Relationships between total body electrical conductivity (TOBEC) and carcass composition of male broilers

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Summary

Two experiments with male broilers were performed to examine the relationships between total body electrical conductivity (TOBEC) and carcass composition. The TOBEC-measurement principle relies on higher conductivity of body fat free mass compared to body fat mass due to the fact that both compartments differ markedly in their contents of free movable ions. Experiments were designed to induce large differences in body fat contents by increasing dietary protein concentrations (20 % and 30 % in experiment 1, which lasted from day 1 to 25 of age; 20 %, 25 % and 30 % in experiment 2 which lasted from day 1 to 35 of age). As expected, an increase in dietary protein concentration resulted in heavier broilers and reduced feed to gain ratio, in leaner carcasses and lower fatness as indicated by higher dressing and breast meat percentages and lower body proportions of abdominal plus visceral fat and breast skin, respectively. TOBEC-values were positively correlated to live weight (LW, kg) and breast meat yield (BM, % of live weight) whereas negative relationships were detected to abdominal plus visceral fat (AF, % of live weight). The following multiple linear regression equations were estimated:

Experiment 1,
TOBEC-value = -982 + 28.2 *BM + 1630 *LW (r^2 = 0.834, n = 126) TOBEC-value = -572 - 85.5 *AF + 1747 *LW (r^2 = 0.849, n = 126)
Experiment 2,
TOBEC-value = -655 + 13.8 *BM + 581 *LW (r^2 = 0.527, n = 96) TOBEC-value = -52 - 51.6 *AF + 433 *LW (r^2 = 0.621, n = 96)

It was concluded that it should be possible to predict the proportions of breast meat yield or abdominal plus visceral fat of broilers with knowledge of live weight and TOBEC-values. However, the moderate proportion of variance accounted for the chosen model has to be considered.

Keywords: Total body electrical conductivity (TOBEC), broiler, carcass composition

Zusammenfassung

Beziehungen zwischen der Gesamtkörper-Leitfähigkeit (TOBEC) und der Schlachtkörperzusammensetzung von männlichen Broilern

Es wurden 2 Versuche mit männlichen Broilern durchgeführt, um die Beziehungen zwischen der Gesamtkörper-Leitfähigkeit (TOBEC) und der Schlachtkörperzusammensetzung zu untersuchen. Das TOBEC-Messprinzip beruht auf der höheren Leitfähigkeit der fettfreien Körpermasse im Vergleich zur Fettmasse, was zurückzuführen ist auf die deutlichen Unterschiede frei beweglicher Ionen in beiden Kompartments. Die Versuche wurden durch ansteigende Futterproteinkonzentrationen (20 % und 30 % im Versuch 1 vom 1. bis 25. Lebenstag; 20 %, 25 % und 30 % im Versuch 2 vom 1. bis 35. Lebenstag) so angelegt, dass große Unterschiede in der Verfettung induziert wurden. Wie erwartet führte eine ansteigende Futterproteinkonzentration zu schwereren Broilern und zu einem verringerten Futteraufwand, in mageren Schlachtkörpern und geringerer Verfettung was sich in einer höheren Schlachtausbeute, einem höheren Brustfleischanteil bzw. einem reduzierten Anteil von Innenfett und Brusthaut äußerte. Die TOBEC-Werte waren positiv korreliert zur Lebendmasse (LW, kg) und zum Brustfleischanteil (BM, % der Lebendmasse), während negative Beziehungen zum Innenfettanteil (AF, % der Lebendmasse) festgestellt wurden. Folgende multiple lineare Regressionsgleichungen wurden abgeleitet:

Versuch 1
TOBEC-Wert = -982 + 28.2 *BM + 1630 *LW (r^2 = 0.834, n = 126) TOBEC-Wert = -572 - 85.5 *AF + 1747 *LW (r^2 = 0.849, n = 126)
Versuch 2
TOBEC-Wert = -655 + 13.8 *BM + 581 *LW (r^2 = 0.527, n = 96) TOBEC-Wert = -52 - 51.6 *AF + 433 *LW (r^2 = 0.621, n = 96)

Es wurde geschlussfolgert, dass es möglich sein sollte, den Brustfleischanteil bzw. den Innenfettanteil von Broilern bei Kenntnis der Lebendmasse und der TOBEC-Werte vorherzusagen. Allerdings ist hierbei das mäßige Bestimmtheitsmaß des gewählten Modellansatzes zu berücksichtigen.

Schlüsselworte: Total body electrical conductivity (TOBEC), Broiler, Schlachtkörperzusammensetzung

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Introduction

Knowledge of body chemical composition and of carcass composition of broilers is of special interest in studying nutritional effects. Normally, slaughtering of broilers with subsequent carcass analysis or body chemical analysis are necessary to obtain such information which is expensive in terms of labor and money. Therefore, non-invasive and easy for use-procedures for determination of body composition would be helpful; especially if a subsequent observation of body composition over longer periods of time with the same animals is intended.

