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Original article

Sources of shared variability in muscle and fat weight Distribution in Pekin ducklings

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Abstract — A factor analysis with a varimax rotation was applied to 10 highly intercorrelated fatness and meatiness traits on 144 Pekin ducks to disclose the main sources of shared variability, deduce the factors that describe muscle and fat distribution and predict total carcass muscle and fat from orthogonal fatness and meatiness traits. Muscle and fat weight distribution appeared to be controlled by common and unique factors. The communalities ranged from 0.79 (drumstick muscle) to 0.95 (neck muscle and drumstick fat) and the uniqueness (special size factors) made the balance. Findings indicated the most of the common variability (86 %) in muscle and fat weight distribution could be accounted for by factors representing fatness, muscling, neck muscle and drumstick fat factors. Independent fatness and meatiness traits derived from factor analysis accounted for 97 % and 98 % of the variation in total carcass muscle and total carcass fat, respectively. © Elsevier / Inra

factor analysis / Pekin ducks / muticollinearity / muscle weight variations / fat weight variations

Résumé — Origines de la variabilité conjointe de la distribution corporelle du muscle et du gras chez le canard Pékin. Une analyse factorielle utilisant une rotation varimax a été appliquée à dix caractéristiques de muscles et de gras mesurées sur 144 canards Pékin pour i) identifier les principales sources de variabilité commune, ii) déterminer les facteurs contrôlant la répartition du muscle et du gras, iii) prédire la quantité totale de muscle et de gras dans la carcasse à partir des caractéristiques orthogonales de la carcasse. La répartition pondérale des muscles et du gras semble à la fois contrôlée par des facteurs communs et des facteurs spécifiques. Les facteurs communs ont un effet compris entre 0,79 (muscle du pilon) et 0,95 (muscle du cou et gras du pilon). Les facteurs spécifiques (facteurs de la taille) influencent l'équilibre muscle/gras. Les résultats obtenus montrent que l'essentiel de la variabilité (86 %) de la répartition pondérale des muscles et du gras peut être attribué à quatre facteurs communs représentant le gras (I), les muscles (II), les muscles du cou (III) et le gras du pilon (IV). Les données de gras et de muscle dérivées de l'analyse factorielle expliquent respectivement 97 et 98 % de la variabilité de la quantité totale de muscle et de gras dans la carcasse. © Elsevier / Inra

analyse factorielle / canard Pékin / multicollinéarité / muscle / gras

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1. INTRODUCTION

A superior carcass is characterized by a desirable distribution of its total meat between different cuts. At their prevailing market ages, ducks compared with other poultry species had proportionally less total carcass muscle occurring in breast and leg [16] and less muscle and greater fat, especially subcutaneous fat, in the carcass [6, 14].

Since carcass traits are intercorrelated both genetically and phenotypically [3–5, 7, 8, 10–12, 18], the analysis of these traits should address interdependence among independent variables. Independent factor scores derived from factor analysis have been used advantageously as predictors of total carcass muscle and bone and other performance traits [11, 13, 15] and as a selection criterion for genetic improvement of muscle weight distribution [12].

The objectives of this study were to disclose the main sources of shared variability, deduce factors that describe muscle and fat distribution of Pekin ducklings and to estimate carcass meatiness and fatness utilizing orthogonal carcass traits derived from factor analysis. In a previous paper we reported sources of shared variability in muscle and bone weight distribution using the same ducklings [11].

2. MATERIALS AND METHODS

One-hundred-and-forty-four (equal number of males and females) Pekin ducklings, approximately 1683 g in live weight and 10 weeks of age were used in this study. The birds were slaughtered by severing the carotid artery and jugular veins. After dry plucking birds were eviscerated. The feet and shanks were removed at the tibio-tarsus joint and the head at the atlanto-occipital articulation. After dressing carcasses were stored at –20 °C. Prior to cutting and dissection, carcasses were thawed for approximately 18 h at 5 °C while being in their bags. The right sides were then jointed into the following commercial cuts: thigh, drumstick, wing, breast, neck and tail as described by Shahin [10]. In each, cut skin, subcutaneous fat, intermuscular fat, muscle and bone were dissected and weighed. The sum of these parts over all cuts gave total side muscle (TSM), total side bone and total side skin plus subcutaneous fat and total side intermuscular fat. The sum of skin plus subcutaneous fat and intermuscular fat was referred to as total side fat (TSF). The data from males and females were combined since the two data dispersion matrices did not differ significantly (untabulated).

2.1. Statistical analysis

The data were subjected to factor analysis procedure [9]. The main source of shared variation among correlated muscling and fatness variables (p) was expressed in terms of fewer mutually uncorrelated common factors F_1, ..., F_q (where $q < p$) than the original variables [1].

