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Relationships between parameters of meat performance in Czech Pied bulls and their crossbreds with beef breeds

Vztahy mezi ukazateli masné užitkovosti u býků českého strakatého skotu a jeho kříženců s masnými plemeny

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ABSTRACT: Meat performance parameters were studied in 119 bulls – F_1 crossbreds of Czech Pied and Black Pied cattle with beef sires – Aberdeen Angus (AA), Limousine (LI), Blonde d'Aquitaine (BA), and Charolais (CH). Czech Pied bulls (n = 51) were used as a control group. Bulls were reared and fattened under comparable conditions at a fattening performance testing station. High correlations (***) were found between 500-day live weight and dressed carcass weight (DCW), net gain (NG), total meat weight, grade I meat weight, grade II meat weight, and bone weight in all groups. As for dressing percentage, positive correlations were found only in LI group (r_{xy} = 0.336*) and C group (r_{xy} = 0.292*). The effect of slaughter weight on MLLT (*musculus longissimus lumborum et thoracis*) was evident only in AA group and in CH group (r_{xy} = 0.482*, r_{xy} = 0.490*, resp.). Correlations between 500-day live weight and kidney fat and 500-day live weight and separable fat were highly positive (***) excluding AA group (r_{xy} = 0.447*, r_{xy} = 0.675**, resp.). As for the growth rate in the pre-fattening period (150–500 days of age), high correlations (from * to ***) characterized all observed parameters excluding dressing percentage (r_{xy} = 0.239 up to r_{xy} = 0.253). In MLLT, a positive correlation was determined only in CH group (r_{xy} = 0.353*). High correlations (***) were found between net gain, dressed carcass weight and observed parameters of carcass value (excluding MLLT) in all groups. Correlations between net gain and MLLT were found in crossbreds sired by AA (r_{xy} = 0.648**), CH (r_{xy} = 0.559***) and C bulls (r_{xy} = 0.315*). Effects of DCW on MLLT were evident in the same groups (r_{xy} = 0.566*, r_{xy} = 0.549***, r_{xy} = 0.307*, resp.). As for protein content, significant positive effects on kidney fat were established only in LI, BA, and C groups (r_{xy} = 0.569***, r_{xy} = 0.687***, r_{xy} = 0.394**, resp.) and the same effects on separable fat were found in LI and C groups (r_{xy} = 0.421**, r_{xy} = 0.365**, resp.). In BA group, protein content affected 150-day live weight (r_{xy} = 0.510*), 500-day live weight (r_{xy} = 0.567*), and total meat weight (r_{xy} = 0.499*). As for fat content, it had positive effects on 500-day live weight (r_{xy} = 0.335*) in LI group, daily gains in the pre-fattening period (r_{xy} = 0.523*) in AA group, kidney fat in LI and C groups (r_{xy} = 0.531*** and r_{xy} = 0.319*, resp.) and separable fat in AA, LI, and C groups (r_{xy} = 0.566*, r_{xy} = 0.364* and r_{xy} = 0.387*, resp.).

Keywords: beef breeds; commercial crossing; fattening; carcass value; correlation

ABSTRAKT: Pro vyhodnocení sledovaných ukazatelů bylo do pokusu zařazeno 119 býků kříženců F_1 generace českého strakatého a černostrakatého skotu s býky masných plemen aberdeen angus (AA), limousin (LI), blonde

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d'aquitaine (BA) a charolais (CH). Kontrolní skupinu tvořilo 51 býků českého strakatého skotu (C). Býci byli odchováni a vykrmeni za srovnatelných podmínek na stanici kontroly výkrmnosti skotu. V rámci všech skupin byla prokázána vysoká těsnost vztahů (***) mezi živou hmotností býků v 500 dnech věku a hmotností jatečně opracovaného těla (HJOT), netto přírůstkem (NP), hmotností masa celkem, hmotností masa I. a II. jakosti a hmotností kostí. K jatečné výtěžnosti byl pozitivní vztah pouze u skupin LI (r_{xy} = 0,336*) a C (r_{xy} = 0,292*). Velikost svalu *musculus longissimus lumborum et thoracis* (MLLT) byla porážkovou hmotností ovlivněna pouze u skupiny AA a CH (r_{xy} = 0,482*, resp. r_{xy} = 0,490*). Vliv živé hmotnosti v 500 dnech věku na hmotnost ledvinového loje a hmotnost oddělitelného tuku byl u všech skupin pozitivní (***), pouze u skupiny AA s nižší těsností (r_{xy} = 0,447*, resp. r_{xy} = 0,675**). Při posouzení vztahu mezi intenzitou růstu za období od 150 do 500 dnů věku a sledovanými ukazateli byla potvrzena v rámci všech skupin vysoká míra vlivu (od * do ***) na všechny sledované ukazatele, kromě jatečné výtěžnosti (r_{xy} = –0,239 až r_{xy} = 0,253). K velikosti MLLT byla prokázána kladná korelace pouze u skupiny CH (r_{xy} = 0,353*). Vztahy mezi netto přírůstkem, hmotností JOT a sledovanými ukazateli jatečné hodnoty (mimo velikosti MLLT) vykázaly u všech skupin vysokou těsnost (***). Závislost mezi výší netto přírůstku a velikostí MLLT byla prokázána pouze u skupin býků kříženců po otcích AA (r_{xy} = 0,648**), CH (r_{xy} = 0,559***) a u skupiny C (r_{xy} = 0,315*). Vliv hmotnosti JOT na MLLT byl prokázán u stejných skupin (r_{xy} = 0,566*, resp. r_{xy} = 0,549***, resp. r_{xy} = 0,307*). Při zjišťování vlivu na obsah dusíkatých látek v mase byl prokázán významný pozitivní vliv pouze v rámci skupin LI, BA a C ve vztahu ke hmotnosti ledvinového loje (r_{xy} = 0,569***, resp. r_{xy} = 0,687***, resp. r_{xy} = 0,394**) a ke hmotnosti oddělitelného tuku u skupin LI a C (r_{xy} = 0,421**, resp. r_{xy} = 0,365**). U skupiny BA ovlivnila obsah dusíkatých látek hmotnost ve 150 dnech věku (r_{xy} = 0,510*), hmotnost v 500 dnech věku (r_{xy} = 0,567*) a hmotnost masa celkem (r_{xy} = 0,499*). Obsah tuku v mase vykázal pozitivní závislost s živou hmotností v 500 dnech věku u skupiny LI (r_{xy} = 0,335*), denními přírůstky od 150 do 500 dnů věku u skupiny AA (r_{xy} = 0,523*), s hmotností ledvinového loje u skupin LI a C (r_{xy} = 0,531***, resp. r_{xy} = 0,319*) a s hmotností oddělitelného tuku u skupin AA, LI a C (r_{xy} = 0,566*, resp. r_{xy} = 0,364*, resp. r_{xy} = 0,387*).

Klíčová slova: masná plemena skotu; užitkové křížení; výkrmnost; jatečná hodnota; korelace

Production of good-quality beef is associated with adequate information specifying relationships between meat performance parameters; many authors mention different values (found in their experiments) characterizing specific correlations. Correlations between meat performance parameters enable to estimate carcass value and presume meat quality with adequate precision.

The animal conformation is associated with productive parameters, so it is necessary to take into account this trait (Urban, 1987). Bulls with large body frame and small chest girth over-passing 500 kg live weight were characterized by low growth rate (Papstein *et al.*, 1993) caused by more intensive growth of adipose tissue. Results of Putz (1993) indicate discrepancy between the extremely large body frame and requirements of the intensively growing carcass. Negative relationships were found between body frame and conformation (meat proportion, commercial grade) in Bavarian Pied cattle. An Anonymous author (1995) reported close relationships between breeding values characterizing sire's meat performance and muscling of sire's female progeny. According to Achler (1994) a positive correlation characterizes the relationship body frame of the animal × weight (body size) of its progeny.

According to Frelich *et al.* (1999) high correlations (r = 0.493** up to 0.802**) between body size and dressed carcass weight of beef bulls (AA, LI, CH, MS) demonstrate relationships between pre-slaughter size of animals, their muscling, and meat coat of bones. The increasing body size was not associated with increased fat proportion in the half-carcass (r_{xy} = –0.302 up to r_{xy} = 0.151); correlations between carcass parameters (dimensions) and fat proportion in the half-carcass were low as well (r_{xy} = –0.368 up to r_{xy} = 208).

Regarding beef quality it is necessary to determine the optimum slaughter weight of fattened cattle; this trait affects positively dressing percentage.

Classification of carcass meatiness also requires slaughter weight differentiation in relation to the sire's characteristics (Šubrt *et al.*, 2000). Schwark *et al.* (1989) reported correlation coefficient r = 0.4 characterizing slaughter weight × dressing percentage in young bulls. Romita and Borghere (1974) found high correlations for pre-slaughter liveweight × dressing percentage (r = 0.90). Šafus *et al.* (1998) studied relationships between productive parameters in Czech Pied cattle. High coefficients were found for the relationship between average 500-day live weight and: corrected gain ($r = 0.693$), average daily gain in the fattening period ($r_g = 0.881$), average daily from birth to 500 days of age ($r_g = 0.986$); between corrected net gain and: average daily gain in the fattening period ($r_g = 0.785$), average daily gain from birth to 500 days ($r_g = 0.701$); between average daily gain in the fattening period and average daily gain from birth to 500 days of age ($r_g = 0.905$). Nakládal and Pinďák (1975) mention positive correlations between net gain and average daily gain in the fattening period (151–500 days of age): $r = 0.83–0.93$. Šubrt (1980) pointed out some aspects associated with the role of net gain in cattle improvement policy. He mentioned highly significant correlations between net gain × and average daily gain in the fattening period ($r = 0.61$). Hirooka *et al.* (1996) found positive correlations ($r_g = 0.48$) between average daily gain in the fattening period and dressed carcass weight in Japanese Brown cattle.

Numerous authors recommend to use kidney fat as a parameter characterizing carcass fatness. Keclík (2000) found high correlations between kidney fat and 150-day live weight and 500-day live weight ($r_{xy} = 0.218$ and $r_{xy} = 0.540$, respectively) in Czech Pied cattle. Šubrt (1980) determined correlation $r = 0.25$ between net gain and kidney fat. Nakládal and Pinďák (1975) found correlation $r = 0.08$ between average daily gain and kidney fat. Šafus *et al.* (1998) mentioned a positive correlation between average daily gain in the testing period and kidney fat ($r_{xy} = 0.500$); more intensive fat deposition in body cavities is presumably associated with higher growth rate.

Hirooka *et al.* (1996) found a negative correlation between subcutaneous fat and marbling ($r = –0.12$); but Arnold *et al.* (1991) reported a positive correlation ($r = 0.19$) between the mentioned traits. These authors found positive correlations between back fat and carcass weight ($r = 0.36$) and between average post-weaning daily gain and marbling ($r = 0.54$) – the mentioned values characterize Hereford steers. Negative correlations are associated with back fat × weaning live weight ($r_g = –0.28$) and back fat × one-year live weight ($r_g = –0.13$). Bellér *et al.* (1980) studied relationships between chemical composition of meat and carcass characteristics in Slovak Pied bulls. Significant correlations characterized the relations between net gain and water content ($r_g = 0.252$), dry matter content ($r_{xy} = 0.260$), and fat content ($r_{xy} = 0.238$).

Evaluation of correlations characterizing parameters of meat performance studied in Czech Pied bulls and in crossbreds with beef bulls (Aberdeen Angus, Limousine, Blonde d'Aquitaine, Charolais) was the principal objective of this study.

MATERIAL AND METHODS

Relationships between selected parameters of meat performance were studied in the group of 119 bulls – F_1 crossbreds of Czech Pied and Black Pied cattle with beef sires (Aberdeen Angus – AA – 19 head, Limousine – LI – 40 head, Blonde d'Aquitaine – BA – 20 head, Charolais – CH – 40 head). Czech Pied bulls (C, $n = 51$) – sons of sires controlled by progeny testing for meat performance – represented a control group. The study was conducted at a fattening performance testing station (FPTS) under identical nutrition, housing and management conditions. Bulls were fattened to the average live weight of 570.5 kg (from 538.4 kg – LI to 597.7 kg – CH), the average daily gain amounted to 1 127 g (from 1 042 g – LI to 1 199 g – CH). Bulls were slaughtered at 502.1 days on average (from 497.3 days – AA to 505.6 days – BA). The following parameters were determined at slaughter: dressed carcass weight (DCW – 333.3 kg on average, from 318.3 kg – LI to 346.8 kg – CH), kidney fat weight (KFW – 8.7 kg on average, from 5.3 kg – BA to 10.7 kg – AA), net gain (NG – 663 g on average, from 633 g – LI to 692 g – CH), dressing percentage (58.2% on average, from 57.7% – C to 59.6% – BA); these parameters were determined 24 h after slaughter: meat weight (124.2 kg on average, from 119.3 kg – LI to 128.6 kg – CH), separable fat weight (8.2 kg on average, from 6.9 kg – BA to 10.3 kg – AA), and bone weight (32.1 kg on average, from 30.2 kg – LI to 33.7 kg – CH).

Musculus longissimus lumborum et thoracis (MLLT; 69.7 cm^2 on average, from 61.2 cm^2 – AA to 75.4 cm^2 – BA) was sampled for analysis of dry matter (27.2% on average, from 26.4% – BA to 28.1% – AA), proteins (21.5% on average, from 21.4 – BA and CH to 21.8% - LI), and fat (2.9% on average, from 1.8% – BA to 3.5% – AA).

