# PE3.07 Tissue Thickness Measurements for Objective Classification of Lamb Carcasses Based on Lean Meat Percentage 336.00

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**Abstract—The objectives of this study were to analyze the interrelationships among hot carcass weight (HCW), carcass dimension, and tissues thickness and area measurements, and to develop models to predict lean meat percentage of lamb carcasses. One hundred and twenty-five lambs, 83 males and 42 females, of Churra Galega Bragançana Portuguese local breed were slaughtered, and carcasses were weighed (HCW) approximately 30 min after exsanguination. After cooling at 4 C for 24-h a set of seventeen carcass measurements were recorded, and left side of carcasses was dissected and lean meat percentage (LMP) was calculated. Data interrelationships were analyzed following the common factor analysis procedure, and models to predict LMP were developed by regression procedures. All variables were highly and positively correlated with HCW ($r > 0.46$), being especially high in the carcass dimensions measurements ($r > 0.75$). Three common factors (factor I = carcass weight; factor II = subcutaneous fat thickness; factor III = breast bone tissues thickness) were retained, and accounted for 83.5% of the variation in the original variables. The best single predictor was C12 fat measurement, and accounted for 66.2% of the LMP variation with a sep of 2.39%. This study shows that prediction of LMP of lamb carcasses can be based on one single fat measurement (C12), If a large set variables is available, their orthogonal CF can be used as predictors avoiding collinearity, and given rise to more stable prediction models.**

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**Index Terms—Carcass, Classification, Lamb, Prediction, Meat.**

## I. INTRODUCTION

The European sheep production systems are characterized by a high number of breeds, with different body size, raised under very different production systems, leading to a great market variety in lambs age and live/carcass weight. Carcass fat levels plays an important role in meat sensory characteristics, however excess of fat is undesirable since leads to higher production costs, and compels meat traders to its removal at selling. A carcass with reference or ideal fat content should present the higher commercial value, and whenever the carcass composition moves away from the ideal composition, its price must suffer penalties. Thus carcass classifications systems presents an important role in the definition of rules for carcasses transactions along the meat chain. European Union lamb carcasses classification and grading system is based on photographic standards [12], by visual appraisal, which is subjective, suffering of inconsistency among slaughter-houses and assessors [5]. Concerning the development of objective classifications systems, the EU legislation defines that they must be based on the prediction of LMP, and models must present standard error of prediction lower than 2.5% [11]. The objectives of this study were to analyze the interrelationships among HCW, carcass dimensions, and tissues thickness and area measurements, and to develop models to objectively predict lean meat percentage of lamb carcasses.