The model used was as follows:

$$X = \Lambda F + U$$

where X = a $p \times 1$ vector of observable variables; Λ = a $p \times q$ matrix of factor loading 'factor- variate correlations' (the pattern matrix); F = a $q \times 1$ vector of factors (non-observable); and U = a $p \times 1$ vector of specific 'unique' factor'.

Multiple regression was used to predict total side muscle weight and total side fat weight from the orthogonal factor scores derived from factor analysis.

3. RESULTS AND DISCUSSION

3.1. Original 'non-independent' variables

Table I presents the means, standard deviations, coefficient of variability and ranges for live weight and muscle and fat traits. Total side muscle ranged from 100 to 325 g with a mean of 236 g and total side fat ranged from 61 to 126 g with a mean of 99 g. Carcass muscle:fat ratio ranged from 0.96 to 3.71 with a mean of 1.91. Pingel [6] reported that at 8 weeks of age the average muscle:skin plus subcutaneous fat ratio was 1.63, 1.92 in Pekin and Muscovy ducks, respectively.

Table I. Means, standard deviations (S.D.), coefficient of variability (CV %) and minimum and maximum values for live and carcass traits in Pekin ducklings.

	Mean	S.D.	CV %	Range
Live weight (g)	1682.6	209.6	12.5	1000–2100
Dissected side weight (g)	469.3	76.1	16.2	257.4–618.2
Total side muscle (g)	235.5	40.1	17.0	100.3–324.5
Total side bone (g)	98.6	10.2	10.3	60.9–125.9
Total side fat (g)	135.3	43.7	32.3	47.3–258.2
Total side subcutaneous fat (g)	121.7	40.0	32.9	44.3–235.4
Total side intermuscular fat (g)	13.6	5.4	39.7	3.0–28.7
Boneless weight (g)	370.8	69.3	18.7	193.2–511.6
% of live weight				
Total muscle	27.9	2.8	9.9	19.9–34.2
Total bone	11.8	1.0	8.7	9.0–14.9
Total fat	15.9	4.2	26.6	6.7–25.2
Total subcutaneous fat	14.3	3.9	27.4	6.2–23.5
Total intermuscular fat	1.6	0.5	33.5	0.5–2.8
Boneless	43.8	4.1	9.5	31.5–52.2
% of total muscle				
Drumstick muscle	13.9	1.5	11.1	10.5–18.5
Thigh muscle	20.1	2.1	10.4	15.9–30.1
Breast muscle	27.8	5.5	19.9	11.9–40.5
Wing muscle	14.1	1.4	10.0	9.0–17.8
Neck muscle	10.2	1.6	15.4	7.3–14.6
% of total fat				
Drumstick fat	7.7	2.7	35.3	4.1–25.4
Thigh fat	17.0	2.9	17.1	9.1–25.4
Breast fat	23.2	3.2	13.8	13.7–32.3
Wing fat	17.0	3.4	19.9	9.7–32.1
Neck fat	17.0	3.0	17.5	6.9–36.4
Muscle:fat ratio in:				
Drumstick	3.9	1.9	49.7	1.0–10.7
Thigh	2.4	1.0	42.1	0.9–5.7
Breast	2.4	1.0	42.6	0.7–5.2
Wing	1.6	0.5	28.9	0.7–2.9
Neck	1.2	0.6	47.9	0.6–6.2
Whole carcass	1.9	0.6	33.0	1.0–3.7

The breast muscle and thigh muscle accounted for 27.8 and 20.1 % of total carcass muscle weight, respectively. The breast fat accounted for 23.2 % of total carcass fat weight. Each of the thigh fat, the wing fat and neck fat accounted for 17.0% of total carcass fat weight. The muscle:fat ratios for various parts of the carcass are also shown in *table I.*

Coefficient of variability ranged from 13.8 % for proportion of total fat in breast to

35.3 % for proportion of total fat in drumstick. Within the same anatomical region the variability of muscle was smaller than that of fat (*table I*).

3.2. The relationship with each other and with TSM and TSF

The weight of muscle or fat in individual cuts appeared to be highly correlated with total weight of the corresponding tissue in the carcass (*table II*). Similar findings have been reported by Janiszewska et al. [2], Walters et al. [17] and Shahin [11, 12]. Total carcass fat had the highest correlation with breast fat weight and the lowest with drumstick fat weight. The correlation between breast muscle weight and TSM was 0.94, while that between breast fat weight and TSF was 0.95. Wawro et al. [18] obtained a correlation of > 0.80 between breast muscle weight and weight of lean in the carcass. Walters et al. [17] found a correlation of 0.90 between percentage breast skin with fat and percentage carcass fat.

