. Another indication on a possible adaptive role associated with the *K* and *k*⁺ genes could be brought by their relative frequencies in local populations.

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REFERENCES

- [1] Bacon L.D., Smith E.J., Crittenden L.B., Havenstein G.B., Association of genes determining feathering (*K*) with an endogenous virus (ev 21) on the Z chromosome, *Poult. Sci.* 64 (Suppl. 1) (1985) 60.

- [2] Dunnington E.A., Siegel P.B., Feather weight of early (k^+) and late (K) feathering young adult broiler, *Poult. Sci.* 65 (1986) 1863–1865.
- [3] Dunnington E.A., Siegel P.B., Katambaf N.K., Gross W.B., Response of early and late feathering broilers to various stressors, *Poult. Sci.* 66 (1987) 168–170.
- [4] Godfrey G.F., Farasworth G.M. Jr., Relation of sex-linked rapid feathering gene to chick growth and mortality, *Poult. Sci.* 31 (1952) 65–68.
- [5] Goodman B.L., Muir F.W., The influence of comb and feathering phenotype on body weight and dressing percentage, *Poult. Sci.* 44 (1965) 644–648.
- [6] Gowe R.S., Fairfull R.W., Breeding for resistance to heat stress, in: Dagher N.J. (Ed.), *Poultry Production in Hot Climate*, CAB International, Wallingford Onon, UK, 1995, pp. 11–29.
- [7] Guillaume J., Effets des gènes s et k sur la croissance et l'efficacité alimentaire chez les poussins dans 2 croisements et avec 2 niveaux protéiques, *Ann. Génét. Sél. Anim.* 6 (1974) 29–34.
- [8] Hays F.A., Rate of chick feathering and growing chick weight in Rhode Island, *Red. Poult. Sci.* 30 (1951) 866–869.
- [9] Lowe P.C., Garwood V.A., Independent effects of K and k^+ alleles and maternal origin on mortality and performance of crossbred chickens, *Poult. Sci.* 60 (1981) 1123–1126.
- [10] Lowe P.C., Merkley J.W., Association of genotype for rate of feathering in broilers with production and carcass composition traits. Effect of genotypes, sex, and diet on growth and feed conversion, *Poult. Sci.* 65 (1986) 1853–1858.
- [11] Mac Donald M.W., Methionine supplements in chickens diets. III. The biochemical difference in sulphur-amino acid metabolism between W.L. and Australops, *Austral. J. Agric. Res.* 9 (1958) 161–164.
- [12] Mérat P., Contribution à l'étude de la « valeur sélective » associée à quelques gènes chez la poule domestique. I - Différences quantitatives liées au génotype, *Ann. Biol. Anim. Bioch. Biophys.* 7 (1967) 79–104.
- [13] Mérat P., Mendelian genetics and selection for quantitative traits in poultry: results and perspectives, *World's Poult. Sci. J.* 26 (1970) 571–586.
- [14] Pulmart P.E., Mueller C.D., Effect of sex-linked early feathering on plumage from 6 to 12 weeks of age, *Poult. Sci.* 33 (1954) 715–721.
- [15] Pym R.A.E., Nicholls P.J., Thomson E., Chice A., Farrell D.J., Energy and nitrogen metabolism of broilers selected over ten generations for increased growth rate, food consumption and conversion of food to gain, *Br. Poult. Sci.* 25 (1984) 529–539.
- [16] Serebrovsky A.S., Crossing over involving three sex-linked gene in chickens, *Am. Nat.* 56 (1922) 571–572.
- [17] Sheridan A.K., Mac Donald M.W., The relationship between feathering and body weight in broiler chickens, *Poult. Sci.* 42 (1963) 1468–1471.
- [18] Snedecor G.N., Cochran W.G., *Statistical Methods*, 6th edn., Iowa State Univ. Press, Ames, Iowa, 1967.
- [19] Warren D.C., Inheritance of rate feathering in poultry, *J. Hered.* 16 (1925) 13–18.
- [20] Warren D.C., Payne L.F., Influence of the early feathering gene upon a chick's growth rate, *Poult. Sci.* 24 (1945) 191–192.