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Original article

Genetic influences on growth and partition of fat between depots and its distribution in fowl carcasses

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Summary – Thirty-two Hubbard and 40 Egyptian Fayoumi (dual-purpose) chickens were slaughtered in series at 2-wk intervals between 2–8 wk and 2–10 wk of age, respectively. Genetic differences in the allometric fat growth equation constants were studied. Relative to total body fat *(TBF)*, the breeds did not differ significantly in relative growth of non-carcass fat. The Fayoumi tended to lay down carcass fat at a faster rate than the Hubbard. As *TBF* increased, the proportion of non-carcass fat increased and that of carcass fat decreased in the Hubbard; these depots tended to grow at the same rate as *TBF* in the Fayoumi. The Hubbard had significantly higher relative rates of fat deposition in the thigh, drumstick, breast and lower rates of fat deposition in the wing and neck than the Fayoumi. As the Hubbard matured, their growth cœfficients of carcass fat tended to decrease anteriorly from breast to neck and also from leg to wing. The specific growth rates in almost all parts of the Fayoumi did not differ significantly from that of the total carcass fat. The present study shows for the Hubbard, as compared to Fayoumi, distinct patterns of fat partitioning (higher non-carcass fat: carcass fat; higher intermuscular fat: subcutaneous fat) and distinct patterns of fat distribution (higher proportion of the total depot occurring in the prime cuts). The study also gives some indications of different fat deposition patterns in poultry as compared to ruminants (cattle and sheep).

fat growth / fat partitioning / fat distribution / chicken

Résumé — Influences génétiques sur la croissance, la répartition des graisses entre les dépôts et leur distribution dans les carcasses de poules. *Des abattages de 32 poulets «Hubbard» et de 40 «Egyptian Fayoumi» ont été effectués à des intervalles de 2 semaines entre les stades 2 à 8 semaines et 2 à 10 semaines d'âge, respectivement. Les différences génétiques de constantes des équations de croissance allométrique en graisses ont été étudiées. Les races ne diffèrent pas significativement en croissance relative en graisses hors carcasse (viscérales) par rapport aux graisses totales. Les «Fayoumi» ont tendance à déposer des graisses de carcasse plus rapidement que les «Hubbard». Tandis que les graisses totales augmentent, la proportion de graisses hors carcasse s'accroît et celle des graises de carcasse décroît chez les «Hubbard»; ces dépôts ont tendance à augmenter au même taux que les graisses totales chez les «Fayoumi». Les «Hubbard» ont des taux relatifs de déposition de graisses supérieurs dans la cuisse, le pilon et la poitrine et inférieurs dans les ailes et le cou à ceux des «Fayoumi». Les cœfficients d'augmentation des graisses de carcasse ont tendance, avec la maturité chez les «Hubbard», à décroître de la poitrine au cou et aussi de la patte à l'aile. Les taux de croissance spécifiques dans presque tous les compartiments des «Fayoumi» ne diffèrent pas significativement de ceux des graisses totales. L'étude présente montre des différences de répartition entre «Hubbard» et «Fayoumi» quant à la répartition des graisses (rapports : hors carcasse > carcasse; intermusculaires > sous-cutanées) et de distribution (plus fort pourcentage de dépôts dans les morceaux de première catégorie). L'étude donne aussi des indications sur les modèles différents de dépôt de graisse chez les volailles et les ruminants.*

croissance / répartition des graisses / distribution des graisses / poulet

INTRODUCTION

Fat partition patterns, including an excessive amount of fat in the abdomen, has been a problem to the producer (wasted dietary energy; Lin *et al,* 1980), the processor (waste mangement and product yield; Heath *et al,* 1980) and to consumer acceptance (disadvantageous subcutaneous fat distribution in the carcass; Ricard *et al,* 1983).

Differences in fat partition have already been reported between broiler strains (Littlefield, 1972; Farr *et al,* 1977; Van Middelkoop *et al,* 1977; Griffiths *et al,* 1978; Nordstrom *et al,* 1978; Merkley *et al,* 1980), between layer-type and broiler type (March and Hansén, 1977; March, 1984; Griffin *et al,* 1987) and between dual-purpose and layer-type chickens (Mahmoud *et al,* 1985).

The objective of this study was to determine if the passage from dual-purpose (Fayoumi) to broiler-type (Hubbard) chicken breeds would affect patterns of growth and partition of fat between depots and its distribution between various carcass cuts.