3.3. Varimax rotated 'independent' factors. Their interpretation

Four common factors (one for fatness, one for meatiness, and the others for neck muscle and drumstick fat) have been identified, contributing to 86 % of the variability of the original 10 variables, leaving 14 % to the 10 'unique' factors (*table III*).

The first factor (I) ('fatness') is characterized by high positive loadings (factor-variate correlations) on all fatness traits (*table III*). The variables associated with thigh fat had the highest loadings, followed by the breast fat and wing fat. This factor accounted for 51.7 % of the variation in the original variables. Fatness factor represents a larger amount of variation in the original boneless variables than muscling factor.

The second factor (II) ('muscling'), giving relatively high weight to all muscling traits, accounted for an additional 24.1 % of the total variation. Variables associated with wing muscle and breast muscle had the highest loadings, followed by those associated with leg muscle. This factor presents

Table II. Coefficients of correlation between variables in Pekin ducklings.

	LW	TSM	TSF	SCF	DF	TF	BF	WF	NF	DM	TM	BM	WM	NM
Live weight (LW)														
Total side muscle (TSM)	0.84													
Total side fat (TSF)	0.67	0.37												
Total side Subcutaneous fat (SCF)	0.65	0.33	0.99											
Drumstick fat (DF)	0.35	0.06	0.77	0.79										
Thigh fat (TF)	0.64	0.39	0.89	0.87	0.56									
Breast fat (BF)	0.66	0.40	0.95	0.94	0.70	0.82								
Wing fat (WF)	0.65	0.41	0.83	0.83	0.57	0.72	0.75							
Neck fat (NF)	0.57	0.29	0.88	0.88	0.67	0.74	0.78	0.69						
Drumstick muscle (DM)	0.79	0.80	0.42	0.40	0.20	0.40	0.42	0.43	0.35					
Thigh muscle (TM)	0.72	0.85	0.28	0.25	0.04	0.27	0.33	0.33	0.21	0.71				
Breast muscle (BM)	0.72	0.94	0.27	0.23	−0.02	0.32	0.31	0.32	0.20	0.67	0.70			
Wing muscle (WM)	0.74	0.89	0.24	0.22	−0.02	0.28	0.29	0.22	0.16	0.71	0.75	0.80		
Neck muscle (NM)	0.68	0.58	0.49	0.47	0.28	0.44	0.24	0.50	0.44	0.58	0.57	0.38	0.49	

Table III. Explained variation associated with rotated factor analysis along with communalities and unique factor for each variable. Correlation between factor score coefficients and original variables in Pekin ducklings.

	Rotated common factors					
	I	II	III	IV	Communalities	Unique factor
Drumstick fat	0.608	–0.069	0.058	0.758	0.952	0.048
Thigh fat	0.905	0.198	0.069	0.019	0.863	0.137
Breast fat	0.857	0.223	0.102	0.287	0.876	0.124
Wing fat	0.841	0.169	0.256	0.029	0.802	0.198
Neck fat	0.830	0.085	0.141	0.281	0.795	0.205
Drumstick muscle	0.224	0.788	0.288	0.196	0.792	0.208
Thigh muscle	0.099	0.829	0.332	0.025	0.809	0.191
Breast muscle	0.211	0.903	–0.065	–0.157	0.888	0.112
Wing muscle	0.081	0.919	0.118	–0.018	0.866	0.134
Neck muscle	0.326	0.370	0.840	0.054	0.952	0.048
% of variance	51.7	24.1	5.9	4.3		
Description	Fatness	Muscling	Neck muscle	Drumstick fat		

pattern of variation in muscling independent of fatness. It is worth mentioning that when muscling and fatness traits were considered, the first factor was fatness, while when muscling and bone traits were considered the first factor was muscling [11]. The muscling factor identified by Shahin [11] accounted for 54 % of the variation in fatless carcass traits.

The third factor (III) ('neck muscle factor') accounted for 5.9 % of the total variation with high loadings on neck muscle. The neck structures and functions enable the bird to maintain its balance by shifting the center of gravity during running and flying. It seems that in ducks, neck muscle and other muscles in the carcass were subject to independent determination.

The fourth factor (IV) ('drumstick fat') accounted for 4.3 % of the total variation with drumstick fat having the highest loadings. It may be taken to characterize specifically the bird's distal hindlimb fatness. Shahin [11], working with the same ducks as in the present study, identified a drumstick bone factor that accounted for 6.7 % of the variation of fatless carcass traits.

In brief, most of the common variability in meatiness and fatness traits could be accounted for by factors representing fatness, muscling, neck muscle and drumstick fat.