Two classification groups were formed: round, shoulder, sirloin were classified as prime cuts (grade I meat); chuck, neck, ribs, flank, shank, and trimmed cuts were classified as grade II meat.

Statistical program GLM SAS (1988) was used for data set processing by the least squares method.

RESULTS AND DISCUSSION

Correlations between the meat performance parameters were determined in the framework of individual groups.

Table 1 presents relationships between 150-day live weight and carcass value parameters. Positive correlations between 150-day live weight and dressed carcass weight were confirmed in all controlled groups – correlation coefficient ranged from r_{xy} = 0.449* (AA) to r_{xy} = 0.794*** (BA). Positive correlations between 150-day live weight and dressed carcass weight (r_{xy} = 0.148) were found by Keclík (2000), too.

In the group of AA crossbreds, positive, but insignificant correlations characterized other parameters excluding grade I meat (r_{xy} = 0.573*). In the group of LI crossbred, insignificant correlations (r_{xy} = 0.185) and negative correlations (r_{xy} = –0.184) were found between 150-day live weight and dressing percentage and 150-day live weight and MLLT, respectively. As for the other observed parameters, correlations were significant and ranged from r_{xy} = 0.423** (net gain) to r_{xy} = 0.663*** (separable fat). Similar results characterized crossbreds – progenies of BA sires. Significant correlations between live weight and dressing percentage were found in CH and C groups (r_{xy} = 0.300* – CH, r_{xy} = 0.457*** – C). The two mentioned groups were also characterized by positive correlations between 150-day live weight and MLLT (r_{xy} = 0.355* – CH, r_{xy} = 0.514*** – C). As for CH progenies, insignificant correlation was found between 150-day live weight and kidney fat (r_{xy} = 0.208), a positive tendency was evident in the values of other correlation coefficients (from r_{xy} = 0.397* – separable fat – to r_{xy} = 0.596*** – bone weight). In contrast to the crossbreds no significant correlation was found between 150-day live weight and grade I meat (r_{xy} = 0.273) in the control group. Other correlations were positive and significant.

This table also presents correlations between 500-day live weight (slaughter weight) and carcass value parameters. High correlations (***) were established in all studied groups for DCW (r_{xy} = 0.923 – LI up to r_{xy} = 0.969 – BA), net gain (r_{xy} = 0.901 – AA up to r_{xy} = 0.968 – BA), total meat weight (r_{xy} = 0.792 – C up to r_{xy} = 0.928 – BA), grade I meat (r_{xy} = 0.737 – AA up to r_{xy} = 0.854 – LI), grade II meat (r_{xy} = 0.702 – C up to r_{xy} = 0.910 – BA) and bone weight (r_{xy} = 0.686 – C up to r_{xy} = 0.791 – BA). In AA and CH progenies, significant positive correlations between slaughter weight and MLLT were found (r_{xy} = 0.482* and r_{xy} = 0.490**, resp.). In the control group, the correlation between slaughter weight and MLLT was not significant (r_{xy} = 0.267) in contrast to the correlation between 150-day weight and MLLT. As for correlations between slaughter weight and kidney fat and separable fat, positive correlations (***) characterized all groups – in some groups lower correlations were found: kidney fat (r_{xy} = 0.447* – AA, r_{xy} = 0.670** – BA, r_{xy} = 0.469** – CH), separable fat (r_{xy} = 0.675** – AA). Positive correlations (*) between slaughter weight and dressing percentage were evident only in LI crossbreds (r_{xy} = 0.336*) and in Czech Pied bulls (r_{xy} = 0.292*) in contrast to CH crossbreds (r_{xy} = –0.066). Schwark (1989) reported r_{xy} = 0.4 and Romita and Borghese (1974) r_{xy} = 0.81. In Czech Pied bulls r_{xy} = 0.323 characterized 500-day live weight × dressing percentage (Keclík, 2000). Šafus *et al.* (1998) reported the value r_g = 0.025.

As for correlations between growth rates in the period of 150–500 days of age and carcass value traits, significant correlations characterized all observed traits excluding dressing percentage and MLLT (excluding CH group). High correlations (***) were found in the case of dressed carcass weight (r_{xy} = 0.744*** – LI up to r_{xy} = 0.790*** – BA), net gain (r_{xy} = 0.736*** – LI up to r_{xy} = 0.786*** – C), meat weight (r_{xy} = 0.624*** – C up to r_{xy} = 0.825*** – LI) and grade II meat (r_{xy} = 0.515*** – C up to r_{xy} = 0.824*** – LI). As for grade I meat, lower correlations were determined in AA group (r_{xy} = 0.481*) and in BA group (r_{xy} = 0.572**), high correlations were established in the other groups. Correlations for separable fat ranged from r_{xy} = 0.322* (C) to r_{xy} = 0.700*** (BA). In AA and LI groups, correlations between daily gains and kidney fat were insignificant (r_{xy} = 0.316 and r_{xy} = 0.298, resp.). Significant correlations were found in BA (r_{xy} = 0.646**), CH (r_{xy} = 0.406**) and C (r_{xy} = 0.345*) groups. Correlations between growth rate and bone weight ranged from r_{xy} = 0.603* (AA) to r_{xy} = 0.716*** (BA). In the bulls the correlation coefficient amounting to r_{xy} = 0.066 demonstrates an insignificant effect of growth rate on dressing percentage. As for AA and CH groups, negative insignificant values were calculated (r_{xy} = –0.052, r_{xy} = –0.239 resp.). There was a high correlation between growth rate and DCW in Czech Pied bulls (r_{xy} = 0.927 – Keclík, 2000). In our study r_{xy} = 0.776*** characterized these bulls (control group).

Table 1. Correlations between growth parameters and selected meat performance traits in Czech Pied bulls and in crossbreds – progenies of AA, LI, BA and CH sires

Parameter	Crossbreds sired by AA	Crossbreds sired by LI	Crossbreds sired by BA	Crossbreds sired by CH	Czech Pied bulls
			r_{xy}		
150-day live weight					
Dressed carcass weight (kg)	0.449*	0.437**	0.794***	0.519***	0.472***
Dressing percentage (%)	0.284	0.185	0.380	0.300*	0.457***
Net gain (g)	0.403	0.423**	0.811***	0.516***	0.458***
Kidney fat weight (kg)	0.302	0.623***	0.547*	0.208	0.341*
Meat weight – total (kg)	0.390	0.482**	0.792***	0.456**	0.416**
Weight of grade I meat (kg)	0.573*	0.495**	0.823***	0.420**	0.273
Weight of grade II meat (kg)	0.249	0.442**	0.719***	0.439**	0.434**
Weight of separable fat (kg)	0.378	0.663***	0.496*	0.397*	0.433**
Weight of bones (kg)	0.286	0.536***	0.567**	0.596***	0.396**
MLLT (cm^2)	0.229	–0.184	0.299	0.355*	0.514***
500-day live weight					
Dressed carcass weight (kg)	0.933***	0.923***	0.969***	0.928***	0.962***
Dressing percentage (%)	0.096	0.336*	0.248	–0.066	0.292*
Net gain (g)	0.901***	0.908***	0.968***	0.923***	0.964***
Kidney fat weight (kg)	0.447*	0.541***	0.670**	0.469**	0.496***
Meat weight – total (kg)	0.900***	0.917***	0.928***	0.894***	0.792***
Weight of grade I meat (kg)	0.737***	0.854***	0.836***	0.776***	0.808***
Weight of grade II meat (kg)	0.865***	0.895***	0.910***	0.892***	0.702***
Weight of separable fat (kg)	0.675**	0.616***	0.741***	0.576***	0.519***
Weight of bones (kg)	0.704***	0.728***	0.791***	0.735***	0.686***
MLLT (cm^2)	0.482*	0.057	0.024	0.490**	0.267
Daily gains from 150 to 500 days of age (g)					
Dressed carcass weight (kg)	0.759***	0.744***	0.790***	0.745***	0.776***
Dressing percentage (%)	–0.052	0.253	0.034	–0.239	0.063
Net gain (g)	0.750***	0.736***	0.774***	0.741***	0.786***
Kidney fat weight (kg)	0.316	0.298	0.646**	0.406**	0.345*
Meat weight – total (kg)	0.758***	0.825***	0.736***	0.736***	0.621***
Weight of grade I meat (kg)	0.481*	0.737***	0.572**	0.626***	0.713***
Weight of grade II meat (kg)	0.797***	0.824***	0.770***	0.743***	0.515***
Weight of separable fat (kg)	0.521*	0.326*	0.700***	0.417**	0.322*
Weight of bones (kg)	0.603**	0.551***	0.716***	0.483**	0.527***
MLLT (cm^2)	0.394	0.196	–0.182	0.353*	0.010

Table 2. Correlations between net gain, dressed carcass weight (DCW) and selected meat performance traits in Czech Pied bulls and in crossbreds – progenies of AA, LI, BA and CH sires

	Crossbreds sired by AA	Crossbreds sired by LI	Crossbreds sired by BA	Crossbreds sired by CH	Czech Pied bull
			r_{xy}		
Net gain (g)					
Kidney fat weight (kg)	0.487*	0.640***	0.665***	0.428**	0.452***
Meat weight – total (kg)	0.945***	0.915***	0.941***	0.977***	0.878***
Weight of grade I meat (kg)	0.755***	0.852***	0.875***	0.896***	0.865***
Weight of grade II meat (kg)	0.917***	0.893***	0.909***	0.945***	0.791***
Weight of separable fat (kg)	0.665**	0.681***	0.715***	0.471**	0.466***
Weight of bones (kg)	0.646**	0.720***	0.839***	0.738***	0.640***
MLLT (cm^2)	0.648**	0.083	0.118	0.559***	0.315*
Dressed carcass weight (kg)					
Kidney fat weight (kg)	0.436*	0.545***	0.662**	0.424**	0.445***
Meat weight – total (kg)	0.969***	0.968***	0.975***	0.981***	0.875***
Weight of grade I meat (kg)	0.831***	0.915***	0.884***	0.897***	0.859***
Weight of grade II meat (kg)	0.912***	0.937***	0.953***	0.950***	0.789***
Weight of separable fat (kg)	0.632**	0.605***	0.668***	0.465**	0.459***
Weight of bones (kg)	0.719***	0.748***	0.847***	0.744***	0.650***
MLLT (cm^2)	0.566*	0.144	0.104	0.549***	0.307*

Significant correlations (0.881) between growth rate in the fattening period and DCW were also mentioned by Šafus *et al.* (1998). A significant correlation between growth rate and MLLT (r_{xy} = 0.353*) was established only in CH group.

Table 2 illustrates relationships between net gain, DCW and carcass value parameters. Correlation coefficients ranged in AA group from r_{xy} = 0.487* (kidney fat) to r_{xy} = 0.945*** (meat weight), in LI group from r_{xy} = 0.640*** (kidney fat) to r_{xy} = 0.915*** (meat weight), in BA group from r_{xy} = 0.665*** (kidney fat) to r_{xy} = 0.941*** (meat weight), in CH group from r_{xy} = 0.428** (kidney fat) to r_{xy} = 0.977*** (meat weight) and in Czech Pied bulls from r_{xy} = 0.452*** (kidney fat) to r_{xy} = 0.878*** (meat weight). High net gain is, however, associated with intensive deposition of fat in body cavities as well as in flesh. The correlation between net gain and MLLT was evident only in AA group (r_{xy} = 0.648**), CH group (r_{xy} = 0.559***) and in Czech Pied bulls (r_{xy} = 0.315*).

Similar tendencies were evident for relations between DCW and observed parameters (Table 2).

Table 3 presents data characterizing relations between qualitative characteristics of meat (dry matter, protein and fat contents) and observed parameters of fattening performance and carcass value (150-day live weight, 500-day live weight, daily gains in the fattening period, kidney fat, meat weight, separable fat weight).

In AA group, no significant correlation was found in the case of dry matter content. In LI group and control group, significant positive correlations were found between dry matter and: 150-day live weight (r_{xy} = 0.475**, r_{xy} = 0.291*, resp.), 500-day live weight (r_{xy} = 0.487**, r_{xy} = 0.278*, resp.), kidney fat (r_{xy} = 0.682***, r_{xy} = 0.492***, resp.) and separable fat (r_{xy} = 0.706***, r_{xy} = 0.576***, resp.).

Table 3. Correlations between selected meat performance traits and qualitative meat characteristics in Czech Pied bulls and in crossbreds – progenies of AA, LI, BA and CH sires

Parameter	Crossbreds sired by AA	Crossbreds sired by LI	Crossbreds sired by BA	Crossbreds sired by CH	Czech Pied bulls
	r_{xy}				
Dry matter (%)					
150-day live weight (kg)	–0.240	0.475**	0.563*	0.374*	0.291*
500-day live weight (kg)	0.200	0.487**	0.378	–0.076	0.278*
Average daily gain (150–500 days of age) (g)	0.347	0.290	0.140	–0.287	0.110
Kidney fat weight (kg)	–0.205	0.682***	–0.357	0.210	0.492***
Total meat weight (kg)	0.158	0.294	0.297	–0.009	0.126
Separable fat weight (kg)	0.156	0.706***	0.389	0.224	0.576***
Proteins (%)					
150-day live weight (kg)	–0.132	0.178	0.510*	–0.068	0.219
500-day live weight (kg)	0.059	0.254	0.567*	–0.194	0.258
Average daily gain (150–500 days of age) (g)	0.136	0.198	0.445	–0.180	0.264
Kidney fat weight (kg)	–0.247	0.569***	0.687***	–0.027	0.394**
Total meat weight (kg)	0.139	0.085	0.499*	–0.074	0.274
Separable fat weight (kg)	–0.224	0.421**	0.381	–0.100	0.365**
Fat content (%)					
150-day live weight (kg)	–0.178	0.302	0.296	0.143	0.169
500-day live weight (kg)	0.394	0.335*	0.053	–0.083	0.057
Average daily gain (150–500 days of age) (g)	0.523*	0.216	–0.132	–0.170	–0.029
Kidney fat weight (kg)	0.207	0.531***	0.248	0.227	0.319*
Total meat weight (kg)	0.270	0.266	–0.068	–0.060	–0.005
Separable fat weight (kg)	0.566*	0.364*	0.035	0.253	0.387**

The other correlation coefficients were insignificant. In BA and CH groups, correlation coefficients between dry matter and 150-day live weight were significant (r_{xy} = 0.563*, r_{xy} = 0.374*, resp.). The other correlations were insignificant.