Non-invasive methods for determination of body composition were reviewed by Lukaski (1987) and include, among others, bioelectrical impedance and total body electrical conductivity (TOBEC). Both methods rely on differences in dielectrical properties of fat free mass and of fat mass. In theory, the higher the body fat content, the lower its TOBEC-value should be. This is because ions which mediate conductivity are mainly located in fat free compartments of the body. High correlations between body fat free mass (FFM) and TOBEC-values were reported by several authors for free-range birds (Walsberg, 1988; Castro et al., 1990; Scott et al., 1990) and for broilers (Staudinger et al., 1995; Dänicke et al., 1997). However, the relationships between chemically determined body fat mass (FM) and FM as calculated from differences between live weight and TOBEC-estimated FFM were either briefly discussed or not reported at all. In addition, Bell et al. (1994) and Dänicke et al. (1997) questioned the method from the fact that correlation between live weight and TOBEC-values were even higher than correlation between FFM and TOBEC-values.

Therefore, the aim of the present study was to manipulate body fatness of broilers by feeding diets differing in protein concentration, to measure their TOBEC and try to relate this measure to parameters of carcass composition. A body chemical analysis of carcasses was not performed because of the known close correlations between parameters of carcass composition and body chemical composition (e.g. Dänicke et al., 1993; Peter et al., 1998) which requires a high analytical expenditure.

Material and methods

TOBEC instrument

The TOBEC-analyzer (EM-Scan Inc., Springfield, IL, USA) consists of a base unit (Model SA-3000) which is attached to a detection chamber. The size of this detection chamber has to be matched to the approximate size of the bird. Model SA-3114 (Length, 31.8 cm; inner diameter, 11.4 cm) and model SA-3203 (Length, 61.0 cm; inner diameter, 19.7 cm) were used in the in vitro-experiment, in experiment 1 and in experiment 2, respectively. TOBEC-values obtained from these two different chambers can not be compared because of differences in physical properties of both chambers. The measurement chamber is surrounded by a coil which is driven by an oscillating current. A material with conductive properties which is placed into the chamber will cause changes in the magnetic field generated by the coil. This field change is recorded and finally expressed as TOBEC-value. The base unit and measurement chamber are computer-controlled.

In vitro measurements

In vitro measurements were performed using the measurement chamber model SA-3114 to confirm the theoretical background and general reliability of the method. In doing so, a plastic bottle (length, 21.5 cm, diameter, 9.5 cm, volume, 1240 ml) was used as phantom for all measurements just to make sure that only the contents of the bottle are related to TOBEC-values since it is known that

Table 1: Composition of experimental diets (%)
Tab. 1: Zusammensetzung der Versuchsfuttermischungen (%)

Diet:	P-20	P-25	P-30
Ingredients:			
Maize	48.31	36.95	25.5
Wheat	20.0	20.0	20.0
Fish meal	4.0	4.0	4.0
Soybean meal	15	21.67	28
Isolated soy protein	5.5	9	13
Soy oil	2.8	4	5.2
DL-methionine	0.13	0.2	0.25
L-lysine-HCl	0.1	0.05	-
Di-calcium-phosphate	2.3	2.25	2.1
Limestone	0.56	0.58	0.65
Sodium chloride	0.3	0.3	0.3
Premix[1]	1.0	1.0	1.0
Calculated composition:			
Crude protein	20.0	25.0	30.0
Crude fat	5.5	6.3	7.1
AME_N (MJ/kg)	12.8	12.8	12.8
Lysine	1.12	1.4	1.69
Methionine	0.48	0.6	0.7
Calcium	1.0	1.0	1.0
Total phosphorus	0.8	0.8	0.8
Sodium	0.15	0.15	0.15

[1]Vitamin-mineral premix provided per kg of diet: Fe, 60 mg; Cu, 5 mg; Zn, 51.4; Mn, 60.8; Se, 0.2; I, 0.6; retinol (retinyl acetate), 4000 µg; cholecalciferol, 75 µg; vitamin E (DL-α-tocopheryl acetate), 42 mg; thiamin, 2.1 mg; riboflavin, 6.6 mg; pyridoxine, 4.1 mg; cyanocobalamin, 20.7 µg; pantothenic acid, 15 mg; nicotinic acid, 36 mg; folic acid, 1 mg; biotin, 102 µg; choline chloride, 700 mg; ethoxyquin, 120 mg; Zn-bacitracin, 50 mg

Table 2: Comparison of TOBEC-measurements of media differing in conductive properties (n=8)
Tab. 2: Vergleich der TOBEC-Werte von Medien, die sich in ihren konduktiven Eigenschaften unterscheiden (n=8)

	Mean value	Standard deviation	Coefficient of variation (%)
Empty phantom (air)	10[a]	4	40.2
Phantom + plant oil	61[b]	2	4.1
Phantom + distilled water	237[c]	11	4.8
Phantom + physiological saline	5386[d]	23	0.4

a-d values with no common superscript within rows differ significantly ($p<0.05$)

size and geometry of the sample to be measured is of great importance for precision of measurement (De Bruin et al., 1994). First, the empty phantom was measured. Next, distilled water and increasing concentrations of sodium chloride in distilled water were measured; and finally plant oil was filled into the bottle and TOBEC was determined.

