Estimation of EUROP- Conformation and Fatness of Beef Carcasses by Bioelectrical Impedance Analysis.

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ABSTRACT

Bioelectrical impedance analysis was evaluated on 292 beef carcasses for prediction of their EUROP-conformation and fatness. The bioimpedance analyzer developed for use in clinical medicine was adapted and connected with PC to be applied as a fully automatically measuring system for on-line measurement at a slaughter line. Fatty tissue mass indicated by EU-fatness wasn't dependent significantly on any measured and calculated data. Significant dependencies can be found between conformation and resistance (r = 0,86) and carcass weight (r = 0,85). Warm carcass /slaughter/ weight (W_S, kg), resistance (R, ohm), length of body (L, cm) and reactance ($X_{C,}$ ohm) were used to develop the prediction equations for estimating EUROP-conformation of beef carcasses. The best regression model involving R, L, W_S, L^2/R calculated for 88% of variation (r^2 = 0,88) for EU-conformation respectively. The results suggest that bioelectrical impedance data are useful to predict the conformation of beef carcasses in EUROP classification.

Keywords: bioelectrical impedance, beef carcasses, bioelectrical resistance, EUROP classification

INTRODUCTION

The livestock industry is increasingly consumer driven. Consumers demand high quality lean meat products. In the EU the grades for beef are visually determined in conformation and fat classes. Visual classification is difficult to achieve in an absolutely consistent manner over time, even with independent Inspector control. Therefore, a rapid and objective technique for determining body composition in beef carcasses would be extremely useful in both the commercial and research situation. Bioimpedance analysis (BIA) has been investigated extensively as a technique to determine body composition on laboratory animals and humans (Kushner 1992, Thomas et al. 1992). More recently BIA has been shown to be able to predict skeletal muscle mass in farm animals such as 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; Jenkins et al. 1988).

The bioelectrical impedance sciences are body measurements where resistance and reactance is evident from a circuit that conducts alternating current. The source electrodes introduce alternating current (1 – 500 kHz) at the base of the measuring object (body). The detecting electrodes measure the voltage drop due to this circuit at the anatomical land marks of the fore shank, foot, shin, 8th rib, etc. This is a four-electrode or tetrapolar measurement, which is essential to eliminate electrode and field distribution problems associated with two electrode measurements. The tetrapolar measurement is shown figure 1.

The complex heterogeneous circuits of the human and animal body are many, each being a combination of cells and their supporting environment. When a signal from the electrical impedance analyzer is introduced to the environment of cells a small amount of the signal is leaked through the protein channel to charge the inside of the cell membrane. There are two parallel electrical pathways, one is through the cell and the other around the cell. The cell has an analog to a capacitor, and the aqueous space around the cell to a resistor. Theoretically, *reactance* of the capacitor is a measure of the volume of the cell membrane capacitance and an indirect measure of the intracellular volume or body cell mass (Liedtke 1998). Whereas, body fat, total body water and extracellular water offer *resistance* of a resistor to electrical current, only cell membranes offer capacitive reactance. Obviously the reactance is not affected by the quantity of body fat. The ability or accuracy of BIA to predict total body water, fat free mass and fat has been well documented (Lukaski 1985). Recently BIA prediction equations have been developed that use parallel resistance and reactance as predictors of extracellular mass and body cell mass.

The aim of our research was the evaluation of the ability of BIA for the prediction of the carcass quality by EUROP limits.

MATERIAL AND METHODS

Measurements were carried out under the support of the Federal Centre for Meat Research in Germany (BAFF Kulmbach) with the instrument BIA-MC3 of the firm FEMTO, Berlin, Germany, which works on the method of 4-electrods measurements of impedance (current of 350μA and frequency of 50 kHz). Due to FEMTO recommendation and extensive experiences from applications in human medicine the right anatomically defined points of measurement for injecting needle electrodes were chosen in the front and back limbs (Figure 2).

Because the measurements were implemented directly in the slaughterline, to emulate everyday line conditions, the measurement system had to be performed under the following conditions:

- time of measurement of one carcass was less then 10 seconds
- on-line control of disturbance effects and validity control of measured values
- minimalization of side effects of manual service during reading and processing values

These conditions were performed by connecting the instrument BIA with a computer through the RS 232C line and the automatization of the entire measurement process. For automatic control, measuring instrument, data acquisition and processing, a special program was developed by using the Professional Development Environment TestPoint. The program offers a convenient measuring system through a virtual operational board shown on the display of the computer. The use of virtual buttons allows the start of measurement, calibration, changing of the measuring frequency, test of batteries and saving data into files. Before starting the measurement process, it is possible to set or correct the number of measurements and the number of the carcass. The measurement process itself performs repeated measurements of resistance (R) and reactance (X_S). It processes both measured and manually added values. Afterwards, values are put into tables of the format ASCII and into tables of the simultaneously working program Excel. On-line control is provided by repeatedly measuring during 10 sec and immediately applying statistical evaluation. The test is carried out 5 times and counted average value and standard deviation (S_x) is taken only from the third, fourth and fifth measurement because, the first and sometimes the second values have higher deviation caused by slow frequency synchronization of the sinusoidal current source.