## II. MATERIALS AND METHODS

One hundred and twenty-five lambs, 83 males and 42 females, of Churra Galega Bragançana (CGB) Portuguese local breed, weighing 10.3 to 41.6 kg, randomly selected from the experimental flock at the Escola Superior Agrária de Bragança. Lambs were raised with their mothers in natural suckling until slaughter, and had access to pasture, natural meadow hay, and a commercial concentrate mixture with mineral-vitamin supplementation. Lambs were slaughtered after 24-h fast in the experimental slaughter-house at the Escola Superior Agrária de Bragança, and carcasses were weighted approximately 30 min after slaughter in order to obtain the HCW according to Fisher and Boer [3]. After chilling at 4ºC for 24-h, carcasses were suspended on a gamble with 21-cm distance between legs. The following carcass measurements were taken: 1) carcass length (K, cm) measured from the base of the tail to the base of the neck [14]; 2) leg length (F, cm), representing the smallest distance from the perineum to the interior face of the tarsal-metatarsal articular surface [14]; 3) buttocks width (G, cm) measured using the measuring calliper at the level of the proximal edge of the patellae (Fisher and Boer, 1994); 4) thorax circumference (U, cm) measured using a tape held horizontally around the thorax at the level of the caudal portion of the scapula; and, 5) buttock circumference (CB, cm) was measured using a tape held horizontally around the buttocks at the level of the caudal insertion [3]. Carcasses were halved through the centre of the vertebral column, and the kidney knob and channel fat (KKCF) was removed and weighed. The left side was quartered and tissues measurements were performed with a caliper on maximum LM depth (mm) and subcutaneous fat thickness (mm) between the 12th and 13th ribs (B12 and C12, respectively), 1th and 2th lumbar vertebrae (B1 and C1, respectively), and 3rd and 4th lumbar vertebrae (B3 and C3, respectively). Additionally, LM area between the 12th and 13th ribs (LEA12), 1st and 2nd lumbar vertebrae (LEA1), and 3rd and 4th lumbar vertebrae (LEA3) was traced on acetate sheet and LM area was measured using a digital planimeter (model KP-90; Koizumi Placom, Niigata, Japan). Lastly, total breast bone tissue thickness (mm) was taken with a sharpened steel rule at middle of the 2nd (BT2), 3rd (BT3) and 4th (BT4) sternebrae. All carcasses were dissected into muscle, subcutaneous fat, intermuscular fat, bone, and remainder (major blood vessels, ligaments, tendons, and thick connective tissue sheets associated with muscles), and the carcasses lean meat percentage was calculated. Data were analyzed using the R Development Core Team [15] software. Summary statistics were computed by the sapply() function, and correlations among variables by the cor() function. The psych package [16] was used to perform a CFA, and the factors were retained using the mineigen criterium Krzanowski [7]. Simple and multiple linear models to predict LMP were developed through regression procedures under the MASS package [20]. Models fitting quality was evaluated through the coefficient of determination of estimation ( ), standard error of estimate (see). Models validation was perfomed by k-fold cross-validation using the cv.lm() function in the DAAG package [9], and the crossval() funtion under the bootstrap package [13], and the coefficient of determination of prediction ( ) and standard error of prediction (sep) were computed..

