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Prediction of DEVCo cut weights from chilled ovine carcasses using single-frequency bioelectrical impedance measurements

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ABSTRACT

Single-frequency bioelectrical impedance (resistance and reactance) was measured from one hundred and thirteen chilled lamb carcasses. The carcasses were later cut into the DEVCo cuts and every cut was weighed. These cuts were: Legs, Loin, Rack, Shoulders, Shanks, Flap, Breast and Neck. The bioelectrical impedance data, together with carcass weight and temperature, were used to predict the weights of each of the DEVCo cuts. The best prediction was for the DEVCo Legs cut (adjR^2 = 0.945), and the worst prediction was for the DEVCo Neck cut (adjR^2 = 0.369). The data analysis revealed carcass weight to be the single best predictor of DEVCo cut weights, and that adding the bioelectrical impedance data did not improve prediction significantly.

Keywords: Bioelectrical impedance; DEVCo cuts; yield.

INTRODUCTION

Value-based marketing and processing of lamb meat is dependent on objective and accurate measurements of characteristics on which a differential pricing scheme or processing can be based. In the past decade, a technique involving measurement of impedance of biological tissue, termed bioelectrical impedance analysis (BIA), has emerged as an inexpensive, non-destructive method of assessing leanness and fat-free mass of humans (Lukaski, 1991).

During a bioelectrical impedance measurement, a low intensity, time-varying electric current is introduced in the body. As the current flows through the body it interacts with the cells. This interaction causes a delay, when compared to the reference signal, which is interpreted as reactance, indicating a cell volume increase or decrease. In addition, the comparison of the magnitude of the reference and body signals reveals the resistance, which is linked to a change in the extracellular volume of the body.

Applications of BIA in case of animal carcasses were reported for bovine (Marchello *et al.*, 1993), ovine (Berg *et al.*, 1994) and pork carcasses (Swantek *et al.*, 1992). The findings reported in these studies yielded to a similar conclusion as in the case with humans.

This study was to investigate if the weight of wholesale meat cuts, such as DEVCo cuts (Kirton *et al.*, 1999), can be predicted using bioelectrical impedance data coupled with carcass weight. Both intracellular and extracellular volumes along the current path, which link to the fat-free mass of that region of the carcass, influence bioelectrical impedance. By introducing electrical current in the carcass at different locations the effect of different regions of the carcass, i.e. different cuts, on BIA measurements is emphasised. BIA data gathered in this way may provide additional information needed to successfully infer cut weights for each carcass. A previous study (Slanger *et al.*, 1994) on prediction of the total weight of retail-ready lamb cuts in a processing plant environment reported very favourable results (R^2 = 0.97; carcass weight only, R^2 = 0.88). The cuts for this study were trimmed to 0.64 cm or less of subcutaneous fat.

MATERIALS AND METHODS

One hundred and thirteen lambs were slaughtered at the AgResearch's Ruakura campus. Next day, after spending about 24 hours in a chiller, bioelectrical impedance was measured for each of the carcasses shortly after leaving the chiller. Together with the bioelectrical impedance data, carcass weight and temperature were recorded. The carcasses were then cut into DEVCo cuts, and each cut weighed on an electronic scale (accuracy ±10 grams). The cuts were not trimmed for excess fat.

The impedance measurements were performed using a four-terminal bioelectrical impedance analyzer (RJL Systems Inc., Michigan, USA). Four 20-gauge vacutainer needles were used as electrodes. The outer pair of needles introduced a 50 kHz, 800 ìA current into the carcasses. The inner pair of needles measured the voltage between the pair, allowing the instrument to calculate resistance (R) and reactance (X) expressed in ohms. The distance between the outer and inner electrodes was always 7 centimetres. Measurement of inner electrodes distance (L) followed each impedance measurement. Three different positions of the electrodes were examined:

- From the tailhead to the top of the shoulder above the first rib, as close to the backbone as possible (denoted BB);
- From the thickest part of the right leg, at the stifle joint, to the midpoint of the thickest part of the right shoulder (RS); and
- As in the RS case, but with the left shoulder instead (OS).

The BB electrode position was expected to introduce a deep, homogeneous current along the backbone, which should allow better prediction of the DEVCo Loin and Rack cuts. The RS and OS electrode positions were designed to enhance prediction of the Legs, Flap and Shoulders cuts.

The statistical analysis was performed using MINITAB software package. After removing obvious outliers[2] from the data sets, predictor equations were derived for each DEVCo cut and each different electrode location using multiple linear regression technique. In choosing best equations we followed this set of rules:

- The set of predictors in any equation must contain at

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[2] The data removed clearly stood out from the rest of the set.

least one impedance variable (R or X);
- Electrode distance (L) must be present in the equation;
- Carcass temperature can be dropped from equations if that will improve the quality of fit.

The equation with the highest value of adjusted squared correlation coefficient (adjR^2) that satisfied the above rules was selected as the best for a particular cut and electrode position.

RESULTS AND DISCUSSION

Bioelectrical impedance data combined with carcass weight (W) and temperature (T) were used to predict the weight of the DEVCo cuts for each carcass. The prediction model was a linear combination of the measured variables: carcass weight (W in kg), resistance (R in ohms), reactance (X in ohms), inner electrodes distance (L in cm) and carcass temperature (T in °C). Table 1 presents the means, standard deviations, minima and maxima of the DEVCo cut and the bioelectrical impedance data sets.

TABLE 1: Means, standard deviations, minima and maxima of the DEVCo cut and bioelectrical impedance data sets.

