EFFECT OF CURRENT, VOLTAGE, FREQUENCY AND CARCASS TEMPERATURE ON IMPEDANCE MEASUREMENTS OF LAMB CARCASSES

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Background

Over recent years the livestock industry has changed from being production oriented to being consumer driven. Because people demand leaner meat, it is important to determine body composition in a non-invasive, objective and practical manner (Marchello *et al*., 1992). Bioelectrical impedance measures the resistance and reactance of a constant current as it passes through a biological mass and is related to the proportions of fat and lean. This arises because muscle and fat have different electrical properties (Marchello *et al*., 1999). Lean tissue is a highly conductive substance composed mostly of water containing electrolytes (~ 75%) (Swatland, 1984). Fat is essentially anhydrous and serves as an insulator, exhibiting impedance to the flow of an applied electrical current (Berg *et al*., 1998). By measuring the resistance to an alternating current passed through the tissues, between electrodes separated by a known distance, the proportions of fat and lean can be estimated. The source electrodes introduce an alternating current at the base of the measuring object. The detecting electrodes measure the voltage drop due to the circuit at anatomical reference points (Bohuslavek et al., 2000). The most common BIA method involves two pairs of electrodes. The positive and negative electrodes of each pair are positioned a short distance from each other. A larger distance separates the two pairs. This four electrode or tetrapolar measurement is essential to eliminate electrode and field distribution problems associated with two electrode measurements (Bohuslavek *et al.,* 2000). Because BIA is safe, inexpensive, portable, rapid, easy to perform, and requires minimal operator training (Kushner, 1992), it would be likely to find favour in the industry. Early work on the application of BIA to measuring body or carcass composition used simple equipment developed for use on humans and operating at fixed current, voltage and frequency. Tong et al. (2001) showed that for pork carcasses impedance readings were dependent on frequency and temperature, but not on current and voltage. Furthermore, they showed that the prediction of carcass composition was improved when impedance measurements were taken at a number of frequencies. In designing a practical device for use on a lamb slaughterline it is important to choose the best combination of current, voltage and frequency and to be aware of the effect of temperature on impedance.

Objectives

The objective was to determine the effect of current, voltage, frequency and carcass temperature on BIA readings of lamb carcasses.

Materials and methods

Data on 49 lamb carcasses of varying fatness were used in this study. A laptop computer equipped with an Agilent 82357A USB/GPIB 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 hot carcasses, at 4 levels of alternating current (0.4mA to 1.4mA in steps of 0.3mA), 4 levels of voltage (100mV to 550mV in steps of 150mV), and 15 frequencies (8kHz to 200kHz at irregular intervals). The cranial transmitting electrode was placed proximal to the fifth cervical vertebrae. The caudal transmitting electrode was inserted into the *gastrocnemius* muscle, proximal to the Achilles tendon. The two receiving electrodes were placed 5cm cranial and 5cm caudal respectively to the transmitting electrode. Hot carcass measurements of Rs and Xc were recorded after carcass dressing, and impedance was calculated. Using the same apparatus and terminal placement, the electrical impedance of 15 carcasses was measured at deep muscle temperatures of 39, 35, 30, 25, 20, 15 and 0°C.

Results and discussion

Impedance is a measure of how current is slowed or stopped as it passes through a material. In biological systems, electrical conduction is related to water and ionic distribution in the conductor. Because fat-free mass (FFM), which includes the protein matrix of adipose tissue, contains virtually all of the water and conducting electrolytes in the body, conductivity is far greater in FFM than fat mass (Pethig, 1979). The hypothetical relationship between impedance and electrical volume was proposed by Nyboer et al. (1943) who first demonstrated that electrically determined biological volumes are inversely related to impedance (Z), resistance (R), and reactance (Xc) where,

$$Z = \sqrt{Rs^2 + Xc^2}\ .$$

Therefore, from the Rs and Xc readings from the LCR impedance (Z) was calculated. The effect of current and voltage on impedance can be seen in Figures 1 and 2. The straight lines clearly indicate that bioelectrical impedance did not change significantly over 4 alternating currents (Fig. 1) or 4 voltage levels (Fig. 2). Frequency did, however, affect impedance. As frequency increased from 8 to 200kHz, impedance significantly decreased (Fig. 3).