In AA group (similarly like in CH group) no positive effect on proteins was proved. In LI group, positive correlations between proteins and kidney fat (r_{xy} = 0.569***) and separable fat (r_{xy} = 0.421**) were found. In BA group, positive correlations between proteins and 150-day live weight, 500-day live weight (r_{xy} = 0.510*, r_{xy} = 0.567*, resp.), meat weight (r_{xy} = 0.499*), and kidney fat (r_{xy} = 0.687***) were calculated. In Czech Pied bulls, a significant correlation between kidney fat and proteins was confirmed (r_{xy} = 0.394**). Similar correlations characterized separable fat × proteins (r_{xy} = 0.265**).

As for fat content, the effect of growth rate in the fattening period was significant in AA group (r_{xy} = 0.523*). In the other groups this correlation coefficient ranged from r_{xy} = –0.170 (CH) to r_{xy} = 0.216 (LI). In AA group, a positive relation between fat content and separable fat was demonstrated (r_{xy} = 0.566*). Hirooka *et al.* (1996) and Arnold *et al.* (1991) did not mention any significant relation between fat content and marbling.

In LI group, positive correlations characterized fat content × 500-day live weight (r_{xy} = 0.335*) and fat content x separable fat (r_{xy} = 0.364**). The effect of kidney fat on fat content was the most significant (r_{xy} = 0.531***). In BA and CH groups, positive correlations with fat content were confirmed. In the control group, effects of slaughter weight and growth rate on fat content were insignificant (r_{xy} = 0.057, r_{xy} = –0.029). Positive correlations were found for kidney fat (r_{xy} = 0.319*) and separable fat (r_{xy} = 0.387**).

As compared with the control group (Czech Pied bulls), data characterizing groups of crossbreds are distorted by variance between specific breeds.

REFERENCES

Anonymous (1995): Chovný cíl a program šlechtění strakatého skotu v Bavorsku. In: Zpravodaj svazu chovatelů a plemenné knihy českého strakatého skotu. 2–11.

Achler B. (1994): Boom bei den Fleischrindern – und wer daran verdienen kann. Top agrar aetra – Fleischrinderproduktion, Landwirtschaftsverlag Münster. 8–12.

Arnold J., Bertrand J.K., Benyshek L.L., Ludwig C. (1991): Estimates of genetic parameters for live animal ultrasound, actual carcass data, and growth traits in beef cattle. J. Anim. Sci. Champaing, III: Am. Soc. Anim. Sci., *69*, 985–992.

Bellér I., Flak P., Ďurečko J. (1980): Vzťahy medzi chemickým složením mäsa a jatočnými ukazatelmi u býčkov slovenského strakatého plemena. In: Produkcia a kvalita mäsa. Nitra.

Frelich J., Voříškova J.,Weglarz A., Zapletal P. (1999): Fattening performance, carcass value and body measurement of Angus, Limousine, Charolais and Simental bulls. In: Coll. Sci. Pap., Fac. Agric. České Budějovice, Ser. Anim. Sci., *1*, 5–14.

Hirooka H., Groen A., Matsumoto M. (1996): Genetic parameters for growth and carcass traits in Japanese Brown cattle estimated from field records. J. Anim. Sci. Champaing, III: Am. Soc. Anim. Sci., *74*, 2112–2116.

Keclík R. (2000): Šlechtění českého strakatého skotu při tvorbě stáda kombinovaného užitkového typu. [Dizertační práce.] JU ZF, České Budějovice. 122 s.

Nakládal J., Pinďák J. (1975): Vliv kompletních směsí na masnou užitkovost a jatečnou hodnotu býčků ve srovnání se senážní výživou. VÚCHS, Rapotín. 43 s.

Papstein H.S. et al. (1993): Wachstumuntersuchungen an Schwarzbnten Bullen verschiedenner Körperbautypen. Arch. Tierzucht., *36*, 597–606.

Putz M. (1993): Fleckvieh: Zuchtziel auf dem Prüfstand. Der Tierzüchter, *45*, 19.

Schwark H.J., Bolze M., Schmalfuss R. et al. (1989): Höhere Lebendmasse produktion und mehr Kälber für die Jungrindermast durch Fremdkälberin der Mutterkuh-haltung. Tierzucht, *43*, 111–113.

Šafus P., Přibyl J., Čermák V. (1998): Genetické korelace mezi vlastnostmi u býků českého strakatého a černostrakatého skotu. Živoč. Výr., *43*, 149–158.

Šubrt J. (1980): Diferenciace porážkové hmotnosti skotu. KDP, VŠZ Brno. 178 s.

Šubrt J., Polách P., Frelich J., Voříšková J. (2000): Morphometric analysis of dressed carcasses of bulls of commercial meat types. Czech J. Anim. Sci., *45*, 37–43.

Romita A., Borghese A. (1974): Production of the 6-mth old Friesian calf. I. Growth rate, dressing percentage, and prediction of carcass composition. Ann. Inst. Experiment. Zoot., *7*, 77–95.

Urban F. (1987): Vztahy vybraných exteriérových znaků a užitkovostí prvotelek. Živoč. Výr., *32*, 17–24.

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Replacement of animal origin feed by plant origin feed in the diet of broiler chickens

Náhrada animálních krmiv v dietě pro výkrm kuřat krmivy vegetabilními

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ABSTRACT: The main goal of this study was to test diets that were specially formulated for the fattening of broiler chickens and in which feed of animal origin (meat-and-bone meal) was utterly replaced by feed of plant origin (Proenergol – treated rape expellers). The results obtained in this study proved that this type of diet was suitable for the fattening of broiler chickens. At the end of the fattening period (on the 42nd day) the average liveweight of chickens in the control group was practically identical to that of the experimental group; i.e. 2.13 kg and 2.10 kg for pullets and 2.34 kg and 2.31 kg for cockerels. On the 14th day, the average weight of both pullets ($P \leq 0.05$) and cockerels ($P \leq 0.01$) in the experimental group was higher than that in the control group. On the 35th day of the fattening period, the average weight of cockerels in the experimental group was found to be higher than that in the control group ($P \leq 0.05$). Furthermore, diets free of animal origin feed affected neither carcass weight nor carcass yield. According to the evaluation of the weight and yield of abdominal fat, neither diet showed any significant effect on the content of fat in carcass. On the 42nd day of the fattening period, haematological and biochemical analyses of blood plasma of chickens were performed. These analyses revealed that the average values of plasma protein in chickens of the control group (34.56 g/l for pullets and 33.92 g/l for cockerels) were significantly lower ($P \leq 0.01$) than those in the experimental group (37.34 g/l for pullets and 36.44 g/l for cockerels). Similarly, plasma phosphorus was 2.44 mmol/l in pullets and 2.15 mmol/l in cockerels of the control group compared with 3.12 mol/l and 2.54 mmol/l in pullets and cockerels of the experimental group. On the contrary, the average plasma concentrations of magnesium were significantly higher ($P \leq 0.05$) in both pullets (0.83 mmol/l) and cockerels (0.81 mmol/l) of the control group in comparison with those in the experimental group (0.77 mmol/l for pullets and 0.72 mmol/l for cockerels).

Keywords: broiler chickens; fattening; animal origin feed; plant origin feed; haematology; biochemistry

ABSTRAKT: Cílem práce byla testace speciálně připravených směsí pro výkrm brojlerových kuřat, ve kterých byla animální krmiva (masokostní moučky) plně nahrazena vegetabilními krmivy (přípravek Proenergol – speciálně ošetřené řepkové výlisky). Dosažené výsledky potvrdily vhodnost použití těchto diet ve výkrmu kuřat. Na konci výkrmu (ve 42. dnu) se prakticky nelišila průměrná živá hmotnost u kontrolních a pokusných kuřat u slepiček (2,13 a 2,10 kg) ani u kohoutků (2,34 kg a 2,31 kg). U pokusných kuřat byla ve 14. dnu ve srovnání s kontrolou prokázána vyšší průměrná hmotnost u slepiček ($P \leq 0{,}05$) i kohoutků ($P \leq 0{,}01$). U kohoutků byla vyšší průměrná hmotnost v porovnání s kontrolou prokázána ($P \leq 0{,}05$) až do 35. dne výkrmu. Diety bez animálních krmiv rovněž neovlivnily hmotnost jatečně opracovaného těla ani jejich jatečnou výtěžnost. Testované diety průkazně neovlivnily ani množství tuku v jatečném těle, hodnoceno na základě hmotnosti abdominálního tuku a jeho výtěžnosti. Ve 42. dnu výkrmu bylo provedeno i hematologické a biochemické vyšetření krevní plazmy kuřat. U kuřat kontrolní

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skupiny byly zjištěny statisticky vysoce průkazně nižší ($P \leq 0,01$) průměrné hodnoty plazmatického proteinu u slepiček (34,56 g/l) i kohoutků (33,92 g/l) oproti skupině pokusné (37,34 g/l a 36,44 g/l) a u plazmatického fosforu u slepiček (2,44 mmol/l) i kohoutků (2,15 mmol/l) oproti pokusné skupině (3,12 mmol/l a 2,54 mmol/l). Naopak u plazmatického hořčíku byly významně vyšší ($P \leq 0,05$) průměrné koncentrace u kontrolních slepiček (0,83 mmol/l) i kohoutků (0,81 mmol/l) oproti pokusným (0,77 mmol/l a 0,72 mmol/l).

Klíčová slova: brojlerová kuřata; výkrm; animální krmiva; vegetabilní krmiva; hematologie; biochemie

The use of meat-and-bone meals for the feeding of farm animals represents a potential risk of transferring prions which may give rise to spongiform encephalopathy. Although the use of animal origin feed for the feeding of farm animals has been banned in the EU countries, in the Czech Republic the use of such feed is still allowed except for ruminants.

Recent developments in the nutrition of farm animals in Europe, however, have forced nutritionists to search for alternative domestic products in order to replace the animal origin feed. One of such alternatives is rape seed, particularly rape meal and rape expellers.

Over the past ten years the use of rape seed for animal feeding has been studied by many researchers. As far as the fattening of broiler chickens is concerned, some researchers tested the use of diets containing 10–30% of rape seed, extracted rape meal or rape expellers. Haščík *et al.* (1994) reviewed the results of such studies and concluded on the basis of their own experiments that rape expellers could replace up to 50% of extracted soybean meal in diets for chickens. Smulikowska *et al.* (1998) obtained promising results when rape seed and rape seed expellers made of yellow-seeded spring and dark-seeded winter rape seed were used for chicken fattening. Rothmaier et Kirchgessner (1995) reported a lower increase in the body weight of broiler chickens fed on rape seed when 0–25% rape seed was replaced by soybean meal. Mawson *et al.* (1994) studied the antinutritional effect of glucosinolates on the growth of animals in order to determine the limiting levels of glucosinolates in the diet. Furthermore, Hyánková *et al.* (1993) addressed the problem whether the substitution of soybean meal by rape seed and peas would affect the rate of mortality, feed conversion and usability and carcass characteristics of broiler chickens. The results of their experiment showed that the feed conversion dropped when the content of rape seed amounted to 20%. Moreover, the liveweight, carcass yield and yield of abdominal fat decreased in tested chickens. However, the rate of mortality, proportion of breast and leg muscles and quality of meat remained unaffected by this diet.

The use of rape seed and rape products for the chicken fattening is also connected with the use of rapeseed oil. This topic was studied by Bickel *et al.* (2001). These authors found that the use of more than 1.3% of rapeseed oil in diets decreased feed intake, resulting in the reduced increase in the body weight of chickens. In their interesting paper, Mendlík *et al.* (1999) compared the effect of Ca salts of fatty acids with that of untreated rapeseed oil during the broiler chicken fattening. These authors concluded that the energy provided by 1 000 g of rapeseed oil is comparable with that of 1 323 g of Ca salts of fatty acids.

MATERIAL AND METHODS

The main goal of this experiment was to compare the production efficiency of two diets: D1 (without feed of animal origin) and D2 (with feed of animal origin). Both diets were balanced in respect to the content of nutrients; the only difference between them was that the animal origin feed (meat-and-bone meal) in diet D1 was replaced by plant origin feed (specially processed rape expellers). The specially processed rape expellers were produced and supplied by ZOD Žichlínek under the commercial name "Proenergol". D1 diet contained 10% of Proenergol, which replaced 10% of meat-and-bone meal used in D2 diet. During the fattening period, three different types of rations were used: BR 1, BR 2 and BR 3. The nutrient composition and the length of the fattening period are shown in Table 1.