MATERIAL AND METHODS

Material

Thirty-two Hubbard chickens and native 40 Fayoumi chickens were used in this study. They were serially slaughtered at 2-wk intervals between 2-8 wk of age for the Hubbard and 2-10 wk for the Fayoumi.

A growth diet containing approximately 21% of crude protein and a metabolizable energy value of 3 200 kcal•kg^{-1} was given to chicks from hatching to 6 wk. They were thereafter fed a diet containing 17% of crude protein, while maintaining the same metabolizable energy level. Feed and water were provided *ad libitum* and conventional brooding and rearing practices were used.

Methods

The birds were individually weighed prior to slaughtering. They were killed by severing the carotid artery and jugular veins. The head was removed at the atlanto-occipital articulation. While dressing, the heart fat and the gizzard fat were removed and the visceral fat from around the cloaca and under the viscera was removed. The sum of the above depots is referred to as total non-carcass fat. After dressing, the carcass was stored in a closed bag at –20°C. Prior to cutting and dissection, the carcasses were thawed for approximately 8 hrs at 5°C while in the bags. The right side of the carcass was prepared for separation of various cuts. The breast containing the sternum and its associated muscle and fat was removed. The hind leg was removed from the carcass at the acetabulum with the pelvic muscles and bones left attached to the leg. The proximal part (thigh) was separated from the distal part (drumstick) at the tibiofemoral joint. The gluteus (oyster) muscles were removed and included with the thigh muscle. The foreleg (wing) and neck were separated from the carcass, the neck being removed as close to the clavicle as possible. Thus the right side was divided into the following commercial cuts: thigh, drumstick, wing, breast and neck. Three groupings of cuts were made. The thigh plus drumstick (leg) represented the combined dark cuts, the breast plus wing represented the combined white cuts and the breast plus thigh represented the combined prime cuts. In each cut the skin and subcutaneous fat were removed from the surface of the superficial muscles and intermuscular fat was removed from between the muscles and from within the indentation of their origin and insertion. The sum of the above depots at the carcass side level is referred to as total dissected fat. The total body fat combined both total-non-carcass fat and 2 x total dissected fat.

Statistical analysis

To assess genotype-group influences on fat growth and partitioning between depots and distribution, the data were analyzed by least-squares analysis (Harvey, 1987). The allometric equation $Y = a X^b$, where a is a constant and b

is the growth cœfficient, formed the basis of the model which was:

$\text{Log } Y_{ij} = A\bullet + G_i + (Gb)_i \text{Log } X_{ij} + E_{ij}$

where:

Y_{ij} = the weight in grams of the component Y for the ij bird;

$A\bullet$ = the intercept;

G_i = fixed effect of the ith genotype-group (i = 1,2);

X_{ij} = the weight in grams of the control component for the ij bird;

b = regression cœfficient of Y on X;

$(Gb)_i$ = the interaction effect (genotype-group x regression cœfficient);

E_{ij} = error assumed to be NID $(0,\sigma^2_e)$

With very few exceptions, regressions in the present study were significantly different between genotype groups, and adjusted means computed using the common regression were thus not legitimately testable for statistical significance. Instead, means were estimated from individual genotype-group regressions at the between-breed common extreme values of the independent variate (X).

RESULTS AND DISCUSSION

Table I gives means and standard deviations for weights of cold carcass and dissected side and weights and percentages of total fat in the body and in the dissected side (unadjusted values).

Genetic influences on growth patterns of fat depots

Relative to total body fat (*TBF*), carcass fat (*TCF*) taken as a whole tended to grow at a lower rate than non-carcass fat (*TNCF*) (table II). Compared with the Fayoumi, the Hubbard had a significantly ($P < 0.01$) lower growth rate for *TCF* and a similar ($P > 0.05$) rate for *TNCF*. As *TBF* increased, its weight partition between *TCF* and *TNCF* remained almost unchanged ($b = 1$) in the Fayoumi. Significant changes were found in the Hubbard including a decrease in the proportion of *TCF* ($b < 1$) and an increase in the proportion of *TNCF* ($b > 1$), in agreement with previous works (Evans, 1972; Griffiths *et al*, 1978; Fisher, 1984).

