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# Sources of shared variability in meat weight distribution and conformation in Pekin ducklings

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**Abstract** — A factor analysis with a varimax rotation was applied to ten highly intercorrelated carcass meatiness and conformation traits on 96 Pekin ducks to disclose the main sources of shared variability, deduce the factors that describe meat distribution and conformation and predict total carcass meat from orthogonal meatiness and conformation traits. Meat weight distribution and conformation appeared to be controlled by common and unique factors. The communalties for meatiness traits ranged from 0.542 for neck meat to 0.870 for breast meat and those for conformation traits ranged from 0.555 for breast width to 0.717 for shank length and the uniqueness (special size factors) made the balance. Findings indicated that most of the common variability (68.4 %) in meat weight distribution and conformation could be accounted for by factors representing breast, length and wing meat factors. The first and third independent meatiness and conformation traits derived from factor analysis accounted for 73.8 % of the variation in total carcass meat. (© Elsevier / Inra)

**factor analysis / Pekin ducks / multicollinearity / meat weight variations / conformation variations**

**Résumé — Origines de la variabilité conjointe de la distribution corporelle du muscle et de la conformation chez le canard Pékin.** Une analyse factorielle utilisant une rotation varimax a été appliquée à dix caractéristiques musculaires et de conformation mesurées sur 96 canards Pékin pour i) identifier les principales sources de variabilité commune, ii) déterminer les facteurs décrivant la distribution musculaire et la conformation, iii) prédire la quantité totale de viande de la carcasse à partir des caractéristiques orthogonales musculaires et de conformation. La distribution des poids de viande et la conformation semblent à la fois contrôlée par des facteurs communs et des acteurs spécifiques. Les facteurs communs pour les caractéristiques musculaires ont un effet compris entre 0,542 au niveau du cou et 0,870 au niveau de la poitrine ; ceux pour la conformation sont compris entre 0,555 (largeur de la poitrine) et 0,717 (longueur de la cuisse). Les facteurs spécifiques (facteurs de la taille) influencent le reste des variations. Les résultats obtenus montrent que l'essentiel de la variabilité (68,4 %) dans la distribution pondérale de viande et la conformation pourrait être attribué à trois

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facteurs communs représentant la poitrine (I), la longueur (II) et la viande des ailes (III). Le premier et le second facteur ont représenté 73,8 % de la variabilité dans la quantité totale de viande de la carcasse. (© Elsevier / Inra)

**analyse factorielle / canard Pékin / multicollinéarité / distribution musculaire / conformation**

## 1. INTRODUCTION

Size and shape (geometric dimensions) of various body parts are the major determinants of the overall size and shape of a live bird or carcass. The effect of conformation or shape on body composition and its usefulness for poultrymen, processors, market demands and consumer appeal have been reviewed previously [3, 4, 13].

Since conformation and meatiness traits are intercorrelated both genetically and phenotypically [7, 10, 13, 14, 18, 19], the analysis of these traits should address interdependence among predictors (multicollinearity). Independent factor scores derived from factor analysis have been used advantageously as predictors of total carcass muscle and bone and other performance traits [15, 18, 20, 21] and as a selection criterion for genetic improvement of muscle weight distribution [19].

The objectives of this study were to disclose the main sources of shared variability, deduce factors that describe meat weight distribution and conformation traits of Pekin ducklings and estimate carcass meatiness utilizing orthogonal carcass and conformation traits derived from factor analysis.

## 2. MATERIALS AND METHODS

### 2.1. Source of data

Sixty-one male and 35 female Pekin ducklings progeny of eight sires (12 per sire) from the experimental poultry farm of the Faculty of Agriculture, Tanta University, were included in the present study. From hatching to 10 weeks (slaughter age), all ducklings received feed and water ad libitum and the diet containing approximately 22 % protein and a metabolizable energy of 2 900 Kcal·kg$^{-1}$.

### 2.2. Traits considered

Prior to killing, the following breast measurements were taken: breast circumference 'heart girth', breast width, keel length and shank length 'tarsometatarsus' as already described by Swatland [23]. The body weight was also recorded. At 10 weeks of age, the birds were slaughtered by severing the carotid artery and jugular veins. After dry plucking, the birds were eviscerated manually; the feet and shanks were removed at the tibiotarsus joint and the head at the atlanto-occipital articulation. Carcass length was measured from the forward edge of the first rib to the anterior edge of the aitch bone. The carcasses were stored at –20 °C and transferred to the Meat Laboratory of the Faculty of Agriculture, Ain Shams University, where they were dissected. Prior to jointing and dissection, the frozen carcasses were thawed at 5 °C while in their bags. The right side of the carcasses were then jointed into the following commercial cuts: thigh, drumstick, wing, breast, neck and tail, as described previously by Shahin [17]. In each cut, muscle, skin, subcutaneous fat, intermuscular fat and bone were dissected and weighed. The sum of muscle, skin plus fat and bone over the side cuts gave the weight of the dissected side. The sum of muscle and skin plus fat over the side cuts gave the weight of the side meat. The percentage of carcass meat in the above-mentioned cuts was defined as the amount of muscle and skin plus fat dissected, respectively, from these cuts, relative to the weight of the side meat. These percentages determined the carcass meat weight distribution. The data from male and female ducklings are combined since the two data dispersion matrices do not differ significantly (unpublished data).