The experiment was carried out in an experimental facility at the Department of Nutrition, Dietetics, Zoohygiene and Plant Products of the Faculty of Veterinary Hygiene and Ecology, University of

Table 1. Nutrient composition of diets used for the fattening of chickens (D1 – diet without animal origin feed, D2 – diet with animal origin feed)

Ration	BR 1		BR 2		BR 3	
Feeding regimen	Day 1–14		Day 15–30		Day 31–42	
Composition (g/kg)	D1	D2	D1	D2	D1	D2
Dry weight	893.67	891.59	893.71	891.81	894.44	892.34
Proteins	220.91	228.46	200.35	207.73	190.69	198.30
Lysine	13.109	13.184	11.054	11.124	11.046	11.123
Methionine	5.340	5.135	5.478	5.270	5.001	4.797
Sulfur-containing AA	9.029	8.992	9.019	8.975	8.479	8.444
Threonine	8.707	8.690	7.722	7.700	7.469	7.454
Tryptophan	2.758	2.803	2.516	2.559	2.405	2.450
Arginine	12.992	13.202	11.365	11.567	10.547	10.760
Fat	64.838	64.434	69.159	68.737	74.486	74.089
Linoleic acid	26.298	26.619	24.031	24.339	23.790	24.116
Fiber	33.349	32.498	38.014	37.122	41.107	40.270
Starch	345.800	346.680	370.870	370.865	377.300	378.475
Sugars	33.075	34.198	29.681	30.770	28.045	29.180
ME (MJ)	12.494	12.520	12.813	12.819	13.012	13.045
Ash	65.120	65.329	59.737	61.447	59.294	59.268
Ca	9.940	11.410	8.93	11.05	9.13	10.94
P	8.020	8.280	7.52	7.76	7.56	7.43
Na	1.800	2.090	1.83	2.08	1.83	1.94
Mg	2.010	2.000	1.91	1.90	1.87	1.86

Veterinary and Pharmaceutical Sciences in Brno. The experimental facility was equipped with automatic control of air-conditioning, feeding and watering of chickens, which enabled to continually monitor the consumption of feed and water and to record temperature and relative air humidity. 150 one-day old chickens (ROSS 308) were included in the experiment. The liveweight of one chicken at the start of the experiment was 42 g on average. The chickens were divided into two groups: experimental group (D1) with 74 chickens (37 pullets and 37 cockerels) and control group (D2) with 74 chickens (37 pullets and 37 cockerels).

During the forty-two days' fattening period, the chickens were weighed individually on the 14th, 21st, 31st and 42nd day. At the end of the fattening period (on the 42nd day) 20 chickens (10 pullets and 10 cockerels) of each group (D1 and D2), i.e. 40 chickens in total, were randomly selected and their blood samples were taken *intra vitam* from *vena basilica* for haematological and biochemical examinations. Then the chickens were slaughtered and their carcass characteristics were assessed. Carcass characteristics included the evaluation of carcass weight (without edible organs) and the calculation of carcass yield. To assess the fat-building effect of diets, the weight and the yield of abdominal fat were evaluated in respect to live weight of chickens.

Haematological examination of blood (stabilized with heparin) consisted of the following tests: the count of erythrocytes (Er) and leukocytes (Le) (using flask dilution method and counting blood cells under the microscope using Bürker chamber), haematocrit value (Hk) (using capillary method for the determination of microhaematocrit after separation at 12 000 revolutions according to Janetzki) and the determination of total haemoglobin content (photometrically at the wavelength of 540 nm).

Biochemical examination of plasma samples was carried out after separation of blood plasma from blood. Parameters such as total protein (CP), glucose (Gl), catalytic concentration of AST and ALT, cholesterol (Chol) and concentrations of calcium (Ca), phosphorus (P) and magnesium (Mg) were determined photometrically using commercially available kits (Bio-la-test).

The results were subjected to statistical processing using the program STATGRAPHIC. Data sets characterized by arithmetic means (x) and standard deviations (s_{n-1}) are provided in tables (Venčikov and Venčikov, 1977). Experimental average values (x) were tested using Student's t-test. Significance of differences between averages was evaluated according to the calculated value (t_d) and the values in tables (Venčikov and Venčikov, 1977). Thus, the significance level of $P \leq 0.05$ means statistically significant difference (*) and $P \leq 0.01$ means statistically highly significant difference (**).

RESULTS

The results obtained in this study show a good level of production efficiency for a diet without animal origin products. It is demonstrated by the growth intensity (expressed as the liveweight of chickens) which was comparable in both groups. Table 2 shows that during the first half of the fattening period the live weight of both female and male chickens receiving the diet without animal origin feed exceeded that of chickens in the control group.

On the 14th day of the fattening period, the body weight of pullets (0.326 kg) and cockerels (0.360 kg) in the experimental group was significantly higher than that of pullets (0.309 kg) and cockerels (0.314 kg) in the control group. The differences in the body weights of pullets in the two groups were statistically significant ($P \leq 0.05$) while those of cockerels were statistically highly significant ($P \leq 0.01$). In the next stage of the fattening period, the body weight of cockerels in the experimental group was significantly higher ($P \leq 0.05$) than that of cockerels in the control group; the body weights of cockerels were 0.750 kg and 0.708 kg on the 21st day and 1 820 kg and 1 710 kg on the 35th day of the fattening period. No significant differences between the body weight of pullets of the two groups were found. On the 42nd day of the fattening period, the differences in the liveweight of pullets (2.10 kg and 2.13 kg) and cockerels (2.31 kg and 2.34 kg) in the two groups (experimental and control) were insignificant.

As shown in Table 2, no statistically significant differences in carcass characteristics between pullets and cockerels in the experimental and control group were found.

On the 42nd day of fattening, the carcass weight of a pullet was 1.45 kg in the experimental group and 1.42 kg in the control group, while the carcass weight of a cockerel was 1.60 kg and 1.74 kg, respectively, at the carcass yield of 71.31% and 67.51% for pullets and 69.38% and 69.15% for cockerels.

The monitoring also included a comparison of the fat-building effects of diets that was based on the evaluation of the weight and yield of abdominal fat. For this parameter no statistically significant differences between the experimental and control groups of pullets (23.51 g and 26.16 g) and cockerels (22.18 g and 26.29 g) were found; the yield of abdominal fat in relation to liveweight was 1.16% and 1.24% in pullets and 0.95% and 1.03% in cockerels. These results characterizing the usability of chickens were obtained at the following feed conversion: 1.98 kg and 2.02 kg for pullets in the experimental and control group; 1.89 kg and 1.93 kg for cockerels in the experimental and control group.

During the forty-two days' fattening period, one pullet (2.7%) in the experimental group and three pullets (8.11%) and two cockerels (5.40%) in the control group died; no cockerel died in the experimental group (0%). In total, three chickens (4.05%) in the experimental group and three chickens (4.05%) in the control group died. On the 42nd day of the fattening period haematological and biochemical analyses of blood plasma were performed (Table 3) in order to evaluate chickens' health.

Table 2. Liveweight and carcass characteristics of chickens during fattening

Liveweight					Carcass characteristics Day 42				
Age	sex	group	x (s_{n-1})	t_d	parameter	sex	group	x (s_{n-1})	t_d
14 days	P	D1	0.326 (0.042)	2.232*	CW (kg)	P	D1	1.45 (0.188)	0.413
		D2	0.309 (0.020)				D2	1.42 (0.129)	
	C	D1	0.360 (0.039)	6.379**		C	D1	1.60 (0.138)	2.055
		D2	0.314 (0.024)				D2	1.74 (0.166)	
21 days	P	D1	0.687 (0.075)	1.000	CY (%)	P	D1	71.31 (8.222)	1.405
		D2	0.672 (0.052)				D2	67.51 (2.356)	
	C	D1	0.750 (0.095)	2.226*		C	D1	69.38 (3.676)	0.162
		D2	0.708 (0.063)				D2	69.15 (2.598)	
35 days	P	D1	1.610 (0.172)	0.240	WAF (g)	P	D1	23.51 (7.323)	0.686
		D2	1.620 (0.182)				D2	26.16 (9.770)	
	C	D1	1.820 (0.214)	2.412*		C	D1	22.18 (7.836)	0.877
		D2	1.710 (0.172)				D2	26.29 (12.580)	
42 days	P	D1	2.10 (0.255)	0.476	YAF (%)	P	D1	1.16 (0.365)	0.433
		D2	2.13 (0.276)				D2	1.24 (0.457)	
	C	D1	2.31 (0.316)	0.476		C	D1	0.95 (0.290)	0.505
		D2	2.34 (0.210)				D2	1.03 (0.407)	

Explanations:

x – arithmetic mean, s_{n-1} – standard deviation, P – pullets, C – cockerels, CW – carcass weight, CY – carcass yield, WAF – weight of abdominal fat, YAF – yield of abdominal fat, t_d – *t*-test

* $P \leq 0.05$

** $P \leq 0.01$

Table 3. Results of haematological and biochemical examination of plasma in chickens on the 42nd day of the fattening period

Parameters	Sex	Group	x (s_{n-1})	t_d	Parameters	Sex	Group	x (s_{n-1})	t_d
Er (T/l)	P	D1	1.69 (0.207)	0.563	AST (μkat/l)	P	D1	1.09 (0.076)	0.577
		D2	1.78 (0.462)				D2	1.07 (0.081)	
	C	D1	1.78 (0.239)	1.409		C	D1	1.08 (0.087)	1.212
		D2	2.10 (0.676)				D2	1.12 (0.060)	
Hk (1/1)	P	D1	0.28 (0.032)	1.562	ALT (μkat/l)	P	D1	0.048 (0.025)	1.495
		D2	0.26 (0.025)				D2	0.066 (0.028)	
	C	D1	0.26 (0.014)	1.118		C	D1	0.047 (0.023)	0.282
		D2	0.27 (0.026)				D2	0.050 (0.024)	
Hb (g/l)	P	D1	74.43 (9.314)	0.672	Chol (mmol/l)	P	D1	2.64 (0.586)	0.684
		D2	72.18 (5.026)				D2	2.46 (0.590)	
	C	D1	66.46 (12.640)	1.558		C	D1	2.66 (0.563)	0.641
		D2	73.35 (6.089)				D2	2.62 (0.269)	
Le (G/l)	P	D1	15.71 (2.928)	2.682*	Ca (mmol/l)	P	D1	2.64 (0.160)	0.915
		D2	12.50 (2.398)				D2	2.57 (0.180)	
	C	D1	12.31 (2.052)	1.327		C	D1	2.56 (0.181)	0.925
		D2	14.06 (3.630)				D2	2.48 (0.098)	
TP (g/l)	P	D1	37.34 (2.641)	2.886**	P (mmol/l)	P	D1	3.12 (0.380)	3.540**
		D2	34.56 (1.518)				D2	2.44 (0.475)	
	C	D1	36.44 (1.937)	3.025**		C	D1	2.54 (0.225)	3.857**
		D2	33.92 (1.785)				D2	2.15 (0.228)	
Gl (mmol/l)	P	D1	15.80 (1.767)	0.218	Mg (mmol/l)	P	D1	0.77 (0.054)	2.677*
		D2	15.62 (1.923)				D2	0.83 (0.091)	
	C	D1	15.84 (1.146)	0.970		C	D1	0.72 (0.038)	2.707*
		D2	16.31 (1.019)				D2	0.81 (0.098)	

As shown in Table 3, the average values of haematological parameters such as total count of erythrocytes, haematocrit value and haemoglobin content, found in pullets and cockerels of the experimental group showed no significant differences from those in the control group. The only significant difference ($P \leq 0.05$) between the two groups was observed in the total count of leukocytes. Thus, the average value of the leukocyte count in pullets of the experimental group (15.71 G/l) was higher than that of pullets in the control group (12.50 G/l).

Similarly to haematological parameters, no differences between average values of the two groups were found for biochemical parameters of blood plasma such as the level of glucose, AST, ALT, cholesterol and Ca. However, highly significant differences ($P \leq 0.01$) between the two groups were detected for plasma protein. The plasma protein level in the experimental group (37.34 g/l in pullets and 36.44 g/l in cockerels) was significantly higher than that in the control group (34.56 g/l in pullets and 33.92 g/l in cockerels). Analogously, the average plasma levels of phosphorus in pullets (3.12 mmol/l) and cockerels (2.54 mmol/l) of the experimental group were highly significantly higher ($P \leq 0.01$) in comparison with those in the control group (2.44 mmol/l in pullets and 2.15 mmol/l in cockerels).

On the contrary, the average plasma levels of magnesium in pullets (0.77 mmol/l) and cockerels (0.72 mmol/l) of the experimental group were significantly lower ($P \leq 0.05$) than those in pullets (0.83 mmol/l) and cockerels (0.81 mmol/l) of the control group.

DISCUSSION

The results of this research demonstrate that specially processed rape expellers (Proenergol) might be a suitable alternative to replace meat-and-bone meal in diets used for the fattening of broiler chickens.

The results of monitoring the liveweight of chickens are shown in Table 2. It is shown that the use of specially processed rape expellers did not significantly decrease the liveweight of chickens on the 42nd day of the fattening period. Moreover, until the 14th day the liveweight of pullets in the experimental group (fed on D1 diet containing processed rape expellers and no meat-and-bone meal) was higher than that in the control group. Similarly, until the 35th day the live weight of cockerels in the experimental group (fed on D1 diet containing processed rape expellers and no meat-and-bone meal) was higher than that in the control group. This may be due to the fact that antinutritional proteins such as glucosinolates, were removed (according to chemical analyses) from rape during a special technological process used in the manufacture of Proenergol. Therefore the absence of antinutritional proteins in feed used in our experiments may explain the fact that we did not observe any growth suppression in chickens reported by Bickel *et al.* (2001), Rothmaier and Kirchgessner (1995), Haščík *et al.* (1994) and Hyánková *et al.* (1993), who used diets containing rape and unprocessed rape products in the chicken diet.