Table 3: Performance (108 broilers per treatment), TOBEC-measurements and slaughter yields of broilers (63 broilers per treatment) fed different dietary protein concentrations (Experiment 1, day 25 of age)
Tab. 3: Leistung (108 Broiler je Behandlung), TOBEC-Werte und Schlachtleistung von Broilern (63 Broiler je Behandlung), denen verschiedene Futterproteinkonzentrationen gefüttert wurden (Versuch 1, 25. Lebenstag)

Dietary protein (%)	Live weight (kg)	Feed to gain ratio (kg/kg)	TOBEC-value	Slaughter yields (% of live weight)						
				Dressing	Breast	Leg	Abdominal + visceral fat	Breast skin	Liver	Intestine
20	0.855	1.482	759	63.9	12.9	20.8	1.8	1.5	2.6	7.6
30	0.910	1.343	946	65.2	15.1	20.9	1.0	1.3	2.6	7.5
ANOVA (p-values)	<0.001	<0.001	<0.001	<0.001	<0.001	0.853	<0.001	0.018	0.756	0.247
PSEM	0.011	0.020	21	0.2	0.2	0.2	0.1	0.1	0.1	0.1

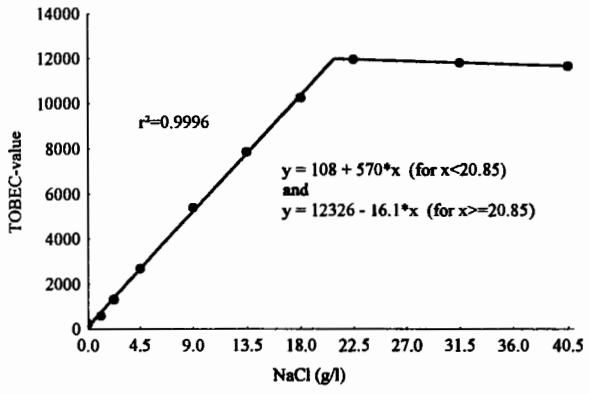


Fig.1: Response of the TOBEC-instrument to increasing concentrations of sodium chloride in distilled water (Data were obtained from the in vitro experiment)
Abb.1: Response des TOBEC-Instruments auf ansteigende Konzentrationen von Natriumchlorid in destilliertem Wasser (Werte aus dem in vitro-Versuch)

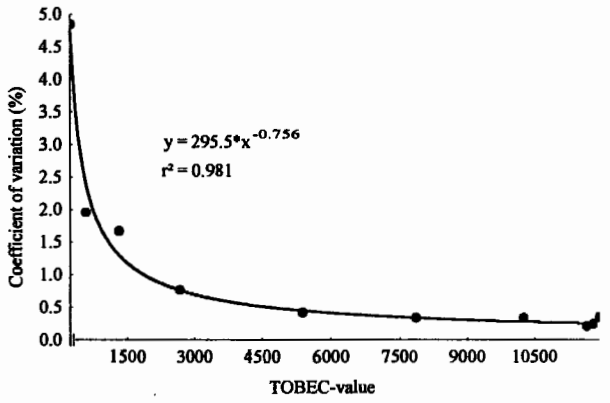


Fig. 2: Dependence of coefficient of variation of TOBEC-measurements on TOBEC-values (Data were obtained from the in vitro experiment)
Abb.2: Abhängigkeit des Variationskoeffizienten der TOBEC-Messungen vom TOBEC-Wert (Werte aus dem in vitro-Versuch)

Experiment 1

Male day-old broilers of the LOHMANN-MEAT-strain were placed into cages of a three-floor cage battery and randomly assigned to two dietary protein concentrations. Lighting and temperature program were in accordance with the recommendations of the breeder.

Diets contained either 20 % or 30 % of crude protein (Table 1) and were offered to the birds for ad libitum consumption until the end of the experiment (day 25 of age). Each diet was tested on a total of 108 broilers assigned to 9 cages with 12 birds in each. Feed consumption and body weights were recorded at the end just before the broilers were subjected to TOBEC-measurements with subsequent determination of carcass composition. First, broilers (7 birds of each cage = 63 birds per treatment) representing the mean live weight of their experimental group were placed into the measurement chamber (Model SA-3114) with the aid of plastic cylinder adapted to the body size in order to restrict movements of broilers during measurements and to make sure that the birds could be placed in the same position within the chamber. A number of individual measurements were repeated several times in order to minimize coefficient of variation. After finishing of the TOBEC-measurements, broilers were killed by cutting the jugular vein after electrical stunning. Bleeding was followed by scalding in a water bath at 57°C for 2 minutes. Carcasses were then subjected to the de-feathering process (approximately 0.5 minutes) using a rotary drum picker. Carcasses were cooled for 20 hours at 4°C before dissec-

