# PREDICTION OF BEEF CARCASS COMPOSITION FROM BIOELECTRICAL IMPEDANCE DATA

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## INTRODUCTION

Techniques for simple, non-destructive and repeatable assessment of the absolute and relative fat-free mass, fat and water content of animals have application in both medical and animal science. Bioelectrical impedance analysis (BIA) developed for estimating body composition in human subjects has been evaluated in animals ( Marchello et al.,1992,1994; Kushner et al., 1992; Swantek et al., 1991,1992). More recently BIA has been shown to be able to predict skeletal muscle mass in farm animals for example in cattle and beef carcasses (Marchello and Slanger 1994), pigs and pork carcasses (Marchello and Slanger 1992; Swantek et al. 1992) and sheep (Cosgrove et al. 1988).The evaluation of carcasses quality is important for their objective classification and thus setting of correct relations between livestock breeders and meat processor at animal purchase. Simultaneously the assumptions for further destination of meat after their compositions are set up, i.e. for retail meat and raw material for meat products.

Needle electrodes in various modifications are frequently used for BIA estimation of body composition of livestock and their carcasses. The needle electrodes offer satisfactory results during laboratory and experimental measurement, e.g. Swantek (1991) on this way checked up the possibility of FFM (fat free mass) estimation at live market swine and pork carcasses. The best regression model of FFM estimation achieved $r^2 = 0{,}84$. During the suitability tests of the BIA method for estimation of beef carcasses conformation, carried out at a high-performance abattoir line (Bohuslavek, 2002), some imperfections of needle electrodes occurred: (difficulty of exact electrodes placing, undesirable contact with bones, damaging). They provided worse results in estimation of quality parameters (the conformation due to EU standards).

The present study was undertaken to determine properties of new planispheric electrodes and new impedance analyzer for assessment of electrical properties of beef carcasses under normal performance at slaughter line. Using electrical values obtained from BIA the weight of *musculus longissimus lumborum et thoracis* and absolute and relative areas proportions of the muscle tissue and the fat on the cross-section between 8th a 9th ribs evaluated by VIA method is estimated.

## MATERIAL AND METHODS

a) *Description of the carcass collection.* The measuring system was verified at an abattoir in Kostelec at Jihlava, where 54 beef carcasses were measured during a part of a shift. The measurement was carried out on left carcass halves.

b) *Description of measuring method and device.* The four-electrodes method of measurement with area elastic electrodes provided on surface Cu-foil about area 30 $cm^2$ was used for measurement of BIA. The new developed impedance analyzer (created in the workplace of author) enabled measurement of impedance and the phase angle on four frequencies (1; 10; and 100 kHz). The mechanical concept of telescopic electrode adapter including means of measurement of their distance was identical along with experiments, which described Bohuslavek (2002). Placement of electrodes allowed simple anatomic definition and enabled the fast attendance and good contact of electrodes. Electrodes were situated from external side of left carcasses. All electrodes were placed on the vertical lines going through heel tendon (tendo calcaneus). The upper measuring electrode was placed on the horizontal line going through the broadest pars of the leg, i.e. on the musculus vastus lateralis, the lower measuring electrode was on the horizontal line going through tuber olecrani. The drive electrodes were placed 85 mm out of measuring electrodes.

c) *Reference values – obtained during dissection of beef carcasses.*
The images of cross-sections between $8^{th}$ and $9^{th}$ rib were taken after cooling by digital camera Olympus 2020 Zoom; constant distance, calibration and camera axis perpendicularity to section plane was secured by special equipment.
The dorsal parts - sirloin incl. backbone was cut from the beef carcasses and weighted (SV). These parts were consecutively boned and again weighted (S). Finally all other tissues were avoided from the *longissimus lumborum et thoracis* muscles and these muscles were weighted too (MLL).

d) *Output values of the analyzer.* The measured impedance and phase angel were for statistical analysis calculated on real and imaginary part of impedance – resistance and reactance. Calculated values correspond to serial arranged RC circuit (Rs, Xcs), as it flows from the measurement principle of the analyzer. While modeling the biological tissue, the intracellular and intercellular space, as model system, may be replaced by parallel RC circuits with the corresponding conductivity and permittivity. The simplest biological equivalent model is a single resistor and capacitor in parallel. Therefore values of serial circuit need to be calculated on resistance and reactance of parallel circuit (Rp, Xcp).

*e) The software LUCIA 3.52 practiced the image processing analysis* of cross-section between 8th and 9th ribs. The areas of muscle tissue and fat expressed in pixels were converted on the $cm^{-2}$ using calibration by means of know dimensions of a control card, whose area was measured by LUCIA too. From these results the ratios (%) of muscle tissue and fat in the individual cross-section of samples were calculated.