We found that the use of processed rape meal (expellers) in chickens of the experimental group resulted in a decrease in feed consumption. The feed consumption dropped from 2.02 kg to 1.98 kg, i.e. by 2.02% in pullets, and from 1.93 kg to 1.89 kg, i.e. by 2.12% in cockerels. These findings are in contrast to the results of the authors cited above, except for Haščík *et al.* (1994), who reported increasing feed consumption in the control group, and Hyánková *et al.* (1993), who found decreasing feed conversion when the content of rape seed in the diet amounted to 20%.

The results concerning carcass characteristics of broilers can also be assessed positively (Table 2). No differences in either carcass weight or carcass yield between the experimental and control groups of male and female chickens receiving tested diets were found. Similarly, no differences between diets were found in the case of the fat-building effect that

Explanations to Table 3:

x – arithmetic mean, s_{n-1} – standard deviation, P – pullets, C – cockerels, Er – number of erythrocytes, Hk – haematocrit value, Hb – haemoglobin content, Le – leukocyte counts, TP – total protein, Gl – glucose, AST, ALT – transaminases, Chol – cholesterol, Ca – calcium, P – phosphorus, Mg – magnesium, t_d – t-test

* $P \leq 0.05$

**$P \leq 0.01$

was evaluated indirectly on the basis of the weight and yield of abdominal fat. Our results differ from those reported by Hyánková *et al.* (1993), who found that the carcass yield and the weight of abdominal fat decreased considerably in animals fed on rape seed. However, in our experiment, carcass characteristics (live and carcass weight) were not influenced because the tested diet showed no effect on the growth intensity of chickens.

One part of the experiment was also the monitoring of chickens' health by means of clinical and laboratory tests. During the fattening period, chickens in either group showed no clinical symptoms associated with deterioration of their health. Moreover, the death rates in both groups were more or less the same and were significantly lower than the death rate under current production conditions. Haematological and biochemical tests of blood samples performed in forty-two day old chickens (Table 3) revealed no significant changes in metabolic profile of chickens in either group. The average values of the total count of erythrocytes, haematocrit value and haemoglobin content in chickens of the experimental group did not differ significantly from those in the control group. However, the count of leukocytes was an exception as its average value in pullets of the experimental group (15.71 G/l) was statistically higher ($P \leq 0.05$) than that in pullets in the control group. No difference in the count of leukocytes occurred in cockerels.

The results of biochemical tests performed with blood plasma of chickens showed more significant differences than those of the haematological examination (Table 3). A highly significant difference ($P \leq 0.01$) between the two groups was found in the case of total plasma protein. The levels of plasma protein in pullets (37.34 g/l) and cockerels (36.44 g/l) of the experimental group were higher than those in the control group (34.56 g/l in pullets and 33.92 g/l in cockerels). The lower levels of plasma protein in chickens of the control group might result from the fact that proteins in the vegetable diet were more efficiently utilized than those in the diet of animal origin. The levels of plasma phosphorus in pullets (2.44 mmol/l) and cockerels (2.14 mmol/l) of the control group were significantly lower ($P \leq 0.01$) in comparison with those in the experimental group (3.12 mmol/l in pullets and 2.54 mmol/l in cockerels). These results can also be explained in terms of more efficient usability of phosphorus and higher digestibility of the plant origin diet compared with the animal origin diet. Unlike phosphorus, the average plasma concentrations of magnesium were found to be significantly higher ($P \leq 0.05$) in both pullets (0.83 mmol/l) and cockerels (0.81 mmol/l) of the control group in comparison with those in chickens of the experimental group (0.77 mmol/l in pullets and 0.72 mmol/l in cockerels). No statistically significant differences in the other biochemical parameters such as levels of glucose, cholesterol, calcium and enzymes (AST and ALT) in blood plasma were found between the two groups. The levels of haematological and biochemical parameters determined in chickens are in accordance with physiological values and reported data (for example Straková *et al.*, 1993).

In conclusion, specially modified rape expellers can serve as a high-quality protein-containing feed that can completely replace meat-and-bone meals in diets used for the fattening of broiler chickens.

REFERENCES

Bickel S., Wetscherek W., Leitgeb R. (2001): Influence of fat source on the performance of broiler, and on relevant carcass characteristics for consumers – 1st Report: Influence of rapeseed oil and animal fat on growing and slaughtering performance of broilers. Bodenkultur, *52*, 45–53.

Haščík P., Kováč M., Hanzlík K. (1994): Substitution of rapeseed oilcake for soybean-meal during the 2nd feeding phase of broilers. Živoč. Výr., *39*, 1041–1047.

Hyánková L., Soukupová Z., Výmola J., Wolf J. (1993): Replacement of soybean-meal in chicken broiler diets by rapeseed and pea. Živoč. Výr., *38*, 601–610.

Mawson R., Heaney R.K., Zdunczyk Z., Kozlowska H. (1994): Rapeseed meal-glucosinolates and their antinutritional effects. 3. Animal growth and performance. Nahr. -Food, *38*, 167–177.

Mendlík J., Kumprecht I., Zobač P., Prokop V. (1999): The effect of fatty acid calcium salts in diets for chick broilers. Czech J. Anim. Sci., *44*, 351–359.

Rothmaier D.A., Kirchgessner M. (1995): Feeding of 00-rape seed to fattening chickens and laying hens. Arch. Geflugelkd., *59*, 241–246.

Smulikowska S., Pastuszewska B., Ochtabinska A., Mieczkowska A. (1998): Composition and nutritional value for chickens and rats of seeds, cake and solvent meal from low-glucosinolate yellow-seeded spring rape and dark-seeded winter rape. J. Anim. Feed Sci., *7*, 415–428.

Straková E., Suchý P., Klecker D. (1993): Variation in the haematological and biochemical parameters of blood of broilers during the feeding. Živoč. Výr., *38*, 725–734.

Venčikov A.I., Venčikov V.A. (1977): Basic methods of statistical data processing in physiology. Avicenum, Prague.

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Requirement of African catfish (*Clarias gariepinus*) larvae for vitamin C administered in dry feed

Potřeba vitaminu C podávaného v suchém krmivu u larev sumečka afrického (*Clarias gariepinus*)

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ABSTRACT: The aim of the paper was to determine requirements of African catfish (*Clarias gariepinus*, Burchell 1822) larvae for vitamin C, with starter feed as the only feed given to fish. The fish received five feeds differing in vitamin C content. The experimental groups were calculated as 0, 50, 100, 500 and 5 000 mg of vitamin C per 1 kg of feed (exact amounts of vitamin measured by HPLC were slightly different). The best growth was achieved by fish receiving about 500 mg of vitamin C (SGR = 21.01, $P < 0.05$, group 4) while the slowest growth (SGR = 18.32, $P < 0.05$) was detected in fish fed the diet with no addition of vitamin C (group 1). The same groups had the lowest and the highest feed conversion rate (FCR = 0.9 and 2.3, respectively, $P < 0.05$) and the ascorbate content in the bodies 9.62 µg/g after 28 days in group 1, 167.6 µg/g in group 4 ($P < 0.05$). The shortest time of complete larval development measured as the time of the air-breathing beginning was found in fish of groups 4 and 5 (308 and 280 D°, respectively) while fish from group 1 receiving the diet deficient in vitamin C finished their development in 607 D°.

Keywords: fish nutrition; African catfish; larvae; vitamin C

ABSTRAKT: Cílem práce bylo stanovení potřeby vitaminu C u larev sumečka afrického (*Clarias gariepinus*, Burchell 1822), které dostávaly startér jako jediné krmivo s různým obsahem vitaminu C. Pro jednotlivé pokusné skupiny byly spočítány dávky 0, 50, 100, 500 a 5 000 mg vitaminu C na 1 kg krmiva (přesná množství vitaminu naměřená pomocí metody HPLC byla poněkud odlišná). Nejlepšího růstu dosáhly ryby, které dostávaly zhruba 500 mg vitaminu C (specifická rychlost růstu SGR = 21,01; P < 0,05, skupina č. 4), zatímco nejpomalejší růst byl zjišten u ryb, které dostávaly krmivo bez přídavku vitaminu C (SGR = 18,32; $P < 0{,}05$, skupina č. 1). Tyto skupiny měly nejnižší, resp. nejvyšší konverzi krmiva (FCR = 0,9, resp. 2,3; $P < 0{,}05$) a obsah askorbátu v těle: (9,62 µg/g po 28 dnech ve skupině č. 1 a 167,6 µg/g ve skupině č. 4; $P < 0{,}05$). Nejkratší doba celého vývoje larev, měřená do začátku dýchání, byla zjištěna u ryb skupiny č. 4 a 5 (308 resp. 280 D°), zatímco ryby ve skupině č. 1, které dostávaly krmivo s nedostatkem vitaminu C, dokončily svůj vývoj za 607 D°.

Klíčová slova: výživa ryb; sumeček africký; larvy; vitamin C

The interest in *C. gariepinus* breeding in Europe primarily follows from considerable ease of the adaptation of this fish species to breeding conditions, from its tolerance to prolonged oxygen deficiency periods, possibility of its breeding in high density culture, ease of artificial reproduction, effective utilisation of feed and disease resistance. Originating from tropical and subtropical regions, *C. gariepinus* could take its place in the aquaculture of countries with colder climate wherever there is an access to waste heat from different technological processes, since scarcity of heat or water suitable for fish breeding requires the use of re-circulation.

While the production of table-size fish poses no major problems, it is true that the process of larvae rearing is still insufficiently developed (Verreth, 1994). Efforts made in this respect were focused on both the identification of nutritional factors (Appelbaum and Van Damme, 1988; Verreth and Tongeren, 1989; Hecht, 1996; Hecht *et al.*, 1996) and factors related to the species physiology in the broad sense (Kamler *et al.*, 1994; Kuczyński *et al.*, 1995; Appelbaum and Kamler, 2000).

One of the fundamental factors affecting the results of fish growth and health is vitamin C. The basic function of ascorbic acid in biological systems is related to its active role of a reducing agent and a participant in a number of enzymatic hydrolytic processes (Rudolph, 1939). Vitamin C plays a major role in detoxication processes associated with the elimination of drugs (Zannoni *et al.*, 1972), pesticides (Wagstaff and Street, 1971; Agarwal *et al.*, 1978) or heavy metal residues (Spivey-Fox, 1975; Hilton, 1989). Increased intensity of vitamin C use was also observed in fish exposed to stress factors as a result of handling, transport or injections, which reduce their immunity to pathogens (Wedemeyer, 1969; Maule *et al.*, 1989). Most vertebrates are capable of synthesising ascorbic acid from glucose, but some of them (including a part of the *Teleostei*) are devoid of this capability and as a result, finding foodstuffs rich in vitamin C is a life-determining factor for them. Feeding fish larvae on plankton organisms enriched with vitamin C is one of the methods used for larvae rearing (Merchie *et al.*, 1997; Kolkovski *et al.*, 2000). An alternative method is the development of starter feeds with their composition adjusted to the needs of rapidly growing larvae. The present study aims to determine vitamin C requirements of *C. gariepinus* larvae in the conditions of larvae rearing with the use of feed.

MATERIAL AND METHODS

Ovulation in 10 females of similar size was induced through the injection of suspension containing an extract of carp's pituitary gland (Hogendoorn and Vismans, 1980). Spawn was obtained manually by stripping, whereas sperm was obtained from males after they had been put to death, through homogenisation of their testicles after preceding resection. Incubation took place in Weiss jars at the temperature of 28°C – which was optimum for embryo development (Kamler *et al.*, 1994). Hatching larvae were collected in stews with 10 cm high water column where they were kept until the resorption of yolk sacs advanced to approximately 80%; subsequently, aquaria were stocked at a density of 100 fishes per dm^3 in triplicate. At the initial stage of experiments on larvae, polyethylene aquaria with the working capacity of 7.0 dm^3 and 10 cm high water column were used until the larvae developed the ability to take in atmospheric air. Three walls of the aquarium were partly replaced by a net with mesh diameter of 500 µm, which enabled free flow of water and removal of refuse to the outside. Polyethylene aquaria were placed inside glass aquaria filled with water that provided an external environment for larvae rearing. The inflow of water to the aquaria amounted to 28 dm^3 per hour. A system constructed in this way enabled the application of a specific cleaning procedure consisting in regular (every 24 hrs) replacement of rearing tanks by the new ones. The emptied tanks were carefully washed in hot water, disinfected and dried. After the fish had developed the ability to breathe air, they were transferred to glass aquaria with the capacity of 70 dm^3, and the cleaning procedure was limited to current (every 3 hrs) removal of refuse from the bottom and walls of the aquaria. After the fish had been transferred to glass aquaria (also in triplicate), water inflow amounted to 280 dm^3 per hour. Fish larvae rearing was conducted in blackout conditions that were assumed to have the best effect on the fish (Appelbaum and Kamler, 2000). Dim light with the intensity of 50 lux was used only at the time of feeding.