3.4. Shared variability

Results (*table III*) indicated that 79 to 95 % of the variation in meatiness and fatness traits were brought about by the common factors, whereas 5 to 21 % of their variation were contributed by unique factors specific for each trait. The relatively high estimates of common variance for muscling traits indicate that improving any one of them could result in the simultaneous improvement in the remaining muscling traits.

The communalities for muscle traits ranged from 0.792 for drumstick muscle to 0.952 for neck muscle and these for fat traits ranged from 0.795 for neck fat to 0.952 for drumstick fat.

At the level of the leg, communality for fat (0.863–0.952) was higher than for muscle (0.79–0.81), while for breast, wing and neck communality for muscle was higher than for fat (*table III*). Drumstick muscle and neck fat had the lowest communality with the greatest uniqueness of their own. About 79–80 % of the variation in drumstick muscle and neck fat were brought about by common factors, whereas 20–21 % of their variations were contributed by the unique factor specific for each of drumstick muscle and neck fat. Shahin [11] working with the same ducks as in the present study found that within breast, wing and thigh the communality for muscle was higher than that for bone, but within drumstick and neck the communality for bone was higher than that of muscle.

Table IV. Multiple regression of total side muscle weight (g) and total side fat (g) on original fatness and muscling traits and on their orthogonal traits in Pekin ducklings

	Muscle			Fat		
Independent variables (predictors)	Regression coefficient b	S.E.	t	Regression coefficient b	S.E.	t
(i) Original fatness and muscling traits as independent variables						
Drumstick fat	–0.03	0.08	–0.38	0.92	0.09	9.81**
Thigh fat	0.06	0.06	0.89	1.13	0.08	14.43**
Breast fat	–0.09	0.06	–1.64	–1.37	0.07	19.24**
Wing fat	0.24	0.08	2.87**	1.19	0.10	11.69**
Neck fat	0.15	0.07	2.06*	1.34	0.09	14.44**
Drumstick muscle	0.93	0.12	7.43**	–0.00	0.00	–0.03
Thigh muscle	1.26	0.09	13.80**	–0.06	0.12	–0.52
Breast muscle	0.99	0.03	39.08**	–0.10	0.03	–3.35**
Wing muscle	1.18	0.09	12.91**	0.32	0.11	2.82**
Neck muscle	1.15	0.13	9.17**	–0.01	0.16	–0.07
Intercept	7.37	3.13	2.36*	–1.68	3.88	–0.43
R^2 (%)	99.25			99.04		
RSD	3.59			4.44		
(ii) Their orthogonal fatness and muscling traits as independent variables						
FC1 fatness	9.61	0.57	16.60**	40.47	0.48	84.01**
FC2 muscling	37.61	0.57	65.74**	6.88	0.48	14.28**
FC3 neck muscle	6.73	0.57	11.77**	6.20	0.48	12.88**
FC4 drumstick fat	–2.53	0.57	–4.43**	12.44	0.48	25.82**
Intercept	235.52	0.57	413.11**	135.29	0.48	281.84**
R^2 (%)	97.16			98.31		
RSD	6.84			5.76		

* $P < 0.05$; ** $P < 0.01$.

3.5. The relationship with TSM and TSF

Results of regression analysis of predicting total carcass muscle weight from the 10 intercorrelated muscling and fatness traits showed that all these traits accounted for 99.3 % of the variation in TSM (R.S.D. = 3.6 g). Corresponding R^2 resulting from using independent factor scores as predictors for TSM was 0.97 (R.S.D. = 6.8 g; *table IV*). The final multiple regression equation for estimating total side muscle weight from independent factor scores is:

$$\text{Total side muscle weight (g)} = 235.52 + 37.61\ FC2 + 9.61\ FC1 + 6.73\ FC3 - 2.53\ FC4$$

Results of regression analysis for total carcass fat weight showed that all intercorrelated muscling and fatness traits accounted for 99 % of the variation in TSF (R.S.D. = 4.4 g). Corresponding R^2 obtained from regressing TSF on independent factor scores was 0.98 (R.S.D. = 5.8 g; *table IV*). The final multiple regression equation for estimating total side fat weight from independent factor scores is:

$$\text{Total side fat weight (g)} = 135.29 + 40.71\ FC1 + 6.88\ FC2 + 6.20\ FC3 + 12.44\ FC4$$

In conclusion, the factor analysis technique explores the interdependence in the original 10 fatness and meatiness traits by analyzing them simultaneously rather than individually and it is useful in summarizing and explaining the correlations and covariances among these interdependence traits in terms of four interpretable common factors. The use of orthogonal carcass traits derived from factor analysis were more appropriate than the use of the original intercorrelated traits for predicting total muscle weight and total fat weight because multicollinearity of two or more independent variables causes misestimation of the coefficients of such variables.

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