Table 4. Correlation matrix for examined parameters (Experiment 1)
Tab.4: Korrelationsmatrix für die untersuchten Parameter (Versuch 1)

		Live weight (kg)	TOBEC-value	Slaughter yields (% of live weight)						
				Dressing	Breast	Leg	Abdominal + visceral fat	Breast skin	Liver	Intestine
	Live weight (kg)	1.00	0.88*	0.16	0.37*	-0.13	-0.14	-0.09	-0.04	-0.34*
	TOBEC- value		1.00	0.34*	0.54*	-0.05	-0.38*	-0.16	-0.06	-0.35*
Slaughter yields (% of live weight)	Dressing			1.00	0.60*	0.24*	-0.28*	0.12	0.01	-0.44*
	Breast				1.00	-0.00	-0.51*	-0.06	-0.00	-0.29*
	Leg					1.00	-0.08	0.33*	0.11	0.15
	Abdominal + visceral fat						1.00	0.24*	0.00	0.08
	Breast skin							1.00	-0.02	0.08
	Liver								1.00	0.12
	Intestine									1.00

* correlation coefficients are significant ($p<0.05$)

Table 5. Performance (400 broilers per treatment), TOBEC-measurements and slaughter yields of broilers(32 broilers per treatment) fed different dietary protein concentrations (Experiment 2, day 35 of age)
Tab. 5: Leistung (400 Broiler je Behandlung), TOBEC-Werte und Schlachtleistung von Broilern (32 Broiler je Behandlung) denen verschiedene Futterproteinkonzentrationen gefüttert wurden (Versuch 2, 35. Lebenstag)

Dietary protein (%)	Live weight (kg)	Feed to gain ratio (kg/kg)	TOBEC-value	Slaughter yields (%of live weight)						
				Dressing	Breast	Leg	Abdominal+ visceral fat	Breast skin	Liver	Intestine
20	1.862[a]	1.718b	636[a]	70.0	14.9[a]	20.3	2.4[c]	1.7	2.1	6.4
25	2.055[b]	1.573[a]	774[b]	70.8	15.9[b]	20.4	1.6b	1.7	2.0	6.1
30	2.050[b]	1.583[a]	773[b]	70.9	16.0[b]	20.9	1.2a	1.5	2.1	6.2
ANOVA (p-values)	<0.001	<0.001	<0.001	0.104	0.012	0.174	<0.001	0.074	0.149	0.129
Orthogonal effects (p-values)										
Linear	<0.001	<0.001	<0.001	0.045	0.007	0.079	<0.001	0.079	0.639	0.196
Qudratic	<0.001	<0.001	<0.001	0.455	0.2	0.549	0.247	0.151	0.057	0.113
PSEM	0.014	0.018	12.2	0.3	0.3	0.2	0.1	0.1	0.1	0.1

a-c values with no common superscript within rows differ significantly ($p<0.05$)

tion. Head and feet were removed, weights of breast skin, total breast meat (without skin) and the complete right leg were individually recorded. In addition, livers, the empty small intestine and the sum of abdominal and visceral fat were determined. The latter parts were excluded in calculation of dressing percentage. All parts were expressed as percentage of live weight.

Experiment 2

A total of 1200 day-old male broilers (LOHMANN-MEAT-strain) were randomly assigned to three dietary protein concentrations (20 %, 25 % and 30 %, Table 1). Each diet was tested on 400 broilers kept in 50 cages (2-step-cage battery) with 8 broilers per cage.

Experimental conditions and procedures were carried out as described for experiment 1 with the following exceptions: broilers were kept until day 35 of age and the larger measurement chamber (Model SA-3203) was used for TOBEC-measurements. Thirty two broilers of each treatment having the average live weight of their respective group were used for procedures (TOBEC-measurements, carcass analysis). Total number of birds processed per treatment was different from experiment 1 for labour-organizational reasons (especially time required for TOBEC-measurements).

Table 6: Correlation matrix for examined parameters (Experiment 2)
Tab. 6: Korrelationsmatrix für die untersuchten Parameter (Versuch 2)

		Live weight (kg)	TOBEC-value	Slaughter yields (% of live weight)						
				Dressing	Breast	Leg	Abdominal+ visceral fat	Breast skin	Liver	Intestine
	Live weight (kg)	1.00	0.69*	0.09	0.28*	0.07	-0.51*	-0.09	-0.15	-0.30*
	TOBEC- value		1.00	0.32*	0.41*	0.15	-0.68*	-0.19	-0.06	-0.17
Slaughter yields (% of live weight)	Dressing			1.00	0.43*	0.35*	-0.28*	-0.04	-0.06	-0.23*
	Breast				1.00	0.17	-0.35*	-0.08	0.00	0.02
	Leg					1.00	-0.18	-0.08	-0.16	-0.01
	Abdominal + visceral fat						1.00	0.38*	-0.05	0.13
	Breast skin							1.00	-0.03	-0.12
	Liver								1.00	-0.04
	Intestine									1.00