Since the commencement of exogenous feeding the fish exclusively received "starter" feed, produced especially for the experimental purposes at Golysz, with its composition supplemented with vitamin C (ascorbate n-polyphosphate) in amounts varying according to the experiment variant (Table 1, 2). The main components of starter feed were: whole wheat flour, LT fish meal, yeasts, beef liver, vitamin and mineral mixtures. Vitamin mixture was prepared in laboratory according to NRC recommendations for Channel catfish (NRC, 1983), but without vitamin C addition. Vitamin C was sprayed on the surface of daily portion at the beginning of each day of experiment, then the feed was dried on air. The fish were fed manually every 30 minutes (day 1 to 7) or every 60 minutes (day 8 to 28). The daily feed ration was established at the level of 30% of the current biomass, which was sufficient for satisfying the needs of the fish without excessive amount of the remainder.

Every 7 days, the stocks in all aquaria were counted; a sample of 30 larvae was taken that were subsequently put to sleep with 2-phenoxyethanol and individually measured and weighed in order to assess the growth. At the same time, a sample of 10 larvae was taken that were left without feeding for 4 hours; subsequently, the content of ascorbates in their bodies was tested. The commencement of air intake from above the water surface by the fish was adopted as a criterion marking the end of the larval stage; at that point, by night unfed fish were put into separate tanks 20 fish per each, and after 60 minutes of adaptation, triplicate fifteen-second tests were made on them to determine the number of respiratory movements (during fifteen seconds, three observers counted respiratory bottom-surface movements).

Based on control weighings and countings of fish, the principal parameters describing the fish growth rate and food assimilation (FCR) were calculated using the formulae given by Filipiak *et al.* (1993). The ascorbate content in feeds and fish bodies was analysed by HPLC methods described by Hoffman *et al.* (1992). The recorded differences were tested for statistical significance by the analysis of variance (ANOVA) and LSD test, applied at the $P < 0.05$ significance level.

RESULTS

In the 28-day period of larvae rearing, the highest average individual body weight was recorded in the fish from Group 4 (833.19 mg per fish), which slightly surpassed the fish from Group 5 (823.54 mg per fish). In Groups 2 and 3, the average individual body weight amounted to 609.88 mg per fish and 761.04 mg per fish, respectively (Table 2). The lowest average body weight amounting to 392.11 mg per fish was recorded in the fish from Group 1. On account of uniform material being used for stocking, the distributions of average individual growth and average daily growth rates (SGR) were similar. Fish survival rates were diversified, and reached the lowest value of 11% in Group 1. In the following groups, fish survival rates were higher and amounted to 30, 32 and 59% in Groups 2, 3 and 4, respectively, while the highest survival rate amounting to 79% was recorded in Group 5 (Table 2). The highest FCR value, amounting to 2.3, was recorded in Group 1. Lower FCR values were recorded in Groups 2 and 3 (1.6 and 1.3, respectively) while the lowest FCR value was found in the fish from Group 4 (FCR = 0.9), which were slightly surpassed by the fish from Group 5 (FCR = 1.0) (Table 2).

The ascorbate content in the bodies of the fish receiving feeds with varying vitamin C contents increased with the lapse of the experiment time, reaching a stable level after different periods. In Group 1, the vitamin C content in fish tissues increased continuously from 4.67 µg/g on the stocking day to 9.62 µg/g on day 28 of the experiment (Table 3). Likewise, in Group 2, a continuous increase in the vitamin C content in the tissues – from 4.62 to 72.48 µg/g was observed. In Group 3, the vitamin C content in fish was observed to increase continuously from 4.69 µg/g on the stock-

Table 1. Scheme of the experiment and dry feed composition

Number of feed/fish group	1	2	3	4	5
Crude protein (g)	518	517	518	518	518
Ether extract (g)	48	48	48	48	48
NFE (g)	248	248	248	248	248
Crude fibre (g)	40	40	40	40	40
Crude ash (g)	145	145	145	145	145
Vitamin C declared (mg)	0	50	100	500	5 000
Vitamin C detected (mg)	0	53	88	485	4 978

Table 2. Results of the experiment (mean values ± SD)

	Group				
	1	2	3	4	5
Initial mean individual weight (mg)	2.32 ± 0.31	2.32 ± 0.31	2.32 ± 0.31	2.32 ± 0.31	2.32 ± 0.31
Final mean individual weigh (mg)	392.11 ± 38.72	609.88 ± 29.64	761.26 ± 31.11	833.19 ± 27.28	823.54 ± 32.14
SGR (%)	18.32^a ± 1.08	19.90^b ± 0.71	20.69^c ± 0.34	21.01^d ± 0.21	20.97^{c,d} ± 0.39
FCR	2.30^a ± 0.32	1.60^b ± 0.32	1.30^c ± 0.21	0.90^d ± 0.11	1.00^d ± 0.14
Survival rate (%)	11.30^a ± 5.13	30.04^b ±3.31	32.11^b ± 1.27	59.00^c ± 5.24	79.23^d ± 6.73

Results in columns denoted by the same letters are not significantly different ($P < 0.05$)

ing day to 163.84 µg/g on day 21 of larvae rearing; afterwards, vitamin C content in the tissues reached a stable level (161.27 µg/g on day 28 of the experiment). The fish from Groups 4 and 5 accumulated vitamin C reserves the fastest and at a similar pace (from 5.02 to 167.60 µg/g on day 14 day in Group 4 and from 4.93 to 163.27 µg/g on day 14 in Group 5) (Table 3).

Depending on the variant, the first differences in vitamin C contents in fish tissues appeared already after 7 days when the lowest amount of vitamin C was accumulated in the fish from Group 1 (6.55 µg per g), higher amounts were recorded in Groups 2, 3 and 4 (25.21; 119.68 and 142.03 µg/g, respectively). After 7 days, the maximum amount of vitamin C was accumulated in the fish from Group 5, in which the amount of 146.72 µg/g was recorded. After 14 days of the experiment, the lowest amount of accumulated vitamin C was recorded in Group 1 (7.80 µg/g), higher amounts in Groups 2 and 3 (33.99 and 112.82 µg/g), and the highest amount of 197.60 µg/g in Group 4. The fish in Group 5 accumulated vitamin C in an amount similar to that recorded in Group 4 (163.27 µg/g). After 21 days, the lowest amount of vitamin C was again accumulated in the fish from Group 1 (8.66 µg/g), a higher

Table 3. Ascorbate content in the bodies of larvae (µg/g)

Stocking day	Group				
	1	2	3	4	5
0	4.67a ± 1.27	4.62a ± 1.29	4.69a ± 1.63	5.02a ± 1.54	4.93a ± 1.38
7	6.55a ± 2.11	25.21b ± 4.24	119.68c ± 11.31	142.03d ± 19.56	146.72d ± 21.22
14	7.80a ± 2.47	33.99b ± 6.17	112.82c ± 16.74	167.60d ±.23.51	163.27d ± 25.05
21	8.66a ± 2.39	36.89b ± 6.39	163.84c ± 24.15	163.81c ±.26.74	164.10c ± 28.07
28	9.62a ± 3.91	72.48b ± 19.44	161.27c ± 23.56	159.92c ± 27.11	161.59c ± 25.05

Results in columns denoted by the same letters are not significantly different ($P < 0.05$)

Table 4. Time of the larval period finishing and the intensity of air-breathing

	Group				
	1	2	3	4	5
Day of the experiment	21.7	14.7	12.7	11.0	10.0
Air-breathing movements (bottom-surface cycles per 1 individual)	3.1 ± 0.3	3.5 ± 0.6	4.1 ± 0.7	5.5 ± 0.7	5.4 ± 0.9
Development time (D°)	607	411	355	308	280
Mean body weight (mg)	141.78 ± 21.15	115.35 ± 27.78	103.05 ± 20.25	88.99 ± 18.77	88.79 ± 18.15

amount was recorded in Group 2 (163.84 µg/g), while the fish in Groups 3, 4 and 5 accumulated similar amounts of ascorbates: 163.84, 163.81 and 164.10 µg/g, respectively. A similar trend was also observed after 28 days of the experiment, when the contents of 9.62, 72.48, 191.27, 159.92 and 161.59 µg of ascorbates per 1 g of fresh tissue were recorded for Groups 1, 2, 3, 4 and 5, respectively (Table 3).

The ability to take in atmospheric oxygen was developed by fish from particular experiment groups at different times and with varying intensity. The fish from Group 5, with the average individual body weight of 88.79 mg per fish, started breathing air the soonest – as early as on day 10 – making an average of 5.4 respiratory movements per 1 minute. The fish from Group 1 (the average individual body weight = 141 mg per fish) were the last to start breathing air – as late as on day 22. The full range of changes according to variants is presented in Table 4.

DISCUSSION

The growth of fish in most of the adopted experiment variants should be perceived as very good. Similar growth rates, which allowed to reach the average individual body weight of almost 1 g after 28 days of larvae rearing, were achieved through feeding newly-hatched *Clarias gariepinus* on live or frozen *Artemia salina* larvae as their first food, later to be gradually replaced by trout starter feed (Hogendoorn, 1980). The use of frozen zooplankton as a comparative feeding variant resulted in the limited growth of fish that achieved the mass of 330 mg per fish after 28 days. In most studies, feeding with starter feeds without any addition of natural food from the very beginning eventuated in a slow-down of fish growth, and the fish mortality rate increased by even as much as 80% (Verreth *et al.*, 1987; Appelbaum and VanDamme, 1988). Therefore the nutritive value of the feed used in this study can be compared with that of mixed feeding with zooplankton and feed.

An obvious relation between vitamin C content in the feed and growth rate of the hatch was repeatedly recorded in similar experiments carried out on newly-hatched larvae and young fry of other fish species. The fry of *Ictalurus punctatus* from a related taxonomic group achieved a maximum mass increase when exposed to a vitamin C dose amounting to 200 mg/kg (Duncan and Lovell, 1994), yet it must be stressed that no tests were carried out for higher doses. Other experiments (Lim and Lovell, 1978; Li and Lovell, 1985) point to the dose of 30 up to 60 mg/kg as an optimum dose for growth stimulation. The hatch of another species related to *Clarias gariepinus*, namely *Silurus glanis*, when fed *Tubifex* worms enriched with ascorbic acid, showed no improvement in growth as compared with the control group receiving the same feed without addition of vitamin C (Papp *et al.*, 1995). The results of the present study indicate that the best growth rate was recorded in the fish that from the very beginning of exogenous feeding received feeds enriched with 485 mg of vitamin C per 1 kg. In the same group, the lowest FCR value was recorded. The highest survival rate was recorded in the group receiving the dose of 4 978 mg of vitamin C per 1 kg, which could be caused by the improved resistance of fish given such a high dose of vitamin C against handling stress to which the fish are exposed due to the adopted larvae rearing procedure. The protective role of vitamin C in relation to the detrimental influence of stress factors was observed in *Ictalurus punctatus* (Mazik *et al.*, 1987). Similar vitamin C requirements of newly-hatched *Clarias gariepinus* as compared with other fish species were recorded by Merchie *et al.* (1997), but their research was carried out with live *Artemia salina* enriched with vitamin C being used as the only source of food instead of artificial dry feed.

If newly-hatched *C. gariepinus* received feed containing 485 mg of vitamin C per 1 kg feed, the accumulation of maximum tissue reserves occurred as soon as after 14 days. Further increase in the vitamin C dose, either through increasing the vitamin content in the feed or through prolonged feeding time, did not lead to an increase in the vitamin C reserves in fish bodies. This indicates that for newly-hatched *C. gariepinus* during the period of 14 days from the commencement of feeding, a vitamin C dose approximating 500 mg per 1 kg of feed is the optimum. The fact that the same level of vitamin C concentration was achieved after 21 days in the case of fish fed 88 mg of vitamin C per 1 kg of feed seems to indicate that vitamin C requirements in the growing larvae of *C. gariepinus* decrease with their growth. This observation seems to explain the exceptionally high vitamin C requirements of newly-hatched *C. gariepinus* as described by Merchie *et al.* (1997), which during the first 10 days of feeding amounted to more than 1 500 mg of vitamin C in the dry mass of *Artemia salina* used as the only food.

The data presented above correlates well with the occurrence of the end of the larval stage indicator, which in the case of *C. gariepinus* is marked by the commencement of air intake from above the water surface. This stage of development was achieved as early as on day 10–11 by the fish receiving the same doses of vitamin C that led to the occurrence of the highest mass increase. The transition to breathing with atmospheric air radically decreases the fish susceptibility to the effects of possible oxygen deficiency and ensures operational comfort (Haylor and Oyegunwa, 1993). 485 mg of vitamin C per 1 kg of feed given to newly-hatched *C. gariepinus* in the present study performed the function of an agent stimulating the individual growth rate. Never before has this aspect of vitamin C been described in literature.

To sum up the results of the study, based on the maximum increase in the average individual body weight, the lowest FCR, the dose of vitamin C that yields the best effects in the case of both these criteria, the concentration 500 mg of vitamin C in 1 kg of dry feed can be recognised as covering larvae requirements.

REFERENCES

Agarwal N.K., Juneja C.J. Mahajan C.L. (1978): Protective role of ascorbic acid in fishes exposed to organochlorine pollution. Toxicology, *11*, 369–375.

Appelbaum S., Kamler E. (2000): Survival, growth, metabolism and behaviour of *Clarias gariepinus* (Burchell, 1822) early stages under different light conditions. Aquacult. Eng., *22*, 269–287.

Appelbaum S., van Damme P. (1988): The feasibility of using exclusively artificial dry feed for the rearing of Israeli *Clarias gariepinus* (Burchell, 1822) larvae and fry. J. Appl. Ichtyol., *4*, 105–110.