Variable	Number of observ.	Mean	Std. Dev.	Min	Max
Legs cut (kg)	113	4.91	0.64	3.29	6.66
Loin cut (kg)	113	1.52	0.25	0.85	2.29
Rack cut (kg)	113	1.23	0.21	0.66	1.68
Shoulders cut (kg)	113	3.7	0.57	2.26	5.62
Shanks cut (kg)	112	0.61	0.01	0.43	0.97
Breast cut (kg)	112	0.49	0.12	0.26	0.91
Flap cut (kg)	112	1.08	0.21	0.66	1.64
Neck cut (kg)	113	0.54	0.08	0.34	0.73
Carcass weight (kg)	113	14.52	1.95	9.3	19.9
Carcass temperat. (°C)	113	5.25	0.81	3.5	8
BB R (Ohms)	113	260.34	23.52	202	329
BB X (Ohms)	113	75.98	10.17	47	104
BB L (cm)	113	39.78	2.96	33	49
RS R (Ohms)	113	336.58	27.16	277	405
RS X (Ohms)	113	99.41	12.86	61	136
RS L (cm)	113	56.239	3.45	48	66
OS R (Ohms)	113	335.06	28.29	276	409
OS X (Ohms)	113	100.26	13.60	57	134
OS L (Ohms)	113	63.73	3.62	56	73

The values of adjR^2 for each electrode location and DEVCo cut together with residual error standard deviation (RSD) are given in Table 2. Also presented are the sets of variables used in the best predictor equations with corresponding *P*-values.

The DEVCo cut predicted best was the Legs cut for all electrode positions (adjR^2 = 0.945, RSD = 0.149 kg in OS position). The worst predicted DEVCo cut was the Neck cut, also for all electrode positions considered (adjR^2 = 0.361, RSD = 0.066 kg in RS position). The next two worst predicted DEVCo cuts are the Breast and Loin cuts. The group of relatively well-predicted DEVCo cuts, adjR^2 in the 0.7-0.8 range, are the Shanks, Flap and Rack cuts. The best predicted, adjR^2 above 0.9, are the Shoulders and Legs cuts.

TABLE 2: Statistical results of the best predictor equations for three DEVCo cuts, including all electrode locations. These DEVCo cuts represent three different groups of prediction accuracy. Results when carcass weight (W) only is used are given for reference.

DEVCo cut	Electrode location: BB position Predictors (*P*-value)	BB AdjR^2, RSD/kg	RS position Predictors (*P*-value)	RS AdjR^2, RSD/kg	OS position Predictors (*P*-value)	OS AdjR^2, RSD/kg
Legs	W (0.000)	0.928, 0.172	W (0.000)	0.928, 0.172	W (0.000)	0.926, 0.172
	W (0.000) R (0.002) X (0.298) L (0.135) T (0.000)	0.942, 0.155	W (0.000) R (0.000) X (0.047) L (0.061) T (0.000)	0.945, 0.151	W (0.000) R (0.000) X (0.049) L (0.001) T (0.000)	0.945, 0.149
	W (0.000)	0.772, 0.101	W (0.000)	0.772, 0.101	W (0.000)	0.766, 0.1
Rack	W (0.000) X (0.477) L (0.031) T (0.050)	0.783, 0.098	W (0.000) X (0.885) L (0.001) T (0.096)	0.795, 0.096	W (0.000) R (0.593) L (0.001) T (0.073)	0.789, 0.096
	W (0.000)	0.382, 0.195	W (0.000)	0.382, 0.195	W (0.000)	0.403, 0.193
Loin	W (0.000) X (0.398) L (0.053) T (0.001)	0.459, 0.183	W (0.000) R (0.396) L (0.023) T (0.000)	0.465, 0.182	W (0.000) R (0.479) L (0.005) T (0.001)	0.496, 0.178

The different electrode locations (BB, RS or OS) had little influence on prediction of DEVCo cut weights. It is interesting to note that one of the worst predicted DEVCo cuts, the Loin cut, was slightly better predicted from the OS electrode location (adjR^2 = 0.403), instead of its "preferred" BB location (adjR^2 = 0.382).

Carcass weight (W) appears to be the single best predictor of DEVCo cut weights. Adding other available predictors (R, X, L and T) did not have almost any significant effect except for the Breast and Loin cuts. In these cases, the adjR^2 values for the prediction equations were improved by about 0.08 and 0.11, respectively, for all three different electrode locations.

CONCLUSION

The statistical analysis of our BIA data for DEVCo cut weights of hundred and thirteen chilled lamb carcasses yielded a wide range of prediction success. All commercially valuable cuts, except the Loin cut, were predicted well, with the Legs and the Shoulders cut being the best predicted of them all (adjR^2 > 0.93). Carcass weight was the single most influential predictor. We found that the correlation between carcass and DEVCo cut weights had the decisive effect on the regression results; addition of the BIA data only slightly improved them. This strong correlation between carcass and cut weight is significantly higher than in Slanger *et al.* (Slanger *et al.*, 1994), and could therefore explain the reduced impact of BIA measurements on predicting cut weight.

The theoretically predicted influence of sensing electrode location on BIA has not been observed in our data. However, we cannot conclude that the actual current flow does not have any effect on BIA, because our BIA data had at least for an order of magnitude smaller influence on DEVCo cut weights than carcass weight. Better understanding of the physics of electric current flow through the carcass, preferably using computer modelling and simulations, is needed to explain this somewhat surprising result.

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