*f) Processing of results, statistical evaluation.* Data obtained from impedance analysis were replenished by calculating values, for examples the "$D^2/R_p$, $L^2/R_p$ as electric volume (Swantek et. al. 1992, Hegarty et. al. 1998) with generally very good correlation to carcass weight. Another calculated value is the reactance ration, 1Xcp/1Xcp, 100Xcs/1Xcs, which was expected to relate to fatness. Firstly higher correlation between referential values (weights of dissected sirloin and results VIA of cross-section between 8. and 9. rib) and data from impedance analysis were looked for. Consequently the regression formula for estimation of *musculus lumborum et thoracis* and ratio (%) areas of muscle and fat obtained from VIA cross-section between 8. and 9.rib were looked for as well. Estimation formulae have been calculated with multiple stepwise regression analysis.

## RESULTS AND DISCUSSION

The correlations investigation between BIA variables was carried out on two groups of reference values. First group was represented by weights of the parts received by dissection of left carcass halfs: SV, S, MLL. According to assumption deduced from foregoing measurements (Bohuslavek 2000) the highest correlation was achieved between the carcass weight and the quantity $D^2/100Rp$, which represent so-called electrical content. The correlation coefficient r = 0,892 belongs to the highest value achieved by the author up to now. Relatively very high correlation degree was found between *longissimus lumborum* muscle weight (MLL) and BIA variables. Specific values of the resistance (100Rp/D) and those of the reactance (100Xcp/D) measured at the frequency of 100 kHz show high correlation r = 0.9068 and r = 0.9058, and thus they are good predictors for the estimation of the weight of this muscle.

The second group of reference values obtained by the VIA of the images of the cross-sections between the 8th and 9th rib was represented in relative and absolute objects (areas) of the muscle tissue, fat and bones. The variables derived from reactance 100Xcp (100Xcp/L …r = 0.816 and $L^2$ / 100Xcp…. r = 0.86) show the highest dependence to muscle tissue area. There is also a high dependence of the reactance on the muscle tissue amount. Therefore it may be supposed that the variables derived from the reactance measured at the frequency 100kHz will be good predictors of the estimation of muscle tissue ratio in the carcass.

Regression analysis was oriented to find the best regression model (equation) for estimating selected references values – sirloin weight (S), relative ratio of muscle tissue (% muscle) and adipose tissue ratio (%fat) in cross-section. The best calculated regression equations are summarized in TABLE 1. Sirloin weight is more exactly estimated by the model Nr.1 where coefficient of determination $r^2$ = 0,88 and coefficient of the correlation r = 0.94 was achieved. As the conformation class due to EU standards is significantly dependent on the ratio of the meat I (great parts), we can expect good estimation of the conformation class using these BIA variables. The best regression equation for the estimation of relative ratio of the muscle tissue (% muscle) by VIA shows satisfactory coefficient of the determination $r^2$ = 0,71. The best equation for the estimation of the relative fat ratio by VIA is represented by the model Nr. 3 with the coefficient of determination $r^2$ = 0,79 and until now this is the best-achieved result in direct estimation of adipose tissue ratio in carcass. In all equations the significance level of the independent variables is P<0.05, but mostly P<0.005.

**Table 1 Regression models for beef carcasses (n = 54)**

| Model no. | Dependent variables | Independent variables | Equations | $r^2$ / r** | RSD* |
|---|---|---|---|---|---|
| 1. | MLL [ kg ] | 1Rp/D<br>100Xcp/D<br>100Xcp/1Xcp | MLL = 12.211 – 3.41*$10^{-2}$ * 1Rp/D – 8.19*$10^{-3}$ * 100Xcp/D – 0.463 * 100Xcp/1Xcp | 0.884/0.94 | 0.4 |
| 2. | muscle [ % ] | 1Rp<br>L^2/100Rp<br>1Xcp/100Xcp | muscle = 0.279 * 1Rp + 3.65*$10^{-2}$ * L^2/100Rp + 4.782 * 1Xcp/100Xcp - 66.373 | 0.717/0.85 | 7.0 |
| 3. | fat [ % ] | 1Xcp<br>L^2/100Rp<br>1Xcp/100Xcp | fat = 107.372 + 5.61*$10^{-3}$ * 1Xcp - 2.48*$10^{-2}$ * L^2/100Rp - 3.095 * 1Xcp/100Xcp | 0.629/0.79 | 7.6 |

*[RSD]…stand. error of estimation $r^2$ / r** … coefficient of correlation / determination;*

It can be concluded that the use of new planispheric electrodes contributed to the higher accuracy of the measurement of beef carcasses by the BIA method and to more facile and reliable application of electrodes on carcass surface. It can be assumed that after avoiding of distractive influence of different carcass temperature at the end of slaughter line and after improvement of the proportionality of adjusted distance of electrodes to carcass length, the achieved results will be more precize.

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