**Table I.** Means, standard deviations (SD) and coefficient of variability (CV %) for live performance and carcass traits in Pekin ducklings.

| | Mean | SD | CV % |
|---|---|---|---|
| *Live performance* | | | |
| Breast circumference (cm) | 26.17 | 1.70 | 6.50 |
| Breast width (cm) | 13.43 | 1.13 | 8.41 |
| Keel length (cm) | 12.06 | 0.83 | 6.88 |
| Shank length (cm) | 6.47 | 0.58 | 8.96 |
| Live weight (g) | 1 689.60 | 208.90 | 12.36 |
| *Carcass traits* | | | |
| Carcass length (cm) | 22.09 | 1.22 | 5.52 |
| Side (muscle + fat + bone) weight (g) | 462.97 | 75.75 | 16.36 |
| Side meat weight (g) | 364.00 | 69.71 | 19.15 |
| Drumstick meat weight/ side meat weight (%) | 11.37 | 1.17 | 10.29 |
| Thigh meat weight/ side meat weight (%) | 18.98 | 1.54 | 8.11 |
| Breast meat weight/ side meat weight (%) | 27.65 | 3.77 | 13.63 |
| Wing meat weight/ side meat weight (%) | 15.24 | 1.21 | 7.94 |
| Neck meat weight/ side meat weight (%) | 11.95 | 1.12 | 9.37 |
| Leg meat weight/side meat weight (%) | 30.35 | 2.32 | 7.64 |

### 2.3. Statistical analysis

The data were subjected to a factor analysis [16]. The main source of shared variation among correlated meatiness and conformation variables ($p$) was expressed in terms of fewer mutually uncorrelated common factors $F_1, \ldots, F_q$ (where $q < p$) than the original variables [5]. The general model used for factor analysis has been described by Shahin [18, 19].

Stepwise multiple regression was used to predict total side meat weight from the orthogonal factor scores derived from factor analysis.

## 3. RESULTS AND DISCUSSION

*Table I* presents the means, standard deviations and coefficient of variability (CV) for live weight, meatiness and conformation traits. Total side meat ranged from 193 to 495 g with a mean of 364 g. Breast meat and leg meat accounted for 27.7 % and 30.4 %, respectively, of the total carcass meat weight. Ricard [13] reported that compared with broiler chickens, ducks have a longer trunk and reduced legs and shanks.

Breast meatiness was more variable (CV = 13.6 %) than breast conformation (CV ranged from 6.5 % for breast circumference to 8.4 % for breast width) and leg meatiness (CV = 7.6 %) (*table I*).

### 3.1. Non-independent meatiness and conformation traits and their interrelations

The phenotypic correlations among traits are given in *table II*. The various measures of breast development (circumference, width, length) and live weight can be characterized as having high correlations with one another. The correlation between breast circumference and body weight was 0.80 for the Pekin ducks of the present study and 0.84 for chickens studied by Bernier [2]. Each of the breast measurements was positively correlated with the proportion of total meat in the breast. Johnson and Asmundson [9], working with turkey, found that keel length and breast width were significantly correlated with breast muscle weight.

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

| | BC | BW | KL | SL | LW | CL | DSW | SM | DM | TM | BM | WM | NM |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Live performance* | | | | | | | | | | | | | |
| Breast circumference (BC) | | | | | | | | | | | | | |
| Breast width (BW) | 0.635 | | | | | | | | | | | | |
| Keel length (KL) | 0.454 | 0.274 | | | | | | | | | | | |
| Shank length (SL) | 0.016 | 0.029 | 0.092 | | | | | | | | | | |
| Live weight (LW) | 0.801 | 0.640 | 0.543 | –0.005 | | | | | | | | | |
| *Carcass traits* | | | | | | | | | | | | | |
| Carcass length (CL) | 0.478 | 0.389 | 0.470 | 0.145 | 0.582 | | | | | | | | |
| Dissected side weight (DSW) | 0.816 | 0.667 | 0.527 | –0.093 | 0.942 | 0.532 | | | | | | | |
| Side meat weight (SM) | 0.808 | 0.655 | 0.510 | –0.107 | 0.927 | 0.505 | 0.995 | | | | | | |
| *% of total meat in* | | | | | | | | | | | | | |
| Drumstick meat (DM) | –0.671 | –0.528 | –0.442 | –0.011 | –0.595 | –0.320 | –0.701 | –0.709 | | | | | |
| Thigh meat (TM) | –0.535 | –0.410 | –0.521 | 0.079 | –0.500 | –0.352 | –0.543 | –0.524 | 0.457 | | | | |
| Breast meat (BM) | 0.735 | 0.527 | 0.474 | –0.046 | 0.653 | 0.363 | 0.759 | 0.769 | –0.749 | –0.724 | | | |
| Wing meat (WM) | –0.126 | –0.201 | 0.033 | 0.070 | –0.190 | –0.125 | –0.270 | –0.304 | 0.137 | 0.032 | –0.280 | | |
| Neck meat (NM) | –0.396 | –0.202 | –0.284 | 0.049 | –0.338 | –0.176 | –0.374 | –0.376 | 0.368 | 0.242 | –0.557 | –0.155 | |