In table II where the depots are arranged in the order of ascending values of b, it appears that the sequence of development of the fat depots occurred in the following manner. In the Hubbard, the earliest developing depot was heart fat, followed by subcutaneous fat, visceral fat, intermuscular fat and gizzard fat. The Fayoumi showed the same developmental sequence except that subcutaneous fat (*TSCF*) and intermuscular fat (*TIMF*) were interchanged. While both breeds showed similar

Table I. General description of 32 Hubbards and 40 Fayoumis used in the study

	Hubbard		*Fayoumi*	
	Mean	*SD*	*Mean*	*SD*
Live weight (g)	892.3	569.3	420.3	252.7
Cold carcass weight (g)	539.4	363.1	237.7	151.8
Dissected side weight (g)	270.0	181.5	117.1	74.8
Total body fat (g)	133.6	102.4	38.3	24.8
Body fat in live weight (%)	14.1	3.0	8.9	1.1
Dissected side fat (g)	55.9	40.2	17.1	10.8
Dissected fat in the side %)	20.4	2.9	14.9	1.8

Table II. Growth cœfficients (b) and their standard errors (SE) and adjusted means for weights of fat depots *(y)* relative to total body fat *(x)*

y	*Hubbard*		*Fayoumi*		*Residual*	*Adjusted means[b] antilog y (%)*		*Significance of difference in*
	b[a]	*SE*	*b*	*SE*	*SD*	*Hubbard*	*Fayoumi*	*slopes*
TCF	*0.964*	0.008	0.993	0.009	0.019	89.65[1] 85.23	91.91 91.20[2]	**
TNCF	*1.305*	0.073	1.138	0.079	0.166	10.34 14.46	7.98 9.28	NS
Heart fat	*0.726*	0.121	0.817	0.130	0.269	1.25 0.93	1.08 0.88	NS
Visceral fat	0.952	0.118	0.896	0.127	0.263	1.84 1.75	1.65 1.47	NS
Gizzard fat	*1.448*	0.086	*1.370*	0.093	0.192	6.80 11.13	5.12 7.69	NS
TSCF	*0.859*	0.056	1.038	0.060	0.129	69.70 59.70	72.13 75.21	*
TIMF	1.081	0.044	*0.848*	0.047	0.107	19.93 25.53	19.78 15.99	**

TCF = total carcass fat *TNCF* = total non carcass fat *TSCF* = total subcutaneous fat *TIMF* = total intermuscular fat. [a] Growth cœfficients in italics were significantly different from 1 at $P < 0.05$. [b] Adjusted to the between-group common extreme total body fat value of 30 g [1] and 90 g [2], using individual genotype regressions. * $P < 0.05$; ** $P < 0.01$; *NS* $P > 0.05$

rates of deposition for each of the non-carcass fat depots relative to *TBF*, the Hubbard had a lower rate of *TSCF* and a higher rate of *TIMF* than the Fayoumi.

Both the Hubbard and Fayoumi showed that the contribution of *TSCF* was greatest, followed by *TIMF*, gizzard fat, visceral fat and heart fat in decreasing order. It would be of interest to contrast the *TSCF*: *TIMF* ratio > 1 found in birds (chickens: Demby and Cunningham, 1980; and ducks: Evans, 1972) with that reported to be closer to or less than 1 in sheep and cattle (Leat and Cox, 1980).

Genetic influences on growth patterns of fat in various cuts

Relative to total dissected carcass fat *(TDF)* and to each of its component depots *(TSCF; TIMF)*, the rates of deposition of these tissues in each cut are shown in table III. Significant between-breed differences were found in the deposition rate of dissected fat and *TSCF* in all cuts and cut combinations. The accumulation of these tissues in the neck and wing was significantly slower and that in breast, thigh, drumstick and combined prime cuts, dark

Table III. Carcass cuts arranged in order of ascending values of growth cœfficients (b) of the contaninig dissected fat, subcutaneous fat and intermuscular fat.