* correlation coefficients are significant ($p<0.05$)

Table 7: Summary of regression analysis
Tab. 7: Zusammenfassung der Regressionsanalysen

y (TOBEC-value) =	b_0	+	b_1	$*x_1$	+	b_2	$*x_2$	r^2	n	Experiment
	-756	+	1822	*LW				0.774	126	1
	3.3	+	60.6	*BM				0.292	126	1
	1020	-	123	*AF				0.144	126	1
	-559	+	640	*LW				0.476	96	2
	349	+	24.3	*BM				0.168	96	2
	866	-	79.5	*AF				0.462	96	2
	-982	+	28.2	*BM	+	1630	*LW	0.834	126	1
	-572	-	85.5	*AF	+	1747	*LW	0.849	126	1
	-655	+	13.8	*BM	+	581	*LW	0.527	96	2
	-52	-	51.6	*AF	+	433	*LW	0.621	96	2

Abbreviations: LW = live weight (kg); BM = breast meat (% of live weight); AF = abdominal plus visceral fat (% of live weight)

Statistics

TOBEC-values, performance and carcass data were subjected to analysis of variance (ANOVA) according to a one-way-factorial design (protein concentration as independent variable). Significant differences between mean values were detected by using the Tukey-test for unequal number of replications.

In addition, simple correlation coefficients and linear regressions between several parameters were estimated.

All statistics were carried out using the Statistica for the Windows™ operating system (StatSoft, Inc., 1994).

Results

In vitro measurements

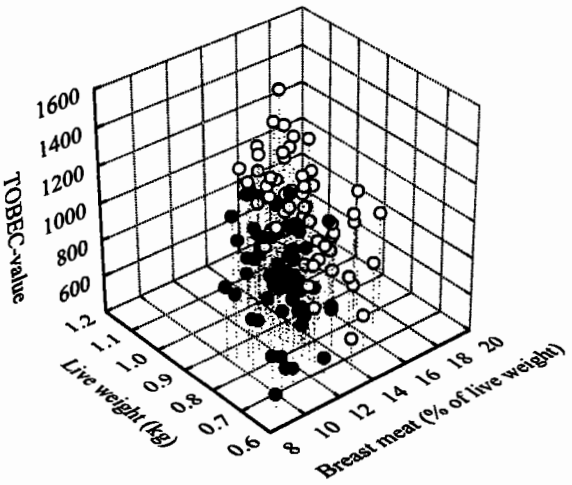
TOBEC-values of 4 media differing greatly in conductivity are shown in Table 2. TOBEC-measurements of empty phantom (air), fat (plant oil), distilled water and physiological saline under constant conditions reflect clearly the differences in conductive properties of these media. Moreover, it can be concluded from the coefficients of variations that measurements of the same sample decreases as the TOBEC-signal increases.

Increasing the concentration of free movable ions in distilled water induced a linear response of the instrument up to a concentration of 20.85 g sodium chloride per l (Figure 1). No further increase was detectable at higher concentrations. Again, the higher the TOBEC-signal the lower the coefficient of variation of measurements (Figure 2).

Experiment 1

The experiment took a normal course and mortality amounted to 2.6 % and was not influenced by dietary treatments. Summarized results of performance data, TOBEC-values and carcass composition are shown in Table 3. Analysis of variance revealed that feeding of a diet containing 30 % crude protein instead of 20 % crude protein increased live weight, TOBEC-values, dressing percentage and breast meat yield significantly whereas feed to gain ratio, abdominal plus visceral fat and breast skin were significantly reduced at the same time. Leg yield, liver- and intestinal proportions were not affected by dietary treatments.

Correlation coefficients between selected parameters are given in Table 4. TOBEC-values were significantly correlated positively to live weight, dressing percentage and breast meat yield whereas significantly negative coefficients were found between TOBEC-values and abdominal plus visceral fat. Simple linear regression equations between abdominal plus visceral fat and TOBEC-values, breast meat yield and TOBEC-values and live weight and TOBEC-values are summarized in Table 7. Combining of the live weight term with the equations relating to breast meat yield or abdominal plus visceral fat to TOBEC-val-



TOBEC-value = -982 + 28.2*breast meat + 1630*live weight
$r^2 = 0.834$

Fig. 3: Relationship between breast meat, live weight and TOBEC-values obtained from 25-day-old male broilers (Experiment 1)
(● = 20 % crude protein; ○ = 30 % crude protein)
Abb.3: Beziehungen zwischen Brustfleisch, Lebendmasse und TOBEC-Werten bei 25 Tage alten Broilern (Versuch 1) (● = 20 % Rohprotein; ○ = 30 % Rohprotein)

ues improved the variance accounted for in such a multiple linear approach considerably (Table 7). The respective scatter-plots for the multiple regressions are shown in Figures 3 and 5. Moreover, data were categorized according to four different live weight classes in order to compare broilers from the two experimental groups but with similar live weights directly with respect to the relationships between breast meat yield and TOBEC-values (Figure 4) and between abdominal plus visceral fat and TOBEC-values (Figure 6), respectively.

