Effects of temperature, current, voltage and frequency on bioelectrical impedance and its ability to predict saleable yield of hog carcasses

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Background

The concept of using bioelectrical impedance to predict body tissue composition can be modeled as a cell suspended in physiological electrolyte. When alternating electrical current flows through the body , electrical resistance is generated as the current is opposed by extracellular physiological fluid and electrical capacitance is generated as the current charges the cell membranes (Foster and Lukaski 1996). Muscle, fat and bone have different electrical properties. Bioelectrical impedance of body tissues can be assessed by applying a small alternating electrical current and measuring the resulting potential difference. Bioelectrical impedance has shown promise as a nondestructive, objective and practical method to assess carcass tissue composition of cattle (Slanger and Mrchello 1994), lamb (Berg et al. 1997) and pig (Marchello et al. 1999).

Objectives

The objectives of this study are to assess the influence of temperature, current, voltage and frequency on bioelectrical impedance and its ability to predict saleable yield of hog carcass.

Methods

Data on 205 market weight hog carcasses, mean hot carcass weight 86±6 kg, of varying fatness level, were used in this study. A laptop computer equipped with a National Instrument (www.ni.com) NI-488.2 PCMCIA interface adapter was used to control a 4-electrode Hewlett Packard 4284A Precision LCR meter (Agilent Technologies, www.agilent.com) to measure electrical impedance of carcasses at deep muscle temperatures of 39, 20, 12 and 3° C respectively, at 5 levels of alternate current (0.2 mA to 1.4 mA in a step of 0.3 mA), 5 levels of voltage (100 mV to 700 mV in a step of 150 mV) and 15 frequencies (8 kHz to 200 kHz at irregular intervals). Electrodes were placed along the inside of the carcass. The cranial transmitting electrode was placed between the 3rd and 4th thoracic spinal processes, mid point between the spine and skin. The caudal transmitting electrode was placed 50 cm ventral to the Aitch bone. The two receiving electrodes were place 10 cm cranial and 10 cm caudal respectively to the transmitting electrodes. The left sides of the carcass were dissected after a 12 hr of chilling. Carcass cutout procedure was in accordance with the 1992 National hog cutout study (Jones et al. 1993). Total saleable yield was defined as the sum of yields from ham, loin, butt, picnic and belly, where ham yield=0.8*ham trim + inner shank + nugget + ham muscle + regular ham+ inner tenderloin + lean trim, loin yield = tenderloin + false lean + chump end + butterfly back, butt yield=0.5* fat trim + 0.8* lean trim + defatted boneless butt, picnic=0.5*fat trim + defatted boneless picnic, and belly yield=side rib + skinless square cut belly. The lean yield percent was expressed a percent of the cold side weight. The data were analyzed by stepwise multiple regression to establish saleable yield prediction models with maximum coefficient of determination (R^2).

Results and discussion

As carcasses were chilled from 39° to 3° C for 12 hr, bioelectrical impedance increased significantly ($P<0.01$) from 122 to 215 Ω (Figure 1). However, bioelectrical impedance did not change significantly ($P<0.05$) from 5 alternating current or 5 voltage levels (Figure 2). These results suggest that (i) bioelectrical impedance prediction equations are temperature dependant, and (ii) the use of any current level to measure bioelectrical impedance is appropriate. Increased alternating current frequency from 8 kHz to 200 kHz significantly ($P<0.1$) increased bioelectrical impedance (Figure 3). Destron optical probe (Anitech PG-100, www.anitech.com) is one of the instruments used for hog grading in Canada. The accuracy (R^2) of predicting percentage saleable yield from using a basic reference model including fat and muscle depths from Destron probe was 0.67 (Table 1). Five frequencies that contributed maximum R^2 to the models were selected by multiple regression analysis. Inclusion of bioelectrical impedance measurements obtained at the best 5 frequencies and the distance between the detector electrodes, in addition to the predictors from the basic reference model resulted in an accuracy ranging from 0.74 to 0.83, depending on temperature. This is equivalent to a 10 to 24% improvement of accuracy. Madsen et al (1999) obtained a correlation of 0.8 when they used multi-frequency bioelectrical impedance to predict beef longissimus dorsi muscle intramuscular fat.