## III. RESULTS AND DISCUSSION

Linear correlations among HCW, carcass dimensions, and tissue measurements are shown in Table 1. All variables were highly and positively correlated with HCW (r > 0.46), these correlations were especially high among HCW and carcass dimension measurements (r > 0.79), and breast bone tissue thickness (r > 0.66). Carcass dimension measurements were highly correlated (r > 0.75) among themselves. Subcutaneous fat thickness had high and positive correlations (r > 0.58) with breast bone tissue thickness. The correlations among LM area and depth measurements were positive moderate to high (from 0.49 to 0.80). The Breast bone tissue measurements were highly correlated among themselves (r > 0.85). Similar results were obtained in the subcutaneous fat measurements which were highly correlated (r > 0.71) among them. These results show that the similar tissues measurements taken at different anatomical positions are collinear. Clearly, collinearity was a general problem in these eighteen variables, being specially evident among HCW and carcass dimension measurements (F, K, G, U, and CB), confirming the findings of Boccard et al. [1] in sheep and Shahin et al. [18] buffalos. Common factors pattern (after varimax rotation), communalities, unique factor, eigen values, and variance explained by the three common factors retained are displayed in Table 2. Common factor analysis was able to identify three common factors which accounted for 81.5% of the variation on the 18 original variables, leaving 18.5% of the variation for the 18 unique factors. Factor I was characterized by high, and positive loadings (factor-variable correlation) in HCW (r = 0.843), carcass dimension measurements (r = 0.826 to 0.887), and LM muscle depth and area measurements (r = 0.669 to 0.801). This factor accounted for 46.5% of the variation in the 18 original variables. Factor II accounted for an additional 20.8% of the variation in the original variables, showed high and positive loadings (r > 0.794) in the subcutaneous fat thickness measurements. Lastly, Factor III accounted for 14.2% of the total original variability in the 18 original variables, and presented high and positive loadings on breast bone thickness measurements (r > 0.685). Original variables contribution to each factor can be evaluated by its loadings (variable-factors correlation) on the common factors extracted. Variables with high loadings in the same factor are correlated, consequently, carry redundant information and give rise to collinearity problems in multiple regression models. Thereby, do not improve the models fitting quality and cause instability on the parameters estimation [17]. Best models based on one, two and three variables for predicting LMP are presented in Table 3. HCW accounted for 17.3% of the variation in LMP (data not shown), confirming the results of several authors [6, 4] where HCW alone was not able to explain the LMP of lamb carcasses. Many studies showed that multiple regression linear models were dominated by live weight [19] or carcass weight [2, 10], however these models were developed to predict muscle weight instead of LMP. The small variation observed in LMP when compared to the variation observed in lean meat weight explains the lower  of models predicting LMP, since the variance increase in the dependent variable results in models with higher  . The best single predictor was C12 measurement, and accounted for 66.2% of the LMP variation with a sep of 2.39%. The different measurements showed different accuracy for prediction of LMP, and fat measurements dominate the models. However, all models based on single predictors (others than C12) presented sep higher than 2.5%, which is the superior limit for approval of prediction equations for objective classifications systems by the EU [11]. Multiple linear regression models (Model 2 and 3) also included C12 measurement, n spite of the  increase, these models presented lower predicting abilities as can be observed by the higher standard error of prediction (sep = 4.04%). Model 4 presented fitting quality similar to Model 1 as can be observed by the . Despite the similarity fitting quality, it is worthwhile to point that Model 4 showed greater stability on the estimation of regression coefficients. It is important to notice that carcass dimension measurements didn't contribute to explain LMP of lamb carcasses. These results confirm the lack of relationship between carcasses conformation and composition, being measurements that reflect skeleton dimension rather than carcasses muscle and fat indicators [8].