As carcasses were chilled from 39 to 0°C, impedance increased significantly from 200 to 380Ω (Fig. 4). This confirms that bioelectrical impedance measurements are temperature dependent. However, if impedance measurements were taken at the same point on the line, this temperature effect would be unimportant, as carcasses would be within 2°C of each other.

All these results, while preliminary, are in strong agreement with those found by Tong et al., (2001) who carried out similar work using pig carcasses.

Conclusions

These results suggest that the use of any current or voltage level in the ranges examined in this study would be appropriate to measure bioelectrical impedance in lamb carcasses. However, as frequency increased from 0 to 200kHz, impedance decreased, suggesting that there may be an optimum frequency for measuring impedance in lamb carcasses. Finally, bioelectrical impedance measurements are temperature dependent, but the effect is probably small enough to be unimportant for measuring carcasses at a fixed point on the kill line. Further work includes the investigation into the use of BIA to accurately predict saleable yield and fat-free-lean weight through carcass dissection and compositional analysis.

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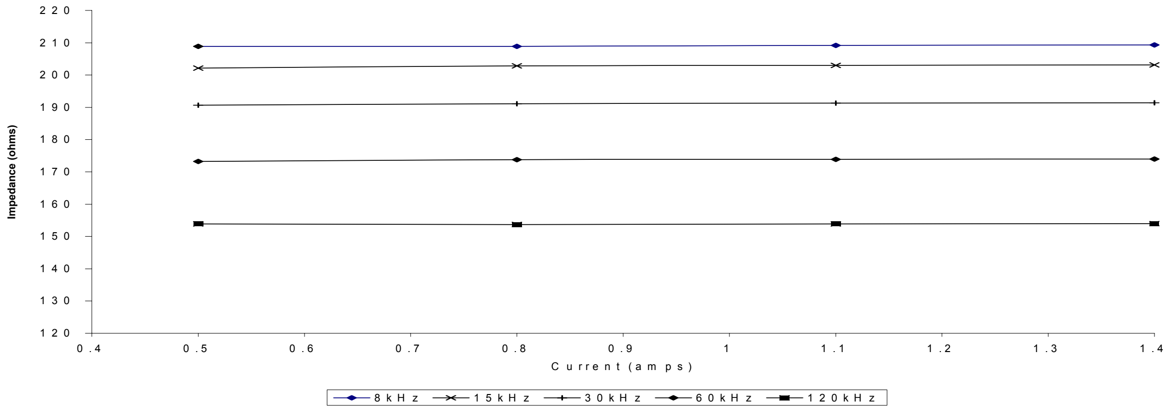