Experiment 2

Mortality was 4.3 % over the whole experiment and was not affected by increasing dietary protein concentrations. Experimental course was normal. Live weight and TOBEC-values increased as dietary protein concentration was increased from 20 % to 25 % whereas 30 % failed to induce a further increase (significant linear and quadratic effects of protein concentration, Table 5). The opposite was observed for feed to gain ratio. Breast meat yield and dressing percentage increased linearly with dietary protein concentration whereas abdominal plus visceral fat decreased in a linear fashion. Leg meat yield and relative weights of breast skin, liver and intestine did not respond to different protein concentrations significantly.

TOBEC-values were significantly correlated positively to live weight, dressing percentage and breast meat yield whereas a negative correlation was found to abdominal plus visceral fat (Table 6). Simple linear regression equations as well as multiple linear regression equations between abdominal plus visceral fat, breast meat yield or live weight (as independent variables) and TOBEC-values (dependent variable) are shown in Table 7. Scatter-plots for the multiple approaches are displayed in Figures 7 and 8.

Discussion

The in vitro-test demonstrated a linear response of the instrument in the measurement range from approximately 200 to 12000 TOBEC-units which corresponded to a sodium chloride concentration of up to 20.85 g/l. It becomes clear that the instrument did not respond to further increases in ion concentration at approximately 12000 TOBEC-units. Saturation of the solution was not visible and was not expected since saturation concentration of sodium chloride in cold water is 357 g/l. Therefore, the observed constraint must be due to the instrument itself and measurements have to be performed in the linear range of the calibration curve (Figure 1). Minimum and maximum in vivo-measurements in broiler experiment 1 were 468 and 1375 TOBEC-units, respectively. Thus, all measurements were carried out in the linear range of the instrument response.

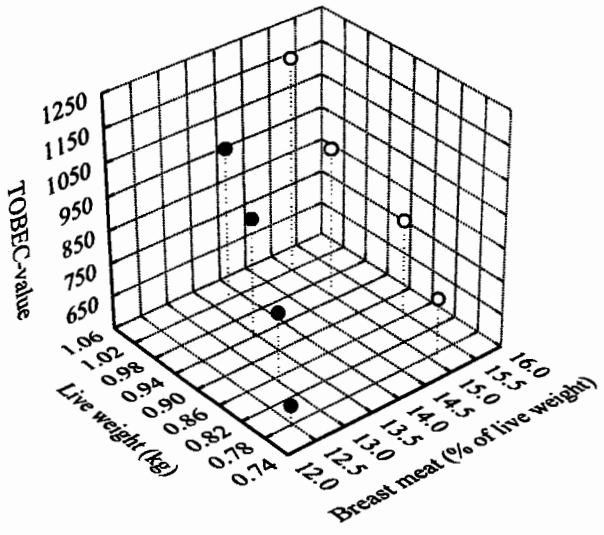
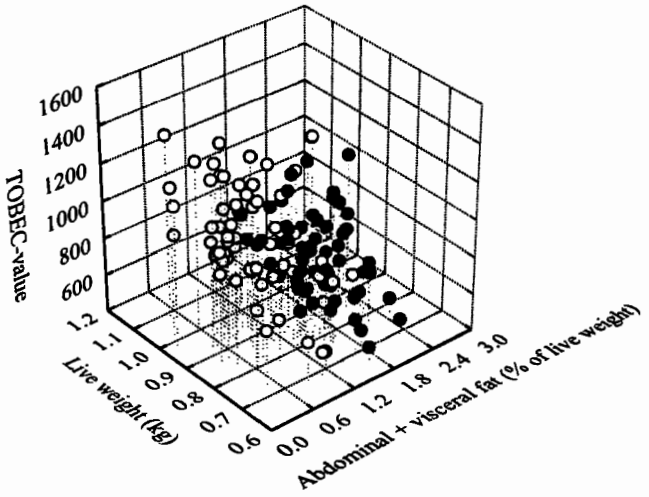


Fig. 4: Relationship between breast meat, live weight and TOBEC-values obtained from 25-day-old male broilers categorized by live weight (Experiment 1)
(● = 20 % crude protein; ○ = 30 % crude protein)
Abb. 4: Beziehungen zwischen Brustfleisch, Lebendmasse und TOBEC-Werten bei 25 Tage alten Broilern, kategorisiert nach Lebendmasse (Versuch 1)(● = 20 % Rohprotein; ○ = 30 % Rohprotein)

The in vitro linearity of TOBEC-response to increasing concentrations of a number of different chlorides was also demonstrated by De Bruin et al. (1994). These authors found the slope of the linear regression lines to be quite different between several chlorides which indicates that changes in ion composition and/or concentration of a living organism would contribute to TOBEC or to its variability. Variability of TOBEC-measurements is the most



TOBEC-value = -572 - 85.5*abdominal plus visceral fat + 1747*live weight
$r^2 = 0.849$