Measurements were carried out in the slaughter line where the automatic classifying system VBS 2000 working on the VIA basis was investigated simultaneously. Thanks to this coincidence we acquired values about morphology parameters of carcasses, more exactly the length, the square and the volume of a whole carcass and its parts. In the accounting office there were data of live weight and carcass weight and the results of the 5-grades EUROP classification system available. During testing VBS 2000, a 15-grades classification of conformation and fatness was done. The values were used as reference values for the statistical analysis.

The measurements were performed on 345 carcasses (only left sides) during two days. After the reduction of carcasses with the standard deviation (S_X) higher then 2 ohms (1%) for resistance (R) and reactance (X_S), only 292 carcasses (97 cows, 186 young bulls, 5 bulls, 4 heifers) were evaluated statistically. Higher deviation was caused by the contact of both carcasses while moving in the slaughter line or by badly injected needles, etc**.** More detailed characteristics of the group of evaluated animals are shown in Table 1.

Statistical analysis.

The statistical analysis was performed by using the regression procedure in Winstat v.3.1 for Win95. Firstly, the data were analyzed by simple regressions in order to determine the relationship between EUROP classification performance (conformation and fatness) and measured impedance. Based on these results a multiple regression analysis was carried out. The prediction equation was selected using the best subsets of the regression analysis.

RESULTS AND DISCUSSION

The measured values of resistance R (ohm), reactance Xc (ohm), warm carcass /slaughter/ weight Ws (kg), and length L (cm) were supplemented by the calculated values: impedance Z (ohm), length divided by resistance L/R , carcass density Wd (weight / volume - kg/m^3) and electrical volume L^2/R , which were published by (Lukaski 1985), (Swantek 1991) and other authors. The correlations between these variables and the EUROP grades (conformation and fatness) are presented in Table 2. Correlation coefficients (r) in Table 2 inform that fatty tissue mass indicated by EU-fatness is not significantly dependent on any measured or calculated value. Significant dependencies are found between the class of EU-conformation and the values: resistance, carcass weight, impedance, R/L, and L^2/R. Similarly to (Swantek 1992), our results do not indicate, that L^2/R is the best model to estimate EU-conformation (FFM-fat free mass), as published by (Lukaski 1985).

The strong dependence between carcass weight and L^2/R is interesting because it shows that even beef fat is an important conductor of alternating current depending on frequency 50kHz. The narrowest dependencies are shown through the simple regression between EUROP-conformation and resistance (Figure 3) and between carcass weight and L^2/R (Figure 4).

Based on the best dependencies the variables were analyzed by stepwise multi-regressions. The results of correlation analysis have shown weak dependence on the measured values on EUROP-fatness. Therefore the regression analysis was carried out only for EUROP-conformation. The prediction equation of EUROP-conformation for the beef carcass are presented in Table 3. The equations are displayed in increasing order. Warm carcass weight (W_S, kg), resistance (R, ohm), body length (L, cm) and reactance (X_C, ohm) were used to develop prediction equations for estimating EUROP - conformation of the carcasses. The values of EU - conformation and fatness were classified by inspectors from the Federal Centre for Meat Research, Kulmbach. The best regression model involving R, L, W_S , L^2/R calculated for 88% of variation (r^2 = 0,88) for EU - conformation respectively. Results suggest that bioelectrical impedance data are useful to predict the conformation of beef carcasses in EUROP-classification.

CONCLUSIONS

It has been shown that BIA has a potential to predict EU-classification in beef carcasses. Results of this study indicate that bioelectrical resistance is a good predictor for rapid estimation of EUROP-conformation. Within the demonstrated approach of BIA measurement on the whole carcass, the prediction of EUROP-fatness seems not to be possible.

Further studies with bioelectrical impedance procedures should investigate the influence of different frequencies of measuring current and the influence of different placement of electrodes. Accurate comparison of bioimpedance data with objective physical values (acquired by dissection and chemical analysis) will be performed by measuring single carcass parts. The study of dielectrical properties of fat free mass and fatty tissue should show the possibility of the carcass leanness estimation.