In ducks, Pingel et al. [12] reported a correlation of 0.60 between keel length and breast muscle yield. Golushko [6] noted that breast muscle weight was significantly correlated with keel height ($r = 0.63$) and keel area ($r = 0.34$) and Sheldon et al. [22] found a highly significant correlation ($r = 0.82$) between the length of the keel and breast fillet weight. Janiszewska et al. [8] reported a significant correlation ($r = 0.51–0.88$) between the lean weight in the carcass and carcass breast circumference. Total meat weight was positively correlated with its proportion in breast and negatively correlated with that in the other cuts.

## 3.2. Varimax rotated 'independent' factors

### 3.2.1. *Interpretation*

Three common factors (one for breast, one for length, and the third for wing) have been identified, which contribute to 68.4 % of the variability of the original ten variables, leaving 32.6 % to the ten 'unique' factors (*table III*).

The first factor (I; 'breast') is characterized by high positive loadings (factor-variate correlations) on breast meatiness and conformation (*table III*). The variables associated with the proportion of total meat in breast had the highest loadings, followed by the breast circumference, breast width and keel length. This factor accounted for 46.8 % of the variation in the original variables and showed that extreme heavy and well-developed breast conformation was offset by a decrease in the leg. Ricard and Rouvier [15], working with chickens, noted that a carcass compactness component was best represented by breast angle, which accounted for 14 % of the variation in conformation traits.

The second factor (II; 'length'), giving relatively high weight to length measurements, accounted for an additional 11 % of the total variation. The variables associated with shank and carcass lengths had the highest loadings on this factor, followed by that

**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 | Communalities | Unique factor |
| Breast circumference | 0.825 | 0.161 | –0.082 | 0.713 | 0.287 |
| Keel length | 0.608 | 0.371 | 0.234 | 0.562 | 0.438 |
| Breast width | 0.648 | 0.179 | –0.321 | 0.555 | 0.445 |
| Shank length | –0.121 | 0.836 | 0.058 | 0.717 | 0.283 |
| Carcass length | 0.478 | 0.569 | –0.125 | 0.568 | 0.432 |
| Drumstick meat (%) | –0.817 | –0.043 | 0.056 | 0.673 | 0.327 |
| Thigh meat (%) | –0.794 | –0.003 | 0.078 | 0.637 | 0.363 |
| Breast meat (%) | 0.929 | –0.057 | –0.061 | 0.870 | 0.130 |
| Wing meat (%) | –0.159 | 0.080 | 0.877 | 0.800 | 0.200 |
| Neck meat (%) | –0.530 | 0.131 | –0.494 | 0.542 | 0.458 |
| Eigenvalues | 5.15 | 1.21 | 1.16 | | |
| % of variance | 46.8 | 11.0 | 10.5 | | |
| Description | Breast | Length | Wing | | |

associated with keel length. Ricard and Rouvier [15], in a study with chickens, found that a major size component was best represented by trunk length, shank length and leg length, which accounted for 59 % of the variation in conformation traits. It is worth mentioning that in poultry, shorter shanks are associated with wider breasts and shorter necks.

The third factor (III; 'wing meat') accounted for 10.5 % of the total variation with high loadings on the proportion of total meat in the wing. It seems that in ducks, wing meat and breast meat were subject to an independent determination.

#### *3.2.2. Shared variability*

The results (*table III*) indicated that about 54–88 % of the variation in meatiness and conformation traits were brought about by the common factors, whereas 46–12 % of their variation were contributed by unique factors specific for each trait.

At the level of the breast, communality for the proportion of total meat in this region (0.870) was higher than those for measurements (0.555–0.713) (*table III*). The proportion of total meat in neck and breast width had the lowest communality with the greatest uniqueness of their own. About 54–56 % of the variation in neck meat and breast width was brought about by common factors, whereas 46–44 % of their variations were contributed by the unique factor specific for each of neck meat and breast width.

