QUANTITATIVE RELATIONSHIPS BETWEEN THE TISSUE COMPOSITION OF BOVINE CARCASS AND EASILY OBTAINABLE INDICATORS

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Abstract – The most accurate determination of beef carcass quality involves dissection of cut or entire carcass. This, however, is very costly and cumbersome. An alternative is to determine easily obtainable indicators. The objective of this study was to derive quantitative relationships between indirect carcass indicators and measured carcass tissue composition. A meta-analysis was applied on 25 published trials with cattle. The selected indicators were USDA yield grade, fat thickness, marbling, ribeye area and carcass conformation and fatness scores. The USDA yield grade was the most highly related to changes in carcass adipose tissue and muscle weights. Fat thickness was also related to changes in both adipose tissue and muscle weights. Other indicators were less correlated with changes in carcass tissue composition. The relationships obtained in this study depend on measurement accuracy and different deposition kinetics for adipose tissue.

Key Words – adipose tissue, carcass composition, cattle.

I. INTRODUCTION

Carcass quality depends on the tissue composition and the muscularity of slaughtered animals. Information about carcass composition helps to determine nutritional requirement, animal performance and the cost of production of beef cattle. Carcass quality in cattle is evaluated by a variety of methods, each of which may involve different techniques. Direct methods determine the composition (tissue or chemical) of the carcass from the complete dissection of the half or the entire carcass. The most accurate method is the chemical analysis of the carcass [1]. However, the physical separation of the carcass into muscle, adipose tissue and bone is a useful indicator of retail composition [2] or tissue development [3]. These measures are difficult and expensive to implement in practice particularly with cattle. Indirect methods are commonly used. In Europe the conformation (ConS) and fatness (FS) scores are used. In other countries as USA, the yield grade (YG), subcutaneous fat thickness (SFT), marbling (Mar) and ribeye area (longissimus dorsi area, LMA) are used. Therefore, the comparison of published quantitative results on carcass quality is difficult because of this diversity of approaches. We recently showed [4] that variations in yield grade and fat thickness may properly explain the variations of chemical composition of carcass. The objective of this study was to determine, from published results, the quantitative relationships between variations of tissue composition of carcass and the variation of easily obtainable indicators.

II. MATERIALS AND METHODS

Publications describing cattle carcass and published in international scientific journals were searched using the web of science without restriction on the years. Selection criteria were results of carcass tissue composition with at least one indicator (YG, SFT, LMA, Mar, Cons and FS). Data extracted from the publications included detailed descriptions of animals (breed, gender…etc) and carcass characteristics. They were entered into a database.

Several additional calculations were performed to complete the database in case of missing data. They were based on data available in the publication.

Cold carcass weight, kg = 0.98 × hot carcass weight (HCW, kg).

Dressing percentage, % = (hot carcass weight ÷ slaughter weight) × 100

The marbling score was harmonized on a scale of 10 (2: traces, 3: slight, 4: small) and the conformation and fatness scores were harmonized on scales of 5 [5].

Publications presenting more than 1 study were separated into experiments that were individually encoded as such. All data were examined graphically in several steps during the analysis. Descriptive statistics (mean, standard deviation, minimum, maximum) and the normality test for each variable were generated. To take in account the other factors of variation (gender, breeds…) methods of meta-analysis were applied in intra-study according to Sauvant *et al.* [6]. Variance–covariance models were developed using Minitab software (Minitab® 16.2.4. 2013), as follows:

$$Y_{ij} = \mu + \mu_i + \beta X_{ij} + \beta_i X_{ij} + e_{ij}$$

Where, i: the index of the study factor, j the index of the treatment number, Yij the dependent variable, Xij: the quantitative explanatory variable, μ the intercept, μi the fixed effect of the study on the intercept, β: the general fixed regression coefficient, βi the fixed effect of the study on slope, and eij the unexplained residual error.

The response variable was the tissue composition of carcass (muscle, adipose tissues in kg). The independent variables for each relationship were the hot carcass weight in kg, associated with one carcass indicator (yield grade , fat thickness in mm , marbling score /10, ribeye area in cm2, conformation score /5 and fatness score/5). For all models, the normality of residuals was verified, and influent data were identified from analysis of residuals, high leverage, Cook's distance and DEFIT [6]. The contribution of each explanatory variable to the total variance of the model was calculated. The models were compared in terms of adjusted R^2, residual means square errors of the model (RMSE) and the mean square error of prediction (MSPE) [7]:

$MSPE = 1/n\ \Sigma_{i=1}\ (X_i—y_i)^2$, where x are predicted values; y are observed values.