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Table 1 Characteristics of the group of evaluated animals

Category	186 Young bulls		97 Cows		5 Bulls		4 Heifers	
	Mean	S. dev.	Mean	S. dev	Mean	S. dev	Mean	S. dev
Conformation *	9,5	1,9	13,2	1,47	9,6	1,1	11,7	0,95
Fatness *	6,6	1,5	6,9	2,1	7,2	0,8	8,4	1,5
Weight [kg]	356,6	43,14	268,7	47,6	403,7	16	259,8	31,7
Impedance [ohm]	161,4	17,5	219	26,7	163	13,8	215,3	8,7
Resistance [ohm]	156,15	17,23	212,8	26,5	157	14,1	209	8,1

* Grading system with 15 conformation- and fat-classes,(EUROP-classes divided into15 subclasses)

Table 2 Correlation matrix for impedance readings and physical characteristics of the half (side) carcass , n = 292

Variable*	EU- fatness	EU-conformation	Carcass density	Carcass Weight
L^2/R	0,164	-0,82	0,75	0,9198
Resistance R	0,024	0,864	-0,866	-0,823
Reactance Xc	-0,091	0,652	-0,678	-0,615
Impedance Z	0,028	0,860	-0,864	-0,819
R/L	-0,027	0,851	-0,822	-0,885
Carcass Weight	0,228	-0,848	0,720	1,00
Length L	0,241	-0,128	-0,022	0,535

***** Resistance *R* (ohm), Reactance *Xc* (ohm), Warm carcass weight *Ws* (kg), Length *L* (cm), Impedance *Z* (ohm), *L/R* = length divided by resistance(cm/ohm), Carcass density *Wd* (kg/m^3), L^2/R electrical volume (cm^2/ohm), EU-fatness and conformation classes (divided into 15 subclasses, 5^- to 1^+, P^- to E^+)

Table 3 Regressions models for EUROP-conformation of beef carcasses (n = 292)

Independent variables	Model no.	Equations Dependent variable = EU_C ***	r^2 / r **	RSD *
L^2/R, Ws	1.	$EU_C = 21{,}94 – 1{,}712*10^{-3}L^2/R – 2{,}176*10^{-2}Ws$	0,737 / 0,858	1,26
R, Ws	2.	$EU_C = 3{,}74*10^{-2}\ R – 1{,}69*10^{-2}\ Ws + 9{,}72$	0,80 / 0,89	1,09
L^2/R, Ws, Xc	3.	$EU_C = 5{,}99*10^{-2}Xc – 5{,}6*10^{-4}L^2/R – Ws * 2{,}55 *10^{-2} + 17{,}76$	0,75 / 0,865	1,2
R, R/L, Ws, L	4.	$EU_C = 0{,}45\ R/L – 6{,}21*10^{-2}R – 3{,}74*10^{-2}\ Ws + 6{,}26*10^{-2}L – 18{,}38$	0,875 / 0,935	0,87
R, L, Ws	5.	$EU_C = 1{,}079*10^{-2}\ R + 4{,}199*10^{-2}\ L – 3.714*10^{-2}\ Ws – 5.56$	0,873 / 0,934	0,88
L^2/R, Ws, L	6.	$EU_C = 4{,}78*10^{-2}L – 1.45*10^{-3}L^2/R – 3{,}3*10^{-2}\ Ws – 5.26$	0,88 / 0,938	0,85
L^2/R, Ws, L, R/L	7.	$EU_C = 5{,}14*10^{-2}\ L – 2{,}24*10^{-3}L^2/R – 7.39*10^{-2}\ R/L – 3{,}43*10^{-2}\ Ws – 3.172$	0,882 / 0,939	0.84

* RSD…Resid.Stand.Dev. (Stand. Error of Estimation), ** r^2/ r…Determination coeff. /Coefficient of correlation