Figure 1: Effects of carcass temperature

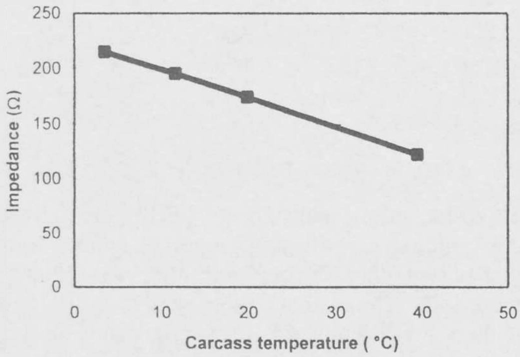

Figure 2: Effects of voltage and current

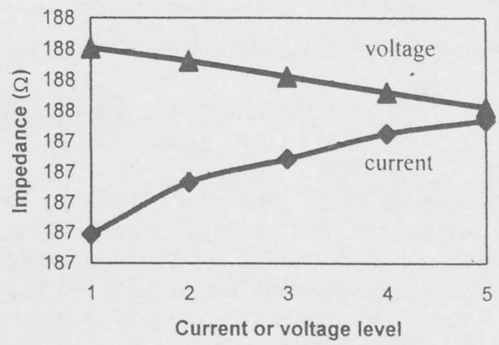

Figure 3: Effects of alternating current frequency

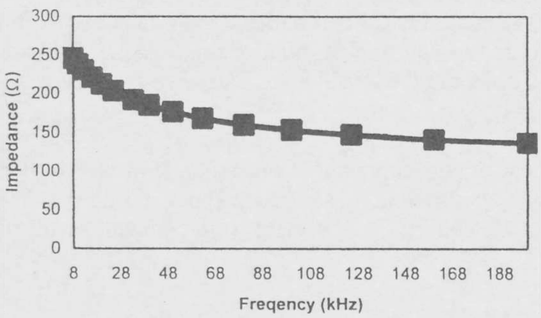

Table 1: Accuracy of predicting saleable yield from adding bioimpedance measurements

Model	Variables in model	R^2	RSD (Ω)
Basic model	Destron fat depth + muscle depth	0.67	2.17
Impedance at 39 °C	Basic model + distance + 5 best frequencies	0.74	1.95
Impedance at 20 °C	Basic model + distance + 5 best frequencies	0.79	1.77
Impedance at 12 °C	Basic model + distance + 5 best frequencies	0.80	1.72
Impedance at 3 °C	Basic model + distance + 5 best frequencies	0.83	1.56

R^2 = coefficient of determination , RSD = residual standard deviation

Conclusions

These results suggest that bioelectrical impedance could provide a low cost and accurate instrument for online hog carcass grading.

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References

Foster, K.R. and Lukaski, H.C. 1966. Whole-body impedance – what does it measure? American Journal of Clinical Nutrition. 64(suppl): 388S-96S.

Jones, S.D.M., Tong, A.K.W., Robertson, W.M. and Skoczylas, P. 1993. National pork cutout project (1992) part 1: a comparison of the 1978 and 1992 cut outs. Report to the National Hog Cutout Committee, Oct 1993, 22 pp.

Madsen, N.T., Borggaard, C., A.J. Rasmussen and L.B. Christensen, 1999. On-line measurement of intramuscular fat/marbling in beef carcasses using electrical impedance. Proceedings of 45th ICoMST, 5-P10.

Marchello, M.J., R.T. Berg, P.M. Swantek and J.E. Tilton, 1999. Predicting live and carcass lean using bioimpedance technology in pigs. Livestock Production Science 58:151-157.

Berg, E.P., M.K. Neary, J.C. Forrest, D.L. Thomas and R.G. Kauffman. 1997. Evaluation of electronic technology to assess lamb carcass composition. Journal Animal Science 75:2433-2444.

Slanger, W.D. and Marchello, M.J. 1994. Bioelectrical impedance can predict skeletal muscle and fat-free skeletal muscle of beef cow primal cuts. Journal Animal Science 72:3124-3130.