Duncan P.L., Lovell R.T. (1994): Influence of vitamin C on the folate requirement of channel catfish, *Ictalurus punctatus*, for growth, hematopoiesis and resistance to *Edwardsiella ictaluri* infection. Aquaculture, *127*, 233–244.

Filipiak J., Trzebiatowski R., Sadowski J. (1993): Określenie optimum zapotrzebowania białkowego dla różnej wielkości sumów afrykańskich (*Clarias gariepinus*) chowanych w wodzie pochłodniczej. Zesz. Nauk. AR Szczecin Ryb. Mor., *156*, 65–75.

Haylor G., Oyegunwa O. (1993): Onset of air breathing and development of accessory breathing organs in relation to temperature in the African catfish, *Clarias gariepinus*. Aquacult. Fish. Manag., *24*, 253–260.

Hecht T. (1996): An alternative life history approach to the nutrition and feeding of Siluroidei larvae and early juveniles. Aquat. Living Res., *9*, 121–133.

Hecht T., Oellermann L., Verheust L. (1996): Perspectives on clariid catfishes culture in Africa. Aquat. Living Res., *9*, 197–206.

Hilton J.W. (1989): The interaction of vitamins, minerals and diet composition in the diet of fish. Aquaculture, *79*, 223–244.

Hoffman K.M., Brown P.R., Maugle P.D. (1992): Comparison of three HPLC methods for the analysis of vitamers of ascorbic acid in shrimp tissue. J. Liquid Chromatogr., *15*, 2581–2610.

Hogendoorn H. (1980): Controlled propagation of the African catfish, *Clarias lazera* (C.&V.). III. Feeding and growth of fry. Aquaculture, *21*, 233–241.

Hogendoorn H., Vismans, M.M. (1980): Controlled propagation of the African catfish, *Clarias lazera* (C.&V.). II. Artificial reproduction. Aquaculture, *21*, 39–53.

Kamler E., Szlaminska M., Kuczynski M., Hamackova J., Kouril J., Dabrowski R. (1994): Temperature – induced changes of early development and yolk utilization in the African catfish, *Clarias gariepinus*. J. Fish Biol., *44*, 181–370.

Kolkovski S., Czesny C., Yackey C., Moreau R., Cihla F., Mahan D., Dabrowski K. (2000): The effect of vitamins C and E in (*n*-3) highly unsaturated fatty acids-enriched *Artemia nauplii* on growth, survival, and stress resistance of fresh water walleye *Stizostedium vitreum* larvae. Aquacult. Nutr., *6*, 199–206.

Kuczynski M., Kryjak P., Szumiec J. (1995): African catfish (*Clarias gariepinus*, Burchell, 1822) tolerance to water pH changes. In: New fish species in aquaculture – conference reports. AR Szczecin. 33–38.

Li Y., Lovell R.T. (1985): Elevated levels of dietary ascorbic acid increase immune responses in channel catfish. J. Nutr., *115*, 123–131.

Lim C., Lovell R.T. (1978): Pathology of the vitamin C deficiency syndrome in channel catfish. J. Nutr., *108*, 1137.

Maule A.G., Tripp R.A., Kaattari S.L., Shreck C. (1989): Stress alters immune function and disease resistance in chinook salmon (*Oncorhynchus tshawytscha*). J. Endocrin., *120*, 135–142.

Mazik P.M., Brandt T.M., Tomasso J.R. (1987): Effects of dietary vitamin C on growth, caudal fin development and tolerance of aquaculture-related stressors in channel catfish. Prog. Fish. Cult., *49*, 13–16.

Merchie G., Lavens P., Dhert Ph., Garcia Ulloa Gomez M., Nelis, de Lenheer A., Sorgeloos P. (1997): The effect of supplemental ascorbic acid in enriched live food for *Clarias gariepinus* larvae at start-feeding. Aquaculture, *151*, 245–258.

National Research Council, Board of Agriculture, Committee on Animal Nutrition, Subcommitee on Warmwater Fish Nutrition (1983): Nutrient Requirements of Warmwater Fishes and Shellfishes. National Academy Press. 102 pp.

Papp Z.G., Kovacs G., Radics F. (1995): Vitamin C status in different embryonic stages and larvae of European catfish (*Silurus glanis*) fed with L-ascorbic acid supplemented diet. Larvi'95, Ghent., 235–237.

Rudolph W. (1939): Vitamin C und Ernahrung. Ferdinand Enke Verlag, Stuttgart. 96 pp.

Spivey-Fox M.R. (1975): Protective effects of ascorbic acid against toxicity of heavy metals. Ann. N.Y. Acad. Sci., *258*, 144–150.

Verreth J. (1994): Nutrition and related ontogenetic aspects in larvae of the African catfish, *Clarias gariepinus*. [D.Sc. Thesis.] Wageningen Agricultural University, Wageningen. 205 pp.

Verreth J., Storch V., Segner H. (1987):. A comparative study on the nutritional quality of decapsulated Artemia cysts, micro- encapsulated egg diets and enriched dry feeds for *Clarias gariepinus* (Burchell) larvae. Aquaculture, *63*, 269–282.

Verreth J., van Tongeren M. (1989): Weaning time in *Clarias gariepinus* larvae. Aquaculture, *83*, 81–88.

Wagstaff D.J., Street J.C. (1971): Ascorbic acid deficiency and induction of hepatic microsomal hydroxylative enzymes by organochloride pesticides. Toxicol. Appl. Pharmacol.,*19*, 10–19.

Wedemeyer G. (1969): Stress induced ascorbic acid depletion and cortisol production in two salmonid fishes. Comp. Biochem Physiol., *29*, 1247–1251.

Zannoni V.G., Flynn E.J., Lynch M. (1972): Ascorbic acid and drug metabolism. Biochem. Pharmacol., *21*, 1377–1392.

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Effects of dietary vitamin E supplementation on α-tocopherol content and antioxidative status of beef muscles

Vplyv prídavku vitamínu E v krmive na obsah α-tokoferolu a antioxidačný stav vo svaloch jatočných býkov

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ABSTRACT: The effect of feeding a high level of vitamin E on the level of α-tocopherol in muscle tissue and on the antioxidative status of *longissimus thoracis* (LT) and *psoas major* (PM) of bulls (Slovak Pied, $n = 16$) was investigated. Treatments ($n = 8$) consisted in supplementation of vitamin E (1 000 mg α-tocopherol acetate/head/day) for the last 100 days before slaughter (average 540 kg live weight). Concentration of α-tocopherol was estimated from *ante-mortem* biopsy (taken before slaughter) samples of *m. semitendinosus* (ST) and *post-mortem* samples of LT and PM. Total protein, total water, intramuscular fat, total pigments, pH 48 h *post-mortem* and rate of oxidation by stimulation with Fe^{2+}/ascorbate were estimated in LT and PM muscles. The level of α-tocopherol was higher ($P < 0.05$) in muscles (LT, PM and ST) from bulls treated with higher vitamin E than in controls in the order PM > ST > LT. The level of α-tocopherol can be controlled also *ante-mortem* (ST muscle). The rate of oxidation was positively influenced by vitamin E supplementation in the order PM > LT. We concluded that dietary vitamin E supplementation (1 000 mg α-tocopherol acetate/head/day) for the last 100 days to finishing bulls increases α-tocopherol concentrations in muscle and improves the antioxidative status of muscle tissue.

Keywords: bulls; vitamin E; α-tocopherol in muscle; antioxidative status

ABSTRAKT: Cieľom práce bolo zistiť vplyv prídavku vitamínu E v krmive na obsah α-tokoferolu a antioxidačnú stabilitu vo svaloch jatočných býkov (slovenské strakaté, $n = 16$). Aplikácia vitamínu E (1 000 mg α-tokoferol acetátu/zviera/deň) v krmive ($n = 8$) sa robila po 100 dní pred zabitím (priemerná hmotnosť 540 kg). Obsah α-tokoferolu sa zistil vo vzorkách *m. semitendinosus* (ST) odobratých biopsiou pred zabitím a vo vzorkách *m. longissimus thoracis* (LT) a *psoas major* (PM) *post-mortem*. Celkový obsah bielkovín, vody, intramuskulárneho tuku, pigmentov, pH 48 h *post-mortem* a rýchlosť oxidácie po stimulácii homogenátov svalu s Fe^{2+}/askorbát sa zistil vo svaloch LT a PM. Obsah α-tokoferolu bol vyšší ($P < 0.05$) vo svaloch býkov po aplikácii zvýšeného prídavku vitamínu E v krmive v poradí PM > ST > LT. Obsah α-tokoferolu vo svale je možné kontrolovať tiež *ante-mortem* (ST). Rýchlosť oxidácie homogenátu svalu bola pozitívne ovplyvnená prídavkom vitamínu E v krmive v poradí PM > LT. Aplikácia zvýšeného prídavku vitamínu E (1 000 mg α-tokoferol acetátu/zviera/deň) v krmive 100 dní pred zabitím zvýši obsah α-tokoferolu a antioxidačnú stabilitu vo svaloch jatočných býkov.

Kľúčové slová: jatočné býky; vitamín E; α-tokoferol vo svale; antioxidačná stabilita

Vitamin E primarily functions as an antioxidant protecting polyunsaturated fatty acids in *in-vivo* and *post-mortem* animal tissues and muscle nutrients (Morrissey *et al.*, 1994) from free-radical attack. Dietary supplementation of vitamin E increases the concentration of α-tocopherol in muscle and reduces the susceptibility of the muscle to lipid oxidation (Buckley *et al.*, 1995). Inclusion of polyunsaturated fatty acids (PUFA) in diets increases the risk of lipid oxidation in the muscle and carcass (Jakobsen, 1995). Oxidation of PUFA in cell membranes leads to disruption of normal membrane structure and function (Storrey, 1996). Vitamin E present in skeletal muscles is able to inhibit lipid oxidation in muscle nutrients. During the *post-mortem* metabolism of muscles the process of lipid oxidation need no longer be tightly controlled due to the weakness of antioxidative defence systems, and this can affect meat quality traits (Lauridsen *et al.*, 1999). Dietary supplementation of cattle with α-tocopheryl acetate was shown to control loss of desirable colour, lipid oxidation and accumulation of metmyoglobin in beef (Arnold *et al.*, 1993; Augustini *et al.*, 1998; Lahučký *et al.*, 1999). The extension of antioxidant status and beef colour display life depend on the level and duration of supplementation with dietary vitamin E and only prolonged dietary supplementation allows for incorporation of α-tocopherol into subcellular compartments (Buckley *et al.*, 1995). As was shown by estimation of α-tocopherol concentrations in beef muscles and its general distribution around the carcass (Lynch *et al.*, 2000), a high degree of meat quality prediction can be established.

The aims of this study were to examine the effects of dietary vitamin E supplementation on α-tocopherol concentration and antioxidative status of beef muscles.

MATERIAL AND METHODS

Animal, diets and sampling procedure

Slovak Pied bulls (n = 16, 17 months of age) were housed in confinement on an experimental farm of the Research Institute of Animal Production, Nitra. During the fattening period they were fed *ad libitum* a whole crop silage based diet, supplemented with 2–3 kg of concentrate. Animals were selected at random and divided into two groups (each n = 8) and fed standard diets containing 20 (basal) or 1 000 mg (supplemented) α-tocopheryl acetate/head/day for approximately 100 days prior to slaughter. Each group was held in separate pens and each animal was fed individually. Animals were slaughtered at an average live weight of 540 ± 45 kg under the conditions of the Institute (RIAP Nitra) facilities. Just before slaughter a biopsy muscle sample of *m. semitendinosus* (approximately 1 g) was taken with quick and efficient spring-loaded biopsy instrument (Biotech, Slovakia) and stored (liquid nitrogen) until analysed. After approximately 48 h of chilling (at 3–4°C) carcasses were cut and *m. longissimus thoracis* (LT), *m. psoas major* (PM) and *m. semitendinosus* (ST) were collected. At the laboratory, all three muscles were portioned (frozen in liquid nitrogen and stored at –40°C) for the assessment of α-tocopherol content. A portion of LT and PM muscles was used for chemical, biophysical and antioxidative status analyses.

Methods and statistical analyses

The contents of α-tocopherol in biopsies of ST and in LT, ST and PM muscles were assessed by high performance liquid chromatography as described by Berlin *et al.* (1994), simplified by Liu *et al.* (1996) and further described by Lahučký *et al.* (2001). Results were expressed in µg α-tocopherol/g muscle.

The pH value of the carcass (LT) was directly determined in 48 h *post-mortem* with portable pH meter, model 3071, Jenway (England) using a combined glass electrode (P19/BNC). Chemical analyses (total protein, intramuscular fat and water) were made with the Infratec-Analyser (Germany) from LT and PM muscles.

Lipid oxidation was determined by measuring 2-thiobarbituric acid reactive substances (TBARS) using a modified method (Salih *et al.*, 1987) and was expressed as µg malondialdehyde (MDA) per g muscle. To evaluate the antiperoxidative status (AS) of LT and PM homogenates the determination of TBARS was used. TBARS were expressed in terms of malondialdehyde, a breakdown product formed during peroxidation stimulated by Fe^{2+}/ascorbate as described by Lahučký *et al.* (2001).

Total pigments were estimated as chlorohematine, measured at 640 nm as described by Pribis and Rede (1987).

The experiments were carried out in accordance with the institution guidelines for animal care (Research Institute of Animal Production, Nitra, 2000).