## IV. CONCLUSION

Clearly, results from the common factors analysis identified three sets of collinear variables which carry redundant information: 1) the set comprised by HCW, carcass dimension measurements, LM area and depth measurements; 2) the set comprised by subcutaneous fat thickness measurement; and 3) the set comprised by breast bone tissue thickness measurements. Prediction of LMP of lamb carcasses can be based on one single fat measurement (C12), which will simplify the carcass classifications systems. If a large set of variables is available, their transformation into CF retain most of the information of original variables, and these new variables, orthogonal CF, can be used as predictors avoiding original predictors colinearity, given rise to more stable models. This application can be very useful for automated systems, like video image analysis, where large sets of predictors can be recorded at high speed and low cost at slaughter-houses level.

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Table 1**:** Correlations among HCW, carcass dimensions, and tissues depth and area measurements

| | HCW | F | K | G | U | CB | B12 | B1 | B3 | LEA12 | LEA1 | LEA3 | C1 | C3 | C12 | BT2 | BT3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| F | 0.79 | | | | | | | | | | | | | | | | |
| K | 0.87 | 0.83 | | | | | | | | | | | | | | | |
| G | 0.94 | 0.75 | 0.84 | | | | | | | | | | | | | | |
| U | 0.93 | 0.81 | 0.87 | 0.89 | | | | | | | | | | | | | |
| CB | 0.95 | 0.77 | 0.85 | 0.94 | 0.90 | | | | | | | | | | | | |
| B12 | 0.77 | 0.55 | 0.63 | 0.74 | 0.68 | 0.78 | | | | | | | | | | | |
| B1 | 0.84 | 0.62 | 0.77 | 0.80 | 0.81 | 0.82 | 0.79 | | | | | | | | | | |
| B3 | 0.56 | 0.51 | 0.60 | 0.59 | 0.61 | 0.61 | 0.57 | 0.63 | | | | | | | | | |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LEA12 | 0.86 | 0.66 | 0.73 | 0.83 | 0.81 | 0.85 | 0.78 | 0.76 | 0.49 | | | | | | | | |
| LEA1 | 0.88 | 0.70 | 0.78 | 0.83 | 0.84 | 0.85 | 0.72 | 0.80 | 0.58 | 0.89 | | | | | | | |
| LEA3 | 0.86 | 0.73 | 0.76 | 0.82 | 0.82 | 0.84 | 0.67 | 0.77 | 0.60 | 0.82 | 0.87 | | | | | | |
| C12 | 0.56 | 0.30 | 0.30 | 0.50 | 0.46 | 0.55 | 0.36 | 0.42 | 0.07 | 0.55 | 0.50 | 0.45 | | | | | |
| C1 | 0.46 | 0.20 | 0.22 | 0.46 | 0.36 | 0.48 | 0.30 | 0.30 | 0.05 | 0.47 | 0.40 | 0.39 | 0.77 | | | | |
| C3 | 0.74 | 0.46 | 0.47 | 0.66 | 0.62 | 0.71 | 0.56 | 0.61 | 0.15 | 0.67 | 0.62 | 0.59 | 0.80 | 0.71 | | | |
| BT2 | 0.77 | 0.47 | 0.60 | 0.75 | 0.68 | 0.76 | 0.62 | 0.62 | 0.37 | 0.72 | 0.69 | 0.66 | 0.61 | 0.63 | 0.70 | | |
| BT3 | 0.78 | 0.50 | 0.60 | 0.74 | 0.69 | 0.75 | 0.63 | 0.64 | 0.39 | 0.72 | 0.69 | 0.68 | 0.58 | 0.58 | 0.68 | 0.93 | |
| BT4 | 0.66 | 0.35 | 0.45 | 0.64 | 0.56 | 0.65 | 0.56 | 0.53 | 0.24 | 0.64 | 0.59 | 0.53 | 0.62 | 0.63 | 0.68 | 0.85 | 0.90 |

Table 2**:** Factor pattern, after varimax rotation, communalities, unique factor, eigen values, and variance explained by the three common factors retained

| Variables | Factor I | Factor II | Factor III |
|---|---|---|---|
| HCW | 0.843 | 0.419 | 0.295 |
| F | 0.836 | 0.137 | 0.100 |
| K | 0.887 | 0.124 | 0.212 |
| G | 0.826 | 0.367 | 0.304 |
| U | 0.865 | 0.286 | 0.236 |
| CB | 0.832 | 0.402 | 0.284 |
| B12 | 0.696 | 0.256 | 0.258 |
| B1 | 0.784 | 0.286 | 0.223 |
| B3 | 0.669 | -0.098 | 0.140 |
| LEA12 | 0.734 | 0.391 | 0.310 |
| LEA1 | 0.801 | 0.328 | 0.262 |
| LEA3 | 0.789 | 0.285 | 0.257 |
| C12 | 0.186 | 0.888 | 0.276 |
| C1 | 0.110 | 0.780 | 0.295 |
| C3 | 0.422 | 0.794 | 0.212 |
| BT2 | 0.447 | 0.461 | 0.685 |
| BT3 | 0.444 | 0.408 | 0.780 |
| BT4 | 0.276 | 0.502 | 0.727 |
| Eigen values | 8.36 | 3.74 | 55 |
| Variance, % | 0.465 | 0.208 | 0.142 |

Table 3**:** Best models to predict LMP based on one, two, and three variables, and on the common factors retained

| Models | $R_e^2$ | see | $R_p^2$ | sep |
|---|---|---|---|---|
| 1 $y = 64.5(\pm 0.40) - 2.24(\pm 0.145)C12$ | 0.662 | 2.37 | 0.650 | 2.39 |
| 2 $y = 61.6(\pm 0.882) + 0.351(\pm 0.096)LEA3 - 2.512(\pm 0.156)C12$ | 0.695 | 2.26 | 0.680 | 4.04 |
| 3 $y = 64.7(\pm 1.204) + 0.543(\pm 0.106)LEA3 - 2.147(\pm 0.180)C12 - 0.319(\pm 0.088)B$ | 0.725 | 2.16 | 0.703 | 4.04 |
| 4 $y = 59.2(\pm 0.203) - 3.04(\pm 0.194)FII - 1.25(\pm 0.196)FIII$ | 0.695 | 2.27 | 0.680 | 2.65 |