*** EU - conformation classes (divided into 15 subclasses, P^- to E^+)

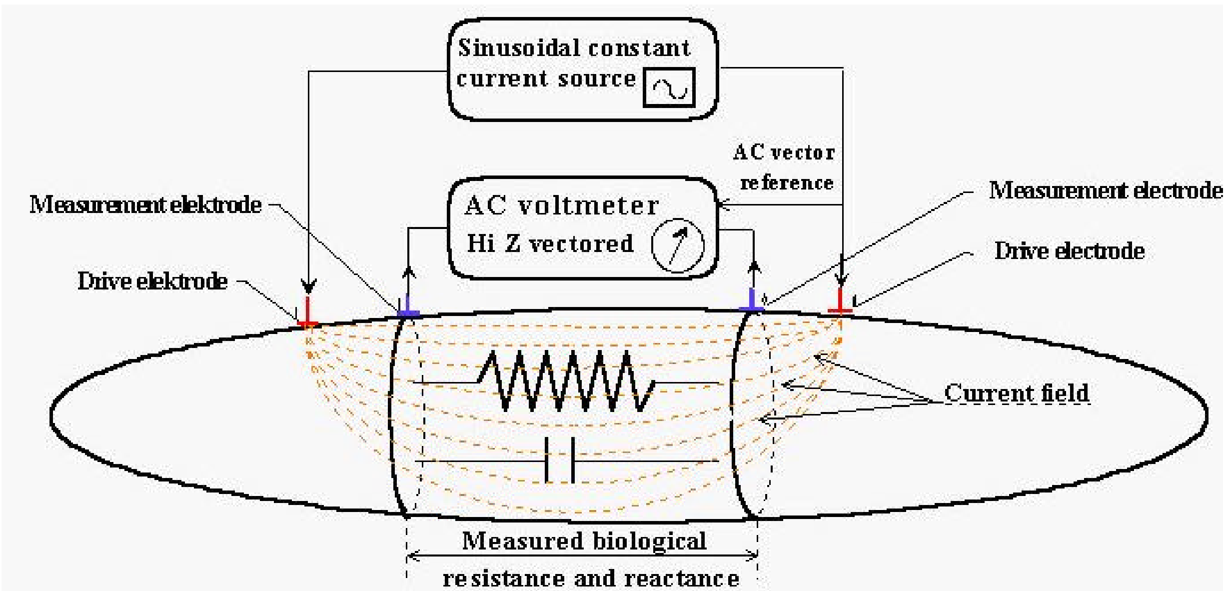

Figure 1. Tetrapolar BIA-measurement

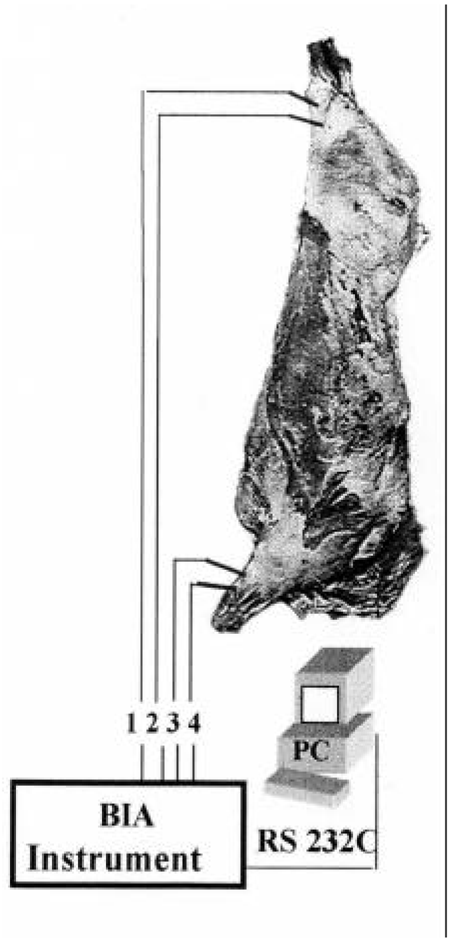

Figure 2. Diagrammatic presentation of BIA - system and optimum placement of drive (1.,4.) and measurement (3.,4.) electrodes.