	Growth cœfficient[a] ± standard error				
	Cut dissected fat relative to total dissected fat		*Cut subcutanous fat relative to total subcutaneous fat*		*Cut intermuscular fat relative to total intermuscular fat*
Hubbard					
Neck	*0.766* ± 0.032 (**)	Neck	*0.764* ± 0.041 (**)	Wing	*0.820* ± 0.068 (**)
Wing	*0.876* ± 0.029 (**)	Wing	*0.887* ± 0.040 (*)	Neck	*0.822* ± 0.058 (NS)
Breast	*1.098* ± 0.033 (*)	Breast	*1.080* ± 0.041 (*)	Drumstick	*0.991* ± 0.076 (NS)
Drumstick	*1.120* ± 0.052 (*)	Thigh	*1.149* ± 0.038 (*)	Thigh	*1.166* ± 0.048 (*)
Thigh	*1.159* ± 0.030 (**)	Drumstick	*1.161* ± 0.065 (*)	Breast	*1.202* ± 0.067 (NS)
White cuts	*1.122* ± 0.012 (**)	Prime cuts	*1.105* ± 0.020 (**)	Dark cuts	*1.133* ± 0.035 (*)
Prime cuts	*1.128* ± 0.016 (**)	White cuts	*1.109* ± 0.015 (**)	White cuts	*1.150* ± 0.026 (**)
Dark cuts	*1.142* ± 0.021 (**)	Dark cuts	*1.137* ± 0.032 (**)	Prime cuts	*1.172* ± 0.030 (**)
Fayoumi					
Neck	0.951 ± 0.033 (**)	Breast	0.982 ± 0.039 (*)	Neck	*0.821* ± 0.076 (NS)
Drumstick	0.976 ± 0.054 (*)	Drumstick	0.990 ± 0.062 (**)	Drumstick	0.881 ± 0.101 (NS)
Breast	1.008 ± 0.034 (*)	Neck	0.998 ± 0.039 (**)	Thigh	1.009 ± 0.064 (*)
Thigh	1.024 ± 0.031 (**)	Wing	1.006 ± 0.038 (*)	Breast	1.038 ± 0.088 (NS)
Wing	1.043 ± 0.030 (**)	Thigh	1.036 ± 0.036 (*)	Wing	*1.232* ± 0.089 (**)
White cuts	1.005 ± 0.013 (**)	White cuts	1.000 ± 0.014 (**)	Dark cuts	0.998 ± 0.047 (*)
Dark cuts	1.006 ± 0.022 (**)	Prime cuts	1.008 ± 0.019 (**)	White cuts	1.003 ± 0.034 (**)
Prime cuts	1.013 ± 0.016 (**)	Dark cuts	1.016 ± 0.031 (**)	Prime cuts	1.017 ± 0.039 (**)

[a] Growth cœfficients in italics were significantly different from 1 at $P < 0.05$; between parentheses: significance of F-value for breed differences in slopes: $P > 0.05$ * $P < 0.05$ ** $P < 0.01$

and white cuts was significantly more rapid in the Hubbard than in the Fayoumi. For *TIMF* a similar trend was found except that the breed differences were not significant in the neck, breast and drumstick.

Growth cœfficients of *TDF, TSCF* and *TIMF* indicated that they tended in the Hubbard to decrease with maturity anteriorly from breast to neck and from hindlimb (dark cuts) to forelimb (wing). The growth cœfficients for almost all parts of the Fayoumi did not differ significantly from 1. The growth patterns of muscle, lean, and edible meat in different cuts of the same Hubbard chickens of the present study (Abdallah *et al*, unpublished data) showed that the growth gradient was inverse to that of fats. This would lead to a higher fat: muscle ratio in breast than in neck and in leg cuts than in wing.

The *b* values given in table II indicate also that as *TBF* increased its weight partition between its various detailed depots showed significant changes. In both breeds, the proportion of heart fat decreased ($b < 1$), that of gizzard fat increased ($b > 1$) and that of visceral fat remained almost constant ($b = 1$). For the Hubbard and Fayoumi, respectively, the proportion of *TSCF* decreased and remained constant and the proportion of *TIMF* remained without change and increased. This observation suggests that as fatness progresses chickens show a decreasing *TSCF: TIMF* ratio. Sheep and cattle are known (Kempster, 1981) to present an increasing pattern.

Genetic influences on fat partition between depots

Mean weights of *TCF* and *TNCF* at fixed TBF weight were compared between the Hubbard and the Fayoumi (table II). At 90 g total body fat weight, the Fayoumi relative to the Hubbard has as much as 64% of *TNCF* and 107% of *TCF*, exhibiting a layer-type fat partitioning pattern. Previous work (Littlefield, 1972; Farr *et al*, 1977; March and Hansen, 1977; Van Middelkoop *et al*, 1977; Griffiths *et al*, 1978; Nordstrom *et al*, 1978; Mahmoud *et al*, 1985; Griffin *et al*, 1987) indicated that layer-type chickens were characterized by much less abdominal fat than broiler or dual-purpose type chickens.

The Hubbard tended to deposit more of the total fat as *TIMF* and less as *TSCF*. The lower *TSCF: TIMF* ratio in the Hubbard reflects its superiority on the scale of degree of improvement as regards meat production (Kempster, 1981). A consistent finding for both genotype-groups of the present study, and probably for other chicken breeds (Becker *et al*, 1981), was that relative to *TBF* the contribution of carcass fat was higher than non-carcass fat.