### 3.3. Prediction of total meat weight from non-independent meatiness and conformation traits and their independent factor scores

Breast circumference alone accounted for 65.2 % of the variability in total side meat weight. In large livestock (cattle, buffalo), this trait has been traditionally used as an indicator of the animal size. Multiple correlations (*table IV*) showed that $R^2$ increased from 0.72 to 0.79 and residual standard deviation (RSD) of the estimate decreased from 37.4 to 33.2 g with stepwise addition of breast meat, breast width, wing meat, keel length and shank length. Six of the ten original intercorrelated predictors remained in the final equation. These results indicated that total meat weight can be predicted with a fair degree of accuracy from breast meat and conformation; as much as 74 % of the variation in total meat weight was accounted for by these traits. Berg and Shoffner [1] concluded that body weight was a dominant factor in predicting meat yield and that use of body measurements in addition to body weight added little in this regard. Michalik and Bochno [11] stated that an index based in body weight, breast muscle thickness and keel length was a reliable predictor of carcass lean weight.

Breast factor score alone accounted for 69 % of the variation in total side meat weight. Ricard [13] suggested that the correlation between general size and meatiness in Muscovy ducks seems to be high and positive. Results of a stepwise multiple regression of total side meat weight on the three varimax factor scores (*table IV*) showed that $R^2$ progressively increased to 0.74 and RSD of the estimate decreased to 36.1 g as the FC3 orthogonal factor score was added. The final prediction equation is:

$$\text{Total side meat (g)} = 364.00 + 58.02\ \text{FC1} - 14.78\ \text{FC3}$$

*Table IV* shows that the regression coefficients in a stepwise multiple regression of total side meat against the three orthogonal varimax factors were stable in various equations. Corresponding regression coefficients obtained from regressing total side meat on original intercorrelated predictors (non-orthogonal) were unstable and sensitive to the addition of variables in the equations. These instabilities make it impossible to estimate the unique effects of individual variables in the regression equation and thus,

**Table IV.** Stepwise multiple regression of total side meat weight (g) on original meatiness and conformation traits and on their orthogonal traits in Pekin ducklings.

| Step | Independent variables (Predictors) | Intercept | Regression coefficient b | SE | $R^2$ | Residual standard deviation |
|---|---|---|---|---|---|---|
| *(i) Original meatiness and conformation traits as independent variables* | | | | | | |
| 1 | Breast circumference | –501.26 | 33.07 | 2.49 | 0.652 | 41.33 |
| 2 | Breast circumference | –396.27 | 21.61 | 3.32 | 0.719 | 37.36 |
| | Breast meat (%) | | 7.05 | 1.50 | | |
| 3 | Breast circumference | –433.46 | 17.13 | 3.53 | 0.743 | 35.91 |
| | Breast meat (%) | | 6.56 | 1.45 | | |
| | Breast width | | 1.96 | 4.25 | | |
| 4 | Breast circumference | –317.82 | 18.46 | 3.51 | 0.757 | 35.12 |
| | Breast meat (%) | | 5.67 | 1.47 | | |
| | Breast width | | 11.25 | 4.19 | | |
| | Wing meat (%) | | –7.16 | 3.15 | | |
| 5 | Breast circumference | –392.21 | 17.05 | 3.43 | 0.775 | 33.98 |
| | Breast meat (%) | | 4.50 | 1.48 | | |
| | Breast width | | 11.54 | 4.06 | | |
| | Wing meat (%) | | –8.59 | 3.09 | | |
| | Keel length | | 13.21 | 4.92 | | |
| 6 | Breast circumference | –323.27 | 17.24 | 3.35 | 0.788 | 33.18 |
| | Breast meat (%) | | 4.25 | 1.45 | | |
| | Breast width | | 11.94 | 3.96 | | |
| | Wing meat (%) | | –8.34 | 3.02 | | |
| | Keel length | | 14.47 | 4.83 | | |
| | Shank length | | –13.78 | 5.95 | | |
| *(ii) Their orthogonal meatiness and conformation traits as independent variables* | | | | | | |
| 1 | FC1 Breast factor | 364.00 | 58.02 | 3.99 | 0.693 | 38.85 |
| 2 | FC1 Breast factor | 364.00 | 58.02 | 3.70 | 0.738 | 36.08 |
| | FC3 Wing factor | | –14.80 | 3.70 | | |

SE: standard error.

could lead to erroneous inferences since the existence of multicollinearity could destroy the precision of estimation.

In conclusion, the factor analysis method is interesting to consolidate and describe the covariation in the ten meatiness and conformation traits into three advantageously interpretable common factors which contribute to 68.4 % of the total variance. The first 'breast' and third 'wing meat' independent factors accounted for 73.8 % of the variation in total weight of the carcass meat.

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