Fig. 5: Relationship between abdominal plus visceral fat, live weight and TOBEC-values obtained from 25-day-old male broilers (Experiment 1)
(● = 20 % crude protein; ○ = 30 % crude protein)
Abb 5: Beziehungen zwischen Abdominalfett, Lebendmasse und TOBEC-Werten bei 25 Tage alten Broilern (Versuch 1)
(● = 20 % Rohprotein; ○ = 30 % Rohprotein)

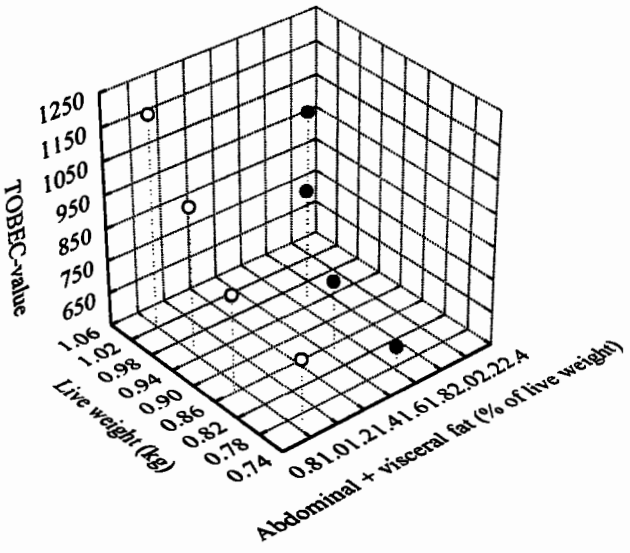
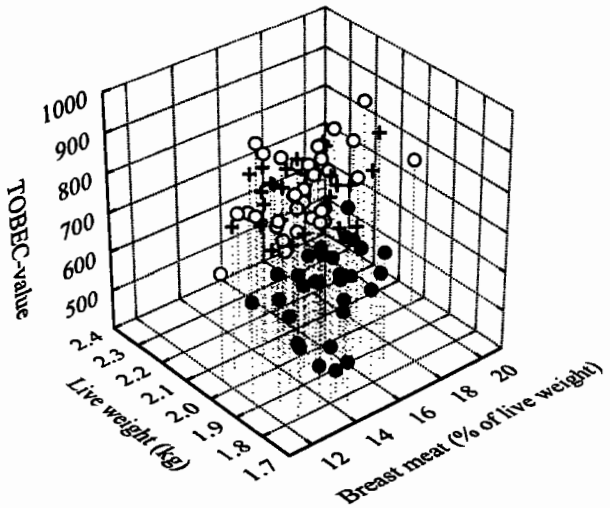


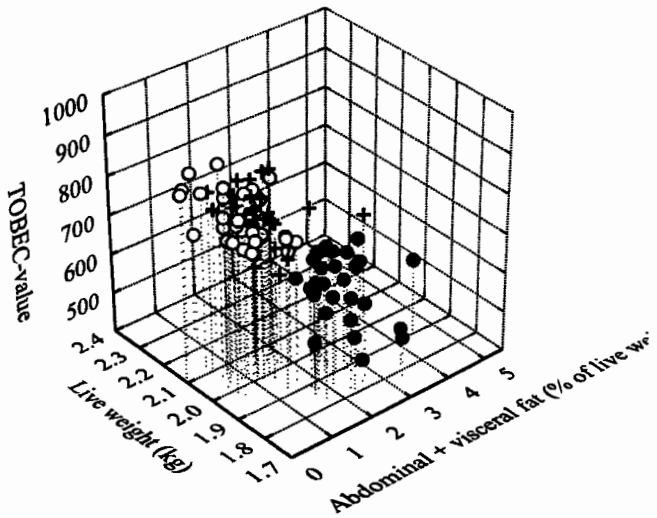
Fig. 6: Relationship between abdominal plus visceral fat, live weight and TOBEC-values obtained from 25-day-old male broilers categorized by live weight (Experiment 1)
(● = 20 % crude protein; ○ = 30 % crude protein)
Abb 6: Beziehungen zwischen Abdominalfett, Lebendmasse und TOBEC-Werten bei 25 Tage alten Broilern, kategorisiert nach Lebendmasse (Versuch 1)
(● = 20 % Rohprotein; ○ = 30 % Rohprotein)

important problem of the method. Coefficient of variation (relative standard deviation) increases as TOBEC-values decrease (Figure 2, Table 2). It can be clearly seen from the course of the regression in Figure 2 that repeated TOBEC-measurements of a homogenous immobile phantom of a similar size start to become much more variable



TOBEC-value = -655 + 13.8*breast meat + 581*live weight
$r^2 = 0.527$

Fig. 7: Relationship between breast meat, live weight and TOBEC-value obtained from 35-day-old male broilers (Experiment 2)
(● = 20 % crude protein; ; + = 25 % crude protein; ○ = 30 % crude protein)
Abb. 7: Beziehungen zwischen Brustfleisch, Lebendmasse und TOBEC-Werten bei 35 Tage alten Broilern (Versuch 2) (● = 20 % Rohprotein; + = = 25 % Rohprotein; ○ = 30 % Rohprotein)