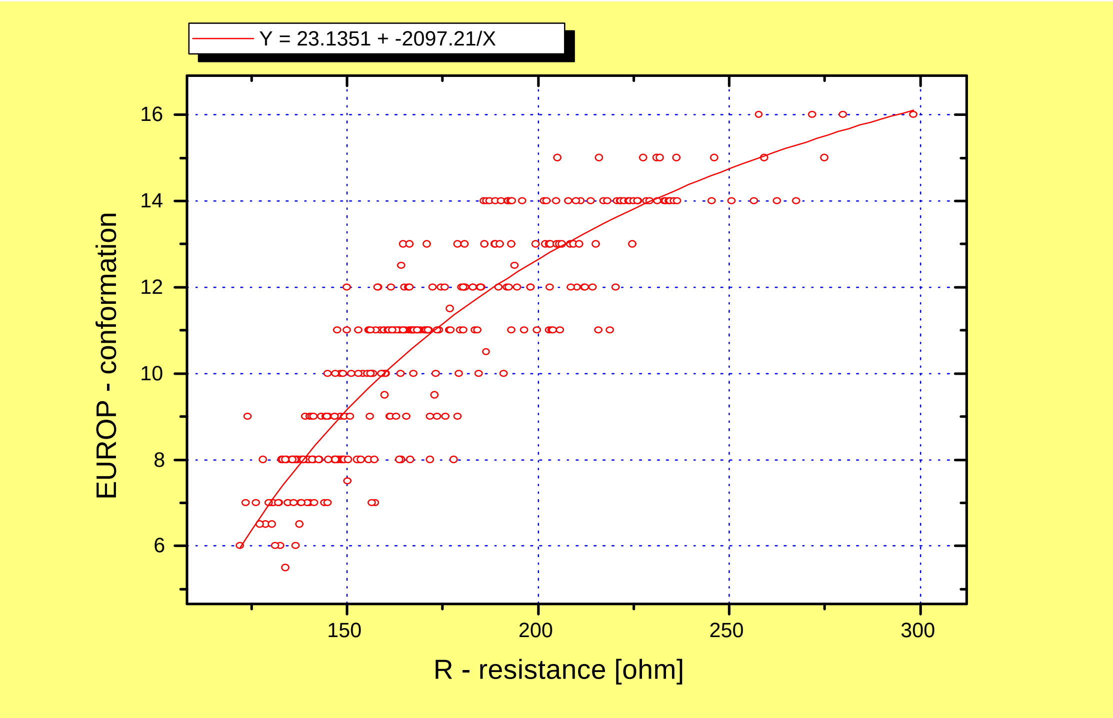

Figure 3. Simple regression on EUROP-conformation of resistance. (r = 0,88; r^2 = 0,79)

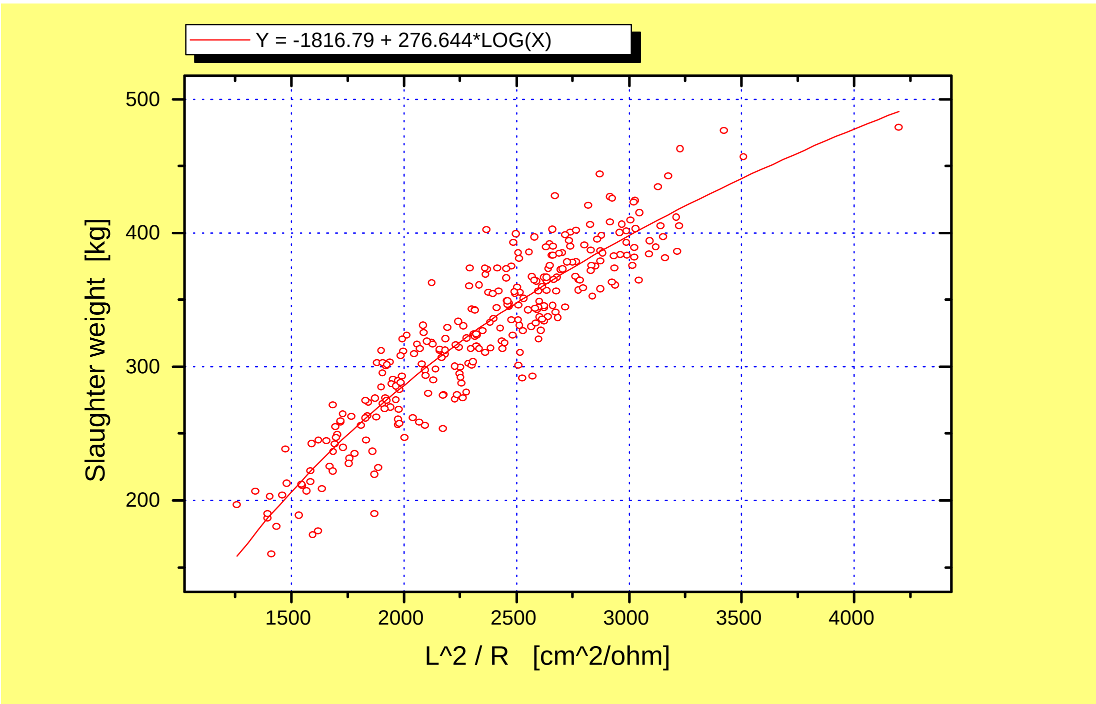

Figure 4. Simple regression on carcass weight Ws of elec. volume L^2/R (r = 0,92; r^2=0,85)