III. RESULTS AND DISCUSSION

A total of 25 scientific papers were identified, they included 28 experiments for a total of 117 treatments. The animals differed in gender (4% female, 43% male, 49% castrated males and 4% implanted castrated males), and/or breeds (45% beef, 29% dual purpose and 26% dairy). The descriptive statistics for variables retrieved from the publications showed wide ranges in all live animal and carcass characteristics (Table 1). The majority of data (88%) were associated with the continental breeds or their cross breeds with the lowest adipose tissue weights and the highest HCW and muscle weights. The remaining 12 % of data came from British breeds. Overall HCW varied between 138 - 487 kg, with 67% of data between 300-380 kg. Adipose tissues varied between 11-137 kg, with 81% of data between 30-80 kg, representing 16-24% of HCW.

Table 1 Mean values, standard deviations (SD), minimum (Min) and maximum (Max) of carcass weight, tissue composition and indicators

Variable	Number[1]		Mean	SD	Min	Max
	n_e	n_m				
Hot carcass weight, kg	116	1	313.8	63.6	138.3	487.5
Cold carcass weight, kg	116	1	307.5	62.4	135.5	477.8
Adipose tissue, kg	116	1	51.6	27.2	11.1	137.2
Muscle, kg	116	1	205.3	54.9	93.1	364.1
Bone, kg	116	1	51.7	12.8	24.6	76.5
Fat thickness, mm	60	57	8.8	3.9	3.2	20.2
Marbling /10	43	74	3.8	0.9	2.3	6.3
Yield grade	22	95	2.7	0.9	1.1	4.7
Ribeye area, cm^2	79	38	68.3	13.6	38.9	106.0
Conformation score /5	67	50	2.9	0.8	0.7	4.8
Fatness score /5	72	45	2.9	0.8	1.4	4.8

1: number of data (treatment): n_e: number of existing data, n_m: number of missing data.

Relationships between carcass tissue composition and indicators are presented in Table 2. Hot carcass weight was more highly correlated with the muscle weight than with adipose tissue weight (Model 7 vs. 1) explaining a greater proportion of the variance (74 vs. 3%). Relationships were generally improved when indicators were included as additional covariate. Most indicators (YG, SFT, Mar, FS) were positively correlated with adipose tissue weight (model 2, 3, 4, 6) and negatively correlated with muscle weight (Models 8, 9, 10, 13), contrary to LMA and ConS (Model 5, 11). These results can be explained by the negative correlations between adipose tissue and muscle weights at similar carcass weight.

Table 2. Intra-study relationships between carcass tissue weights (adipose tissue and Muscle,kg) and easily obtainable indicators (yield grade, subcutaneous fat thickness, marbling score, *longissimus dorsi* area, and score of conformation and fatness of carcass) in finishing cattle.

N°	Y	Number[1]		Equation[2]	RMSE	Adj-R^2	MSEP	% variance explained[3]		
		N_{sy}	N_{tr}					In	HCW	Sy
1	**Adipose tissue, kg**	28	117	$24.41 \pm 9.26^{***} + 0.10 \pm 0.03^{***}$ HCW	9.05	0.89	61.5	-	3	88
2		7	22	$-10.71 \pm 11.8^{NS} + 0.12 \pm 0.04^{***}$ HCW$+20.00 \pm 2.99^{***}$ YG	5.74	0.98	19.5	62	26	10
3		14	57	$2.08 \pm 8.98^{NS} + 0.12 \pm 0.03^{***}$HCW $+3.51 \pm 0.35^{***}$ SFT	4.65	0.98	15.6	74	2	22
4		11	43	$3.52 \pm 10.03^{NS} + 0.09 \pm 0.04^{*}$HCW $+12.28 \pm 1.37^{***}$ Mar	4.91	0.97	16.9	24	35	38
5		16	76	$58.44 \pm 11.05^{***} + 0.22 \pm 0.04^{***}$HCW $-0.81 \pm 0.20^{***}$ LMA	8.99	0.91	61.8	5	15	73
6		15	72	$-1.77 \pm 8.28^{NS} + 0.04 \pm 0.02^{*}$HCW $+12.41 \pm 1.68^{***}$ FS/5	5.55	0.90	23.5	17	0.1	75
7	**Muscle, kg**	28	117	$-38.54 \pm 9.27^{***} + 0.76 \pm 0.02^{***}$ HCW	9.06	0.97	61.5	-	74	24
8		7	22	$1.04 \pm 7.07^{NS} + 0.71 \pm 0.03^{***}$ HCW $-18.04 \pm 1.79^{***}$ YG	3.44	0.99	7.0	0	89	10
9		14	57	$-11.61 \pm 6.20^{NS} + 0.70 \pm 0.02^{***}$HCW $-2.92 \pm 0.24^{***}$ SFT	3.21	0.99	7.4	5	82	13
10		11	43	$-9.62 \pm 9.43^{NS} + 0.70 \pm 0.04^{***}$HCW $-9.17 \pm 1.29^{***}$ Mar	4.62	0.99	14.9	0	70	1
11		16	76	$-73.69 \pm 10.83^{***} + 0.62 \pm 0.04^{***}$HCW $+0.94 \pm 0.20^{***}$LMA	8.82	0.97	59.3	1	69	27
12		14	67	$-54.88 \pm 10.87^{***} + 0.79 \pm 0.03^{***}$HCW $+5.55 \pm 2.87^{*}$ ConS	8.18	0.97	50.9	21	64	13
13		15	72	$-15.11 \pm 8.62^{*} + 0.83 \pm 0.02^{***}$HCW $-12.93 \pm 1.74^{***}$ FS	5.78	0.98	25.5	13	72	13

1: number of data: Nsy: number of studies, Ntr: number of treatments.
2: YG: Yield grade, HCW: Hot carcass weight, SFT: subcutaneous fat thickness, Mar: Marbling, LMA: Longissimus area, ConS: conformation score, FS: fatness score..
3: In: indicator (YG, SFT, Mar, LMA, ConS and FcS), Sy: Study.
NS: not significant $P > 0.10$, *: $P<0.05$, **: $P<0.01$, ***: $P<0.001$.

The SFT and YG were the most highly related to changes of carcass adipose tissue weight (Model 1, 2) with the highest adjusted R^2 and among the lowest RMSE and MSEP. The proportions of variance explained by the study effect were the lowest, indicating that there were no major additional variation factors besides the 2 covariates. These two indicators were already shown to be well related to the proportion of lipids in the carcass [4]. Besides, SFT is considered in the calculation of yield grade; it expresses the quantity of subcutaneous adipose tissue which is related positively to total adipose tissue between birth and adult age [8]. Marbling, despite its relative subjectivity [9] was also related to carcass adipose tissue, even though the quality of the relationship was lower than for SFT and YG because of a greater proportion of the variance explained by the study effect. The proportion of model variance explained by LMA (Model 4) was very small (5%) confirming results by Powell *et al*. [10] who showed that LMA accounted for less than 6% of the variation in chemical carcass composition (protein, fat) when animals of widely varying weights were included. Variability in the exact anatomical location of this measurement cannot be excluded between the used publications. There was no significant relationship between ConS and adipose tissue weight contrary to FS (Model 6) but the proportion of variance explained by FS was 17% which is very low compared with other indicators (YG, SFT, Mar). These results were similar to those of Indurain *et al*. [11] who showed that fatness score was more efficient than conformation for predicting carcass composition.

The first driver of changes in carcass muscle weight was HCW (Model 7), explaining a high proportion of the variance (from 64 to 89 %) in all models (Models 8 to 13), while indicators contributed for only 0 to 21%. In general, the study effect was lower in muscle relationships (Models 7 to 13) than in adipose tissue relationships (Models 1 to 6) indicating that carcass muscle weight was less affected by other variation factors (such as feeding conditions) than adipose tissue [3]. Again, the YG and SFT were the most highly related to changes in carcass muscle weight (Models 8, 9), with the highest adjusted R^2 and among the lowest RMSE and MSEP. By contrast, Mar and LMA were less related to changes of muscle weight (Models 10, 11). There was a significant relationship between ConS and muscle weight (Model 12) but it was associated with a high error of prediction (29% of muscle weight). The relationships between muscle and FS (Model 13) was better than that with ConS. but these two scores (ConS and FS) were poorly related to changes in carcass muscle weights, as already noted for adipose tissues.

IV. CONCLUSION

Our results adjusted on finished cattle data showed that indirect measurements on carcass particularly fat thickness and yield grade can be good indicators of changes in tissue composition of the carcass. The exploration of these relationships should be completed by taking into account other factors of variation (breed, sex...).

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