TOBEC-value = -52 - 51.6*abdominal plus visceral fat + 433*live weight
$r^2 = 0.621$

Fig. 8: Relationship between abdominal plus visceral fat, live weight and TOBEC-values obtained from 35-day-old male broilers (Experiment 2)
(● = 20 % crude protein; ; + = 25 % crude protein; ○ = 30 % crude protein)
Abb. 8: Beziehungen zwischen Abdominalfett, Lebendmasse und TOBEC-Werten bei 35 Tage alten Broilern (Versuch 2) (● 20 % Rohprotein; + = 25 % Rohprotein; ○ = 30 % Rohprotein)

if the mean TOBEC-value decreases below approximately 750 (coefficient of variation > 2 %). This variation represents only the variance of the instrument to which a number of other variance components has to be added which include size or body mass of broilers or unavoidable movements of the bird during scanning. The importance of these variance components has been demonstrated in vitro (De Bruin et al., 1994) and in vivo (Domermuth, 1976; Keim et al., 1988; Morbach and Brans, 1992; Staudinger et al., 1995) and might bias the detection of the interesting variance component which is the fatness of the broiler. For example, coefficient of variation of 3 to 6 TOBEC-measurements were found between 0.1 % and 21 % and was not related to the respective mean TOBEC-values. It has been discussed by Bell et al. (1994) and Dänicke et al. (1997) that higher correlation between live weight and TOBEC-values than between fat free mass and TOBEC-values is a major problem of the method. Also, in the present study, correlation coefficients between TOBEC-values and live weight were the highest of all estimated coefficients in both experiments. Dressing percentage or breast meat which have a low and relatively constant fat concentration might be used as indicators for fat free mass. Correlations between these parameters and TOBEC-values were significantly positive in both broiler experiments. On the other hand, correlation coefficients between TOBEC-values and dressing percentage or breast meat yield were higher than those between live weight and dressing percentage or breast meat yield. This means that TOBEC measurement indeed resulted in an additional information about carcass composition. Simple linear regressions of breast meat yield on TOBEC-values resulted only in weak determination measures (Table 7) whereas inclusion of the live weight term into regressions improved the variance accounted for the model approach considerably (Table 7, Figures 3 and 7). Also, incorporation of abdominal plus visceral fat and live weight into one multiple regression equation improved the explained variance of TOBEC-values markedly (Table 7, Figures 5 and 8). It is of special interest to differentiate between broilers of similar live weights according to their breast meat yield or fatness. For this purpose, broilers of experiment 1 were categorized according to 4 live weight classes and the mean values of live weight and breast meat yield (Figure 4) or abdominal plus visceral fat (Figure 6) were plotted against TOBEC-values. It can be clearly seen that mean values of breast meat yield were distinctly different between experimental groups when similar live weight classes were considered. Moreover, broilers fed the diet containing 30 % crude protein and having comparable live weights as broilers fed the low-protein diet had not only a 1.5 to 2.5 % higher breast meat yield (equals a 7 to 20 % increase) but induced also higher TOBEC values. The opposite is obvious for the abdominal plus visceral fat (Figure 6). Broilers of both experimental groups falling in similar live weight classes were quite different with respect to fatness and TOBEC-values. Broilers fed the 30 %-crude protein diet deposited approximately 45 to 55 % less abdominal plus visceral fat than their counterparts fed the 20 %-crude protein diet. These changes were paralleled by an increase in TOBEC-values. High correlations between inner fat of broilers and total fatness, i.e. total fat accretion, was clearly demonstrated by Dänicke et al. (1993) and Peter et al. (1998). Taking the equation for estimation of total fat concentration by using the proportions of abdominal plus visceral fat and breast skin as given by Dänicke et al. (1993) a total body fat content of 13 and 10 % would result for groups fed 20 or 30 % crude protein, respectively. Although these total fat contents can only be an estimation it makes clear that the TOBEC-method indeed enables to detect large differences in fatness of broilers.

It should be mentioned however, that such clear relationships were not detectable in experiment 2 for several reasons. Firstly, a complete categorization of broilers fed different diets according to live weight was only possible for groups fed diets with 25 or 30 % crude protein since none of these broilers appeared in the live weight range of broilers fed the diet with 20 % crude protein. Secondly, no differences in TOBEC-values were observed between broilers fed the 25 or 30 %-crude protein diets although the former had a significantly higher degree of fatness than the latter (Table 5). Since no differences in breast meat yield for these broilers were observed, the results could suggest that TOBEC is more related to breast meat yield than to fatness. Moreover, it has to be considered that differences in fatness between broilers of both groups were not as large as between both groups tested in experiment 1.

It might be concluded therefore, that only large differences in breast meat yield or fatness might be detectable by the TOBEC-method, considering the moderate determination values given for the multiple prediction equations in Table 7.

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