With the increase in weight of *TDF, TSCF* and *TIMF*, their distribution between prime and secondary quality cuts and that between neck, dark and white cuts remained almost constant ($b = 1$) in the Fayoumi. In the Hubbard their proportions increased in prime cuts and decreased in the secondary cuts. Ricard *et al* (1983) reported data permitting the calculation of *TSCF*-weight distribution with its increase from approximately 14 to 37 g as a result of selection. The proportion of *TSCF* in the neck decreased (25.8% *vs* 21.5%), that occurring in the thigh + drumstick remained almost constant (29.0% *vs* 28.1%) and that in the remaining carcass increased (45.2% *vs* 50.0%). In the Hubbard of the present study (table IV) the increase in *TSCF* from 4 to 35 g resulted in a decrease in its proportion occurring in the neck (26.5% *vs* 16.2%) and wing (22.9% *vs* 17.9%) and an increase in that found in the remaining carcass.

Table IV. Total fat distribution between cuts. Results are for weights, estimated using individual group regressions, of dissected fat, subcutaneous fat and intermuscular fat in each cut at fixed weight of respective total dissected fat *(TDF)* total subcutaneous fat *(TSCF)*, total intermuscular fat *(TIMF)*, weights then converted to percentages

Fat in:		*% of TDF in different cuts at TDF weights of*		*TSCF % in different cuts at TSCF weights of*		*TIMF % in different cuts at TIMF weights at*	
		6 g	*43 g*	*4 g*	*35 g*	*2 g*	*8 g*
Thigh	Hubbard	21.71	29.70	19.40	26.80	27.46	34.57
	Fayoumi	24.20	25.36	21.76	23.53	29.10	29.87
	Hubbard: Fayoumi	0.89	1.17	0.89	1.14	0.94	1.16
Drumstick	Hubbard	8.23	10.42	8.57	12.15	7.45	7.35
	Fayoumi	10.62	10.13	10.71	10.48	8.85	7.51
	Hubbard: Fayoumi	0.78	1.02	0.79	1.16	0.84	0.98
Wing	Hubbard	21.45	16.81	22.85	17.89	19.29	15.03
	Fayoumi	25.61	27.88	25.45	26.35	23.29	32.11
	Hubbard: Fayoumi	0.84	0.60	0.89	0.67	0.83	0.47
Neck	Hubbard	28.69	18.13	26.52	16.21	33.20	26.36
	Fayoumi	21.73	18.56	20.03	18.45	26.74	17.85
	Hubbard: Fayoumi	1.32	0.97	1.33	0.88	1.24	1.48
Breast	Hubbard	19.92	24.16	22.66	26.95	12.60	16.69
	Fayoumi	19.97	20.28	22.05	21.19	12.02	12.66
	Hubbard: Fayoumi	0.99	1.19	1.07	1.27	1.05	1.32
White cuts	Hubbard	41.07	41.02	44.93	44.85	31.87	32.37
	Fayoumi	44.58	46.67	47.87	47.19	35.16	44.66
	Hubbard: Fayoumi	0.92	0.88	0.94	0.95	0.91	0.72
Dark cuts	Hubbard	29.94	40.12	27.97	38.95	34.91	41.92
	Fayoumi	34.81	35.49	32.47	34.01	37.95	37.38
	Hubbard: Fayoumi	0.87	1.13	0.86	1.15	0.92	1.12
Prime cuts	Hubbard	41.94	53.86	42.06	53.75	40.06	51.26
	Fayoumi	44.15	45.64	43.81	44.71	41.11	42.53
	Hubbard: Fayoumi	0.95	1.18	0.96	1.20	0.97	1.21

Genetic influences on fat distribution between cuts

The weight of dissected fat, subcutaneous fat and intermuscular fat occurring in each cut and cut group relative to equal weights of *TDF, TSCF* and *TIMF*, respectively, are presented in table IV. Fat weight in each cut was estimated from individual regressions at the between-breed common extreme values of *TDF* (6 and 43 g), *TSCF* (4 and 35 g) and *TIMF* (2 and 8 g).

At *TDF* of 43 g the Hubbard compared to Fayoumi tended to have proportionately more *TDF* occuring in the thigh (29.7% *vs* 25.4%) and breast (24.2% *vs* 20.3%) and a similar percentage occurring in the neck (18.1% *vs* 18.5%) and drumstick (10.4% *vs* 10.1%) and a lower percentage occurring in the wing (16.8% *vs* 27.9%). Comparable trends were found for the distribution of *TDF* component depots *(TSCF; TIMF)*. These observations suggest that the broiler-type may be characterized by a proportionately higher amount of total fat in the prime cuts (thight + breast) than the dual-purpose type.

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