Statistical analyses were calculated as mean values and standard error and differences were evaluated by t-test.

RESULTS AND DISCUSSION

The biophysical and chemical traits of LT and PM muscles from control and treated animals are presented in Table 1 and Table 2. In LT and PM all samples from control and treated groups had ultimate pH values < 6.0. No significant difference in ultimate pH was found between treatments of groups. Vitamin E supplementation does not influence pH values as was earlier shown on beef by Eikelenboom *et al.* (2000). No significant ($P > 0.05$) effect of the vitamin E treatment was found on total values of protein, water, intramuscular fat content and total pigments. However, the levels of intramuscular fat and total pigments were higher ($P < 0.05$) in PM muscle. Lipid oxidation in fresh muscles (LT, PM), as indicated by the level of MDA, was significantly ($P < 0.05$) affected by the dietary treatments only in PM muscle (Table 2).

The effect of vitamin E supplementation on α-tocopherol content in muscle tissue is presented in Table 3. The levels of α-tocopherol were determined 1 month after slaughter in muscles frozen in liquid nitrogen and stored in the dark at –40°C. Higher levels of α-tocopherol were found in all muscles from animals fed the supplemented diet (1 000 mg α-tocopheryl acetate/head/day) for approximately 100 days if compared with the basal group (20 mg α-tocopheryl acetate/head/day). These differences were significant ($P < 0.05$) for all muscles and similar findings were reported by den Hertog-Meischke *et al.* (1997), Flachowsky (1998) and Lynch *et al.* (2000). Muscles differ in the amount of α-tocopherol they contain. In this study, α-tocopherol in muscles from the treated group decreased in the order *m. psoas major* > *m. semitendinosus* > *m. longissimus thoracis* (Table 3). Chan *et al.* (1996) reported that α-tocopherol concentrations in muscles fol-

Table 1. Meat quality parameters of control (group C) and supplemented (group E) bovine *m. longissimus thoracis* 48 h *post-mortem*

Parameter	Group C (n = 8)		Group E (n = 8)	
	mean	SE	mean	SE
pH	5.65	0.11	5.54	0.11
Total water (%)	74.86	0.59	74.74	0.49
Total protein (%)	22.51	0.52	22.76	0.29
Intramuscular fat (%)	2.15	0.36	2.38	0.31
Malondialdehyde (μg/g)	0.27	0.12	0.21	0.16
Total pigments (μg/g)	116.68	6.37	125.31	9.99

Group C = control group (vitamin E 20 mg/kg diet)
Group E = group with vitamin E (supplementation of vitamin E 1 000 mg/animal/day)

Table 2. Meat quality parameters of control (group C) and supplemented (group E) bovine *psoas major* 48 h *post-mortem*

Parameter	Group C (n = 8)		Group E (n = 8)	
	mean	SE	mean	SE
pH	5.65	0.07	5.56	0.15
Total water (%)	75.01	0.53	74.26	0.84
Total protein (%)	21.91	0.41	21.87	0.25
Intramuscular fat (%)	3.02	0.64	3.62	0.47
Malondialdehyde (μg/g)	0.36	0.17	0.20[a]	0.14
Total pigments (μg/g)	155.17	9.46	164.83	8.52

[a]$P < 0.05$
Group C = control group (vitamin E 20 mg/kg diet)
Group E = group with vitamin E (supplementation of vitamin E 1 000 mg/animal/day)

Table 3. Effect of vitamin E supplementation on the concentration of α-tocopherol in *post-mortem* bovine *m. longissimus thoracis* (LT), *psoas major* (PM) and *ante-mortem m. semitendinosus* (ST) samples

Trait	n	Group C		Group E	
		mean	SE	mean	SE
Piost-mortem					
m. longissimus thoracis	8	2.87	0.21	4.32[c]	0.17
m. psoas major	8	4.24	0.24	6.77[b]	0.37
Ante-mortem					
m. semitendinosus	5	3.56	0.64	6.55[a]	0.94

[a]$P < 0.05$; [b]$P < 0.01$; [c]$P < 0.001$

Group C = control group (vitamin E 20 mg/kg diet)

Group E = group with vitamin E (supplementation of vitamin E 1 000 mg/animal/day)

lowed the order *m. psoas major* > *m. gluteus medius* > *m. longissimus dorsi,* and it is in agreement with the trends found in this study. The average α-tocopherol content was higher in PM muscles than in LT muscles. It could be explained by differences in the number of mitochondria between the muscles (PM being redder as followed from the level of total pigment – Table 1, Table 2 and oxidative) because it was observed before that mitochondria have the greatest capacity of vitamin E storage, when subcellular muscle fractions are compared (Asghar *et al.*, 1991). Interesting is that a similar tendency of α-tocopherol content was found between the samples of ST muscles taken *ante-mortem* (biopsy) and samples of LT and PM taken *post-mortem.* ST muscle was chosen for its availability for this way of biopsy sampling (taken with quick shot or spring-loaded biopsy instrument) in cattle (Lahučký *et al.*, 1998). It follows from the findings of this study that it is possible to use biopsy samples of ST muscle to control α-tocopherol content *ante-mortem.*

Beef muscles which contain predominantly oxidative fibres with higher level of pigments, such as the PM, have been shown to have a higher concentration of α-tocopherol relative to other glycolytic muscles following dietary α-tocopherol supplementation (Lynch *et al.*, 2000).

Incorporation of the antioxidant vitamin E into finishing diet for cattle improves both colour and lipid stability (Sanders *et al.*, 1997; Augustini *et al.*, 1998; Lahucky *et al.*, 1999). It was reported that an optimal α-tocopherol concentration to

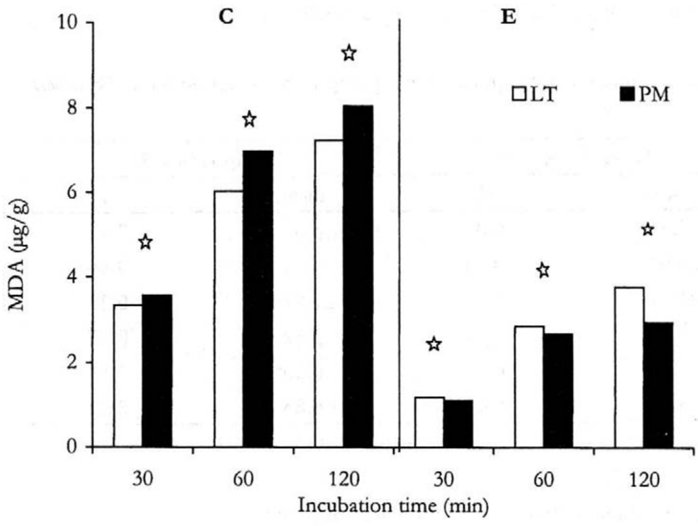

Figure 1. Effect of dietary vitamin E supplementation on the antioxidant stability of *m. longissimus thoracis* (LT) and *psoas major* (PM) (incubation of muscle homogenate with Fe^{2+}/ascorbate)

Group C = control group (vitamin E 20 mg/kg diet)
Group E = group with vitamin E (supplementation of vitamin E 1 000 mg/animal/day)
MDA = malondialdehyde
☆ = differences between C and E groups are significant at each incubation time ($P < 0.001$)

retard metmyoglobin formation in LT muscle was 3.5–4.0 µg/g (Chan *et al.*, 1996). By increasing α-tocopherol concentrations in bovine muscles and its general distribution throughout the bovine carcass, a high degree of antioxidant stability and meat quality prediction can be established. Several studies have shown that dietary supplementation with vitamin E reduces the susceptibility of muscle membranes to Fe^{2+}-induced lipid oxidation (Lauridsen *et al.*, 2000; Lahucky *et al.*, 2001). It follows from Figure 1 that the rate of iron-induced muscle homogenate was strongly influenced by dietary vitamin E and antioxidative status increased in the order PM > LT.

We concluded that dietary α-tocopherol supplementation (1 000 mg/head/day) to bulls during 100 days of finishing increases the α-tocopherol concentration of muscle tissue that may also be controlled in biopsy samples (*m semitendinosus*) *ante-mortem*. The antioxidative status of muscle tissue is substantially improved in the order *psoas major* > *longissimus thoracis*.

REFERENCES

Augustini Ch., Schwartz F.J., Kirchgessner M. (1998): Qualitätsverbesserung von Rindfleisch nach Vitamin E – Zulagen in der Endmast von Jungbullen. II. Fleischfarbe, Fettstabilität und Wasserbindung. Fleischwirtschaft, *78*, 208–217.

Arnold R.N., Arp S.C., Scheller K.K., Williams S.N., Schaefer D.M. (1993): Effects of supplementing cattle with vitamin E upon α-tocopherol eqiulibration in tissues and incorporation into *longissimus fractions* and upon lipid and myoglobin oxidation in displayed beef. J. Anim. Sci., *71*, 105–118.

Asghar A., Gray J.I., Booren A.M., Gomas E., Abouzied M.M. (1991): Effects of supra-nutritional dietary vitamin E levels on subcellular deposition of α-tocopherol in the muscle and on pork quality. J. Sci. Food Agric., *57*, 31–41.

Berlin E., McClure D., Banks M.A., Peters R.C. (1994): Heart and liver fatty acid composition and vitamin E content in miniature swine fed diets containing corn and menhaden oils. Comp. Biochem. Physiol., *109A*, 53–61.

Buckley D.J., Morrissey P.A., Gray J.I. (1995): Influence of dietary vitamin E on the oxidative stability and quality of pig meat. J. Anim. Sci., *73*, 3122–3131.

Chan W.K.M., Hakkarainen K., Faustman C., Schaefer D.M., Scheller K.K., Liu Q. (1996): Effect of dietary vitamin E supplementation on microbial load and sensory assessment in different beef cuts. Meat Sci., *42*, 387–399.

Den Hertog-Meischke M.J.A., Smulders F.J.M., Houben J.H., Eikelenboom G. (1997): The effect of dietary vitamin E supplementation on drip loss of bovine *longissimus lumborum, psoas major* and *semitendinosus muscles*. Meat Sci., *45*, 153–160.

Eikelenboom G., Hoving-Bolink A.H., Kluitman I., Houben J.H., Klont R.E. (2000): Effect of dietary vitamin E supplementation on beef colour stability. Meat Sci., *54*., 17–22.

Flachowsky G. (1998): Transfer von Vitamin-E-Zulage in der Tierernährung in Lebensmittel tierischer Herkunft. Vitaminspur, *13*, 40–44.

Jakobsen K., Engberg R.M., Andersen J.O., Jensen S.K., Lauridsen C., Sorensen P., Henckel P., Bertelsen G., Skibsted L.H., Jensen C. (1995): Supplementation of broiler diets with all-rac-α- or a mixture of natural source RRR-α- ,γ- ,δ-tocopheryl acetate. 1. Effect on vitamin E status of broilers *in vivo* and at slaughter. Poult. Sci., *74*, 1984–1994.

Lahučký R., Palanská O., Mojto J., Zaujec K., Huba J. (1998): Effect of preslaughter handling on muscle glycogen level and selected meat quality traits in beef. Meat Sci., *50*, 389–393.

Lahučký R., Palanská O., Zaujec K., Pavlič M., Huba J. (1999): Impact of vitamin E on meat quality of bulls, (in Slovak). J. Farm Anim. Sci. (Nitra, *XXXII*, 133–138.

Lahučký R., Krška P., Küchenmeister U., Nürnberg K., Bahelka I., Demo P., Kuhn G., Ender K. (2001): Influence of dietary vitamin E supplementation on antioxidative status in muscle and meat quality of pigs. Czech J. Anim. Sci., *46*, 327–332.

Lauridsen Ch., Nielsen J.H., Henckel P., Sorensen M.T. (1999): Antioxidative and oxidative status in muscles of pigs fed rapeseed oil, vitamin E, and copper. J. Anim. Sci., *77*, 105–115.

Lynch M.P., Kerry J.P., Buckley D.J., Faustman C., Morrissey P.A. (2000): Effect of dietary vitamin E supplementation on the colour and lipid stability of fresh, frozen and vacuum-packed beef. Meat Sci., *52*, 95–99.

Liu Q., Lanari M.C., Schaefer D.M. (1996): A review of dietary vitamin E supplementation for improvement of beef quality. J. Anim. Sci., *73*, 3131–3140.

Morrissey P.A., Qiunn P.B., Sheehy P.J.A. (1994): Newer aspects of micronutrients in chronic disease: vitamin E. Proc. Nutr. Soc., *53*, 571–582.

Pribis N., Rede R. (1987): O boji mesa – II. Odredivanje merenje boje mesa. Technologija mesa, *XXIV*, 39–47.

Salih A.M., Smith D.M., Price J., Dawson L.E. (1987): Modified extraction 2-thiobarbituric acid method for measuring lipid oxidation in poultry. Poultry Sci., *66*, 1483–1488.

Sanders S.K., Morgan J.B., Wulf D.M., Tatum J.D., Williams S.N., Smith G.C. (1997): Vitamin E supplementation of cattle and shelf-life of beef for the Japanese market. J. Anim. Sci, *75*, 2634–2640.

Storrey K.B. (1996). Oxidative stress: Animal adaptations in nature. Braz. J. Med. Biol. Res., *29*, 1715–1733.

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Use of BIA method for the estimation of beef carcass composition – weight of *longissimus lumborum* muscle, ratio of muscle tissue and fat in loin cross-section

Použití BIA metody k odhadu složení jatečně upravené půlky skotu – hmotnