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VASCO CADAVEZ  
AND  
DANIEL THIEL

ORGANIZED BY



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# SUBCUTANEOUS FAT DEPTH MAGNITUDE INFLUENCES ITS MEASUREMENT ERRORS: A SIMULATION STUDY

Vasco A. P. Cadavez  
Mountain Research Centre (CIMO)  
Instituto Politécnico de Bragança  
Campus de Santa Apolónia, Apartado  
1172, 5301-855 Bragança, Portugal  
E-mail: vcadavez@ipb.pt

José R. Amaro  
Escola Superior de Tecnologia e Gestão  
Instituto Politécnico de Bragança  
Campus de Santa Apolónia, Apartado  
1134, 5301-857 Bragança, Portugal  
E-mail: rufino@ipb.p

António J. M. Fonseca  
REQUIMTE/ICBAS, Universidade do  
Porto, Campus Agrário de Vairão  
Rua Padre Armando Quintas  
4485-661 Vairão-VC, Portugal  
E-mail: amira@mail.icav.up.pt

## KEYWORDS

Carcass, Lambs, Lean, Meat, Prediction.

## ABSTRACT

The objectives of this study were to evaluate the impact of proportional and absolute errors on subcutaneous fat depth (SFD) measurements, and the effects on the stability of models to predict the lean meat proportion (LMP) of lamb carcasses. Ninety eight lambs (72 males and 26 females) of Churra Galega Bragançana breed were slaughtered, and carcasses were weighed and hot carcass weight (HCW) was recorded approximately 30 min after exsanguinations. During carcasses quartering a calliper was used to perform SFD measurements, over the maximum depth of *longissimus* muscle (LM), between the 12th and 13th ribs (C12), and between the 3rd and 4th lumbar vertebrae (C3). A computer program was written in order to simulate measurement errors for C12 and C3 measurements. Two scenarios were simulated, and C12 and C3 were contaminated with: 1) proportional errors of 5, 10, and 15%, and 2) absolute errors of 0.25, 0.50, and 0.75 mm. Simple linear models to predict LMP were developed using as independent variables: 1) the measured (original) SFD measurements, and 2) the biased SFD measurements. The coefficient of determination and the residual standard deviation were computed. Our study demonstrates that measurement errors can have a high impact on the SFD measurements, and on models stability. We conclude that SFD measurements of higher magnitude should be preferred as predictors of LMP since they are less influenced by measurement errors, thus contributing to more stable regression models.

## INTRODUCTION

The development of objective methods for carcasses classification is an important research topic as can be observed from the recently published papers (Hopkins 2008, Kongsro et al. 2009, Lambe et al. 2009). Commonly, these methods are based on linear regression models to predict the lean meat proportion (LMP), using the subcutaneous fat depth (SFD) and other carcass measurements as independent variables. The general linear

regression model can be represented by Equation 1,

$$Y_i = \beta_0 + \sum \beta_i X_i + \varepsilon_i, \quad i = 1, 2, \dots, n \quad (1)$$

where:  $Y_i$  is the response (LMP) in the  $i$ th case,  $X_i$  is the value of the independent variable (SFD) in the  $i$ th case (assumed to be a known constant measured without error),  $\beta_0$  and  $\beta_i$  are the regression coefficients, and  $\varepsilon_i$  is the independent error term assumed as normally distributed ( $N \sim (0, \sigma^2)$ ).

Generally speaking, the best predictors ( $X_i$ 's) of LMP will be those which give maximum precision in relation to cost (Kempster 1986). Several research studies have been conducted in order to compare the relative precision of LMP predictors, namely: SFD measurements taken on the carcass (Hopkins et al. 2008, Hopkins 2008, Lambe et al. 2009) or in live animals (Teixeira et al. 2006, Thériault et al. 2009). These studies are focused on finding the "Best Predictor", assuming that SFD measurements, taken at different anatomical positions, differ in the predicting ability of LMP. However, no comprehensive explanation is presented for the differences in the predictive ability of alternative (taken at different anatomical positions) SFD measurements within and among studies.

The SFD measurements are affected by several sources of errors (experimental error) as described by Daumas and Dhorne (1992) for pigs, and by Young and Deaker (1994) for lambs. If the error is systematic, the predictor is said biased (Hauck et al. 2008). At abattoir line the carcasses are classified based on one unique SFD measurement, and the errors are always unknown. If SFD measurement suffers of uncontrolled measurement errors the estimation of the regression coefficients will be unstable resulting in biased equations Chatterjee et al. (2000), thus making the prediction of LMP unreliable.

In this paper we present a simulation study concerning the impact of proportional and absolute errors on the predictive stability of regression equations using the SFD measurements as predictors of LMP.

## MATERIALS AND METHODS

### Data

Data used in this study were collected on ninety eight lambs (72 males and 26 females) of Churra Galega Bragançana breed. 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 (kidney and kidney fat included) according to Fisher and Boer (1994). Carcasses were halved through the centre of the vertebral column, and the kidney knob and channel fat was removed and weighed. During carcasses quartering a caliper was used to perform subcutaneous fat depth (SFD) measurements, over the maximum depth of *longissimus* muscle (LM), between the 12th and 13th ribs (C12), and between the 3rd and 4th lumbar vertebrae (C3). The carcasses left side was 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 LMP was calculated as the dissected muscle proportion (%).

### Errors simulation

A computer program was written under the Python language (Lutz 2007) in order to simulate measurement errors for C12 and C3 measurements. Two scenarios were simulated, and C12 and C3 measurements were biased with: 1) errors proportional to the magnitude of the measurement of 5, 10, and 15%, and 2) absolute errors of 0.25, 0.50, and 0.75 mm.

### Statistical analysis

Data were analyzed using the R Development Core Team (2008) software. Linear regression models to predict LMP were developed using as independent variables the original (measured) C12 and C3 measurements and the biased ones, through regression procedures under the MASS package (Venables and Ripley 2002). The coefficient of determination ( $R^2$ ) and the residual SD (RSD) were used to compare the models.

## RESULTS AND DISCUSSION

The means and SD for the original and biased SFD measurements are shown in Table 1. The means for HCW and LMP were 12.1 kg ( $\pm 3.45$ ) and 60.1 % ( $\pm 3.63$ ), respectively. The C3 measurement presented a magnitude 1.9 times higher than that of the C12 measurement.

The correlations of LMP with the original and biased SFD measurements are shown in Table 2. Both, C3 and C12 measurements were moderately and negatively correlated ( $r$  between 0.41 and 0.49) with LMP. When biased with proportional errors, the correlations of C3 and C12

measurements with LMP presented similar values to those observed for original values.

Table 1: Mean and SD of the Original and Biased SFD measurements

Error	C12, mm	C3, mm
Original	2.1 $\pm$ 0.84	3.9 $\pm$ 1.92
Proportional error, %		
5	2.1 $\pm$ 0.84	3.7 $\pm$ 2.08
10	2.1 $\pm$ 0.84	3.9 $\pm$ 1.91
15	2.1 $\pm$ 0.85	3.9 $\pm$ 1.94
Absolute error, mm		
0.25	2.0 $\pm$ 0.88	3.9 $\pm$ 1.92
0.50	2.0 $\pm$ 0.98	3.8 $\pm$ 1.94
0.75	1.9 $\pm$ 1.12	3.8 $\pm$ 2.00

A slight decrease on correlations (1 to 3 percentual units) was observed with the increase of the proportional error (Table 2). However, when biased with absolute errors a different behaviour was observed for C12 and C3 measurements. The correlations of C12 measurement with LMP decreased with the increase of the absolute error, attaining a maximum decrease of 16 percentual units for LMP, when biased with an absolute error of 0.75 mm. For C3 measurement, the decrease in the correlations were substantially lower (around 50% lower), being 6 percentual units when biased with an absolute error of 0.75 mm. Thus, these results show that measurement errors can present a higher impact on the lower magnitude SFD measurements (like C12 measurement).

Table 2: Correlations of Original and Biased SFD measurements with LMP

	C12	C3
Original	-0.59	-0.51
Proportional error, %		
5	-0.58	-0.51
10	-0.57	-0.50
15	-0.56	-0.49
Absolute error, mm		
0.25	-0.55	-0.50
0.50	-0.48	-0.48
0.75	-0.41	-0.45

The simple linear regression models and RSD values for the Original and Biased C12 and C3 measurements as predictors of the LMP are presented in Table 3 and 4, respectively. The models  $R^2$  values for the Original and Biased C12 and C3 measurements as predictors of the LMP are presented in Figure 1 and 2. The original C12 measurement explained 34.7% of the LMP with an RSD of 2.95%, and the original C3 measurement explained 26.4% of the LMP with a RSD of 3.13%. The increase of the proportional errors produced a slight decrease in the  $R^2$

(3.8 percentual units for C1, and 2.0 percentual units for C3 measurement biased with a proportional error of 15%), and an increase in the RSD (0.08% for C12, and 0.04% for C3 measurement biased with a proportional error of 15%). The increase of the absolute errors produced an important decrease in the  $R^2$  (17.9 percentual units for C12, and 5.9 percentual units for C3 measurement biased with an absolute error of 15%), and an increase in the RSD (0.38% for C12, and 0.12% for C3 measurement biased with a proportional error of 15%).

Table 3: Simple linear regression models parameters ( $\pm$ SE) and RSD for the Original and Biased C12 measurements as predictors of the LMP

	Intercept	C12	RSD
Original	65.4 $\pm$ 0.797	-2.53 $\pm$ 0.355	2.95
Proportional error, %			
5	65.4 $\pm$ 0.802	-2.51 $\pm$ 0.358	2.97
10	65.2 $\pm$ 0.808	-2.46 $\pm$ 0.362	3.00
15	65.0 $\pm$ 0.810	-2.37 $\pm$ 0.363	3.03
Absolute error, mm			
0.25	64.7 $\pm$ 0.773	-2.27 $\pm$ 0.352	3.05
0.50	63.6 $\pm$ 0.724	-1.79 $\pm$ 0.332	3.19
0.75	62.6 $\pm$ 0.661	-1.33 $\pm$ 0.302	3.33

Both SFD measurements presented similar results when contaminated with proportional errors (Tables 3 and 4). A slight instability in the estimation of the regression coefficient for C12 (variation of 6.3% from unbiased to biased with proportional error of 15%) and C3 (variation of 5.2% from unbiased to biased with proportional error of 15%) measurements were observed. When SFD measurements were biased with absolute errors a higher instability in the estimation of the regression parameters was observed (Table 3 and 4).

Table 4: Simple linear regression models parameters ( $\pm$ SE) and RSD for the Original and Biased C3 measurements as predictors of the LMP

	Intercept	C3	RSD
Original	63.9 $\pm$ 0.720	-0.972 $\pm$ 0.166	3.13
Proportional error, %			
5	63.9 $\pm$ 0.721	-0.965 $\pm$ 0.166	3.14
10	63.8 $\pm$ 0.719	-0.948 $\pm$ 0.166	3.15
15	63.7 $\pm$ 0.716	-0.921 $\pm$ 0.166	3.17
Absolute error, mm			
0.25	63.7 $\pm$ 0.709	-0.931 $\pm$ 0.165	3.16
0.50	63.4 $\pm$ 0.692	-0.867 $\pm$ 0.162	3.20
0.75	63.1 $\pm$ 0.672	-0.787 $\pm$ 0.158	3.25

For C12 measurement, the regression coefficient showed a variation of 47.4% when comparing the unbiased to the biased measurement with an absolute error of 0.75 mm. For C3 measurement, the regression coefficient showed a variation of 19.0% when comparing the unbiased to the biased measurement with absolute error of 0.75 mm. This

trend increased with the increase of absolute error, and the model instability was higher for C12 measurement (lower magnitude measurement). These result shows that lower magnitude SFD measurements can present unstable regression relationship with LMP.

The use of biased SFD measurements impacts on the predicting ability of the LMP models, and the C12 measurement (lower magnitude) is more susceptible to measurement errors. Thus, the use of SFD measurements of lower magnitude will produce more unstable regression models, since they are more susceptible to measurement errors.

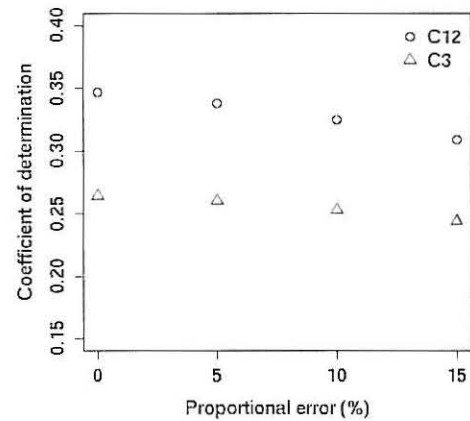


Figure 1: Coefficient of determination values for simple linear regression models using the Original and Biased C12 and C3 measurements contaminated with proportional errors as predictors of the LMP

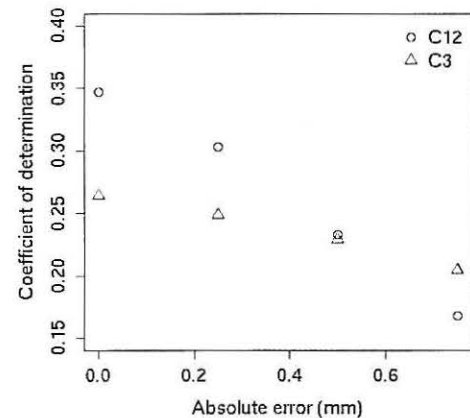


Figure 2: Coefficient of determination values for simple linear regression models using the Original and Biased C12 and C3 measurements contaminated with absolute errors as predictors of the LMP

For regression equations including SFD measurements biased with proportional errors, the  $R^2$  decreased similarly in the C12 and C3; thus the effect was independent of the measurement magnitude. However, the assumption that SFD measurements are affected only by proportional errors

is not realistic, especially if measured by ruler on the carcass.

Differences in fitting quality of models can result from the noise of independent variables, due to the measurement errors. Kempster (1986), considering the search for best predictors of carcass composition, stated that in the real world the examination of the underlying features of growth and development is more important than the prediction problem. Why some predictors are more precise than others? Why do some predictors have more stable regression relationship? This study provides some answers to these questions from Kempster (1986).

Young and Deaker (1994) identified several causes of measurement error that may influence direct measurements, namely: tissue damage at slaughter, tissue displacement during measurement, tissue distortion prior to measurement, positioning of the measurement site, anatomical location. These authors considered that small measurements (like C12 measurement) have proportionally greater errors of measurement, which is confirmed by this simulation study.

## CONCLUSIONS

The magnitude of SFD measurements influences its susceptibility to measurement errors, and SFD of higher magnitude are more stable since they are less affected by measurement errors. Regression models using as predictors SFD measurements of higher magnitude (C3 per example) have more stable regression relationships with LMP across samples. For light carcasses (Mediterranean lambs market) it will be very difficult to discriminate carcasses using the C12 measurement as predictor. Thus, SFD measurements of higher magnitude (like C3 and GR or sternal tissues thickness measurements) should be preferred as predictors, since its higher magnitude leads to lower bias due to measurement errors, contributing to more stable regression models.

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## AUTHOR'S BIOGRAPHY

**VASCO CADAVEZ** is an Adjunct professor in the Department of Animal Science at Polytechnic Institute of Bragança. His research interests include carcass and meat quality, with special emphasis on the development of models for objective classification of carcasses at slaughter line.

**RUFINO AMARO** is an Adjunct professor in the Department of Informatics and Communications at Polytechnic Institute of Bragança. He has a MSc and PhD in Informatics (Parallel and Distributed Systems). His research interests include Distributed Data Structures applied to Computer Graphics and Scientific Computing with Python.

**ANTÓNIO FONSECA** is an Associate Professor in Animal Science at the Department of Veterinary Clinics, Instituto de Ciências Biomédicas de Abel Salazar (ICBAS), Universidade do Porto (UP), and a Permanent member of the REQUIMTE – Laboratório Associado para a Química Verde. His main research topics include understanding rumen function and ruminants nutrition – based on multidisciplinary and non-invasive approaches.