Figure 1. Effects of current

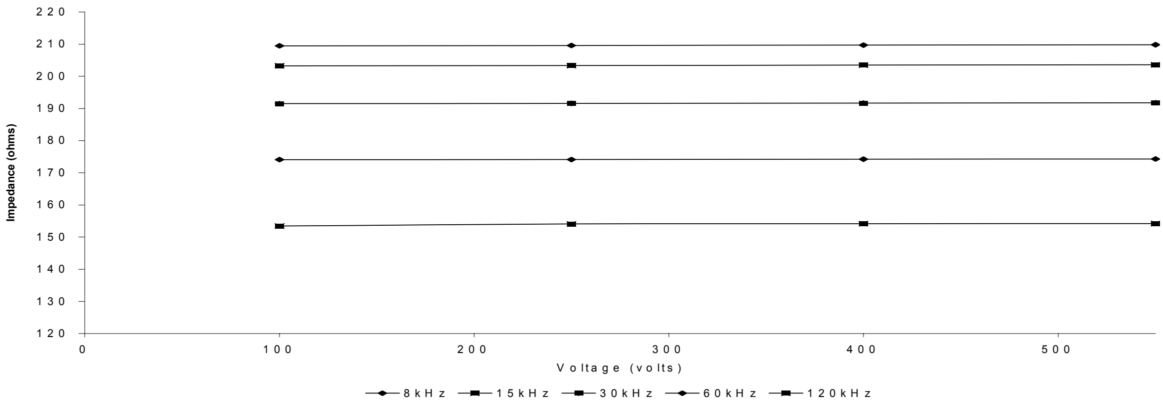

Figure 2. Effects of voltage

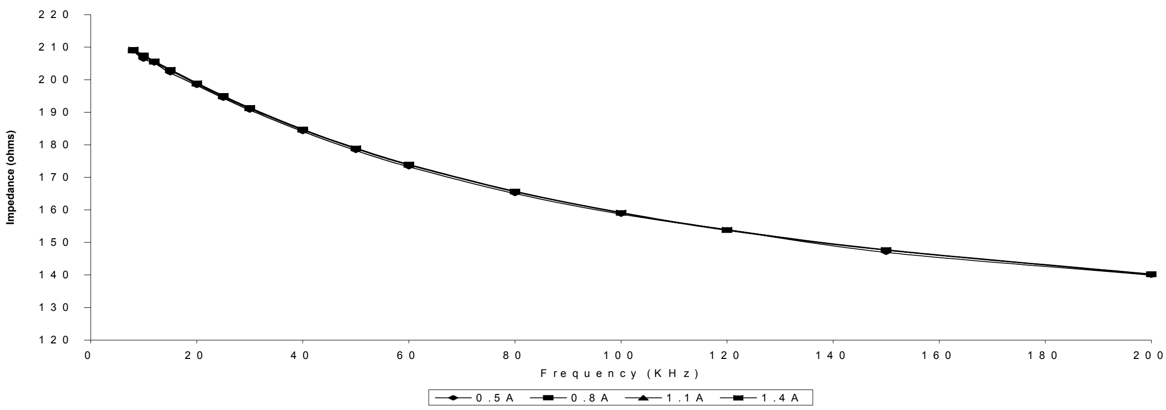

Figure 3. Effects of frequency

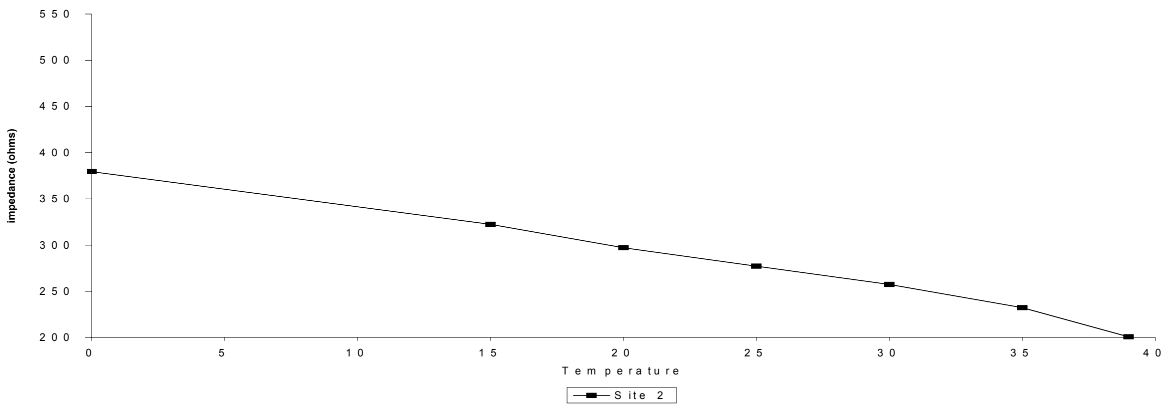

Figure 4. Effect of carcass temperature