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P8 and rib fat depth measurement on beef carcase using a portable microwave system (#623)

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Notes

Introduction

Non-invasive and non-destructive measurements of fat depth are sought after within the beef industries, as overfat carcases cause significant economic loss and wastage for processors. Within the Australian beef industry fat depth is measured manually, however this has the disadvantage of being destructive, subjective and time-consuming [1]. Since biological tissues in animals, feature a high contrast in their dielectric properties (skin, fat, and muscle) at microwave frequencies [2], this represents an opportunity to different fat from lean and thus estimate fat depth and body composition of carcases and live animals. This concept has been tested in lamb carcases where a low-cost portable Microwave System has been developed for measuring C-site back fat depth [3]. This paper details the testing of a similar device in beef, where we hypothesised that it would accurately predict P8 and rib fat depth in beef carcases.

Methods

Two groups of Angus steers (Kill 1, n=56; Kill 2, n=144) were slaughtered at a commercial abattoir on the same day. Their left-side carcase weights ranged between 115-185kg, P8 and rib fat depths ranged between 4-20mm and 2-17mm, measured using vernier callipers. The P8 site was measured 40min post-mortem, and was simultaneously scanned using two portable Microwave Systems. The first (MiS1) operated at frequencies of 100 MHz to 6.5 GHz with output power -10 dBm, and was coupled with an open-ended coaxial probe. The second (MiS2) operated at 100 MHz to 5.4 GHz with output power -10 dBm, and was coupled with a periodic-log antenna. The rib fat site was measured 24hr post-mortem, and also scanned using a portable Microwave System (MiS3) operated at frequencies of 100 MHz to 6.5 GHz with output power -10 dBm, and was coupled with a Vivaldi Patch Antenna. In all cases data was captured in 10MHz intervals, resulting in 641 calibrated and processed frequency domain signals for the MiS1 and MiS3, and 531 for the MiS2.

These signals were then used to estimate the P8 and rib fat depth via Partial Least Squares Regression. Initially a leave-one-out cross validation procedure was used to train a model for each measurement site within each kill group, with R-square (R^2) and root mean square error (RMSE) shown as indicators of precision. To further test transportability, the MiS1 models trained in one kill group were validated in the other, with this process repeated for the MiS2 and MiS3 models. In this case the R^2 of the prediction and root mean square error of the prediction (RMSEP) are shown as indicators of precision, and slope of the relationship and bias estimates indicate accuracy. Bias represents the difference between the predicted and actual values at the mean of the dataset.

Results

The internal cross-validation within individual data sets demonstrated good precision for the prediction of P8 fat depth in hot carcases 40min post-mortem using both MiS1 and MiS2 (Table 1). This was evident within both kill groups, with RMSE values ranging between 0.93mm to 2.76mm. Measurements taken using the MiS2 demonstrated better precision than for MiS1, a trend evident in both Kill 1 and 2 (Table 1). Measurement of rib fat depth in cold carcases using MiS3 demonstrated precision that was comparable to the other systems, although described proportionately less of the variance (R^2 = 0.58 & 0.48).

Further validation testing across data sets demonstrated some loss in precision compared to internal validation testing, particularly for the P8 predictions (Table 2). Alternatively, there was little loss of precision for the rib fat depth measurement.

Although all three systems demonstrated reasonable accuracy, with slope values all close to 1, and bias values deviating little from zero. The largest bias values were for the rib fat measurement taken on the cold carcase, which approached 2mm.

Conclusion

This study demonstrates the capacity of a proposed portable microwave system to estimate P8 and rib fat depth in beef carcasses non-invasively. The results suggest that a range of different probe/antenna hardware can be used for hot and cold carcase measurement to predict fat depth within the carcass. Future research will investigate the development of a microwave probe for multi-site profiling of carcase and live animal back fat.

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	Kill 1			Kill 2		
	P8 (Hot)	P8 (Hot)	Rib fat (Cold)	P8 (Hot)	P8 (Hot)	Rib fat (Cold)
R^2	0.66	0.88	0.48	0.76	0.80	0.58
RMSE (mm)	2.76	0.93	1.75	2.17	1.68	1.63
Microwave System	MiS1	MiS2	MiS3	MiS1	MiS2	MiS3

Table 1 Precision estimates for the prediction of P8 (hot carcase) and Rib (cold carcase) fat depth across 2 kill groups of Angus. Values are R-square (R^2) and root mean square error (RMSE).

	Train in Kill 2, validate in Kill 1			Train in Kill 1, validate in Kill 2		
	P8 (Hot)	P8 (Hot)	Rib fat (Cold)	P8 (Hot)	P8 (Hot)	Rib fat (Cold)
R^2	0.53	0.71	0.44	0.65	0.67	0.56
RMSEP(mm)	3.78	2.34	1.96	3.23	2.70	1.84
Bias(mm)	-0.63	0.19	1.84	0.51	1.28	-2.05
Slope	0.89	1.04	0.82	0.98	0.82	1.18
System	MiS1	MiS2	MiS3	MiS1	MiS2	MiS3

Table 2 Precision and accuracy estimates for the prediction of P8 (hot carcase) and Rib (cold carcase) fat depth in 2 kill groups of Angus steers, where models were trained in 1 kill group and validated in the other. Values are R-square (R^2) and root mean square error (RMSEP) of the prediction, bias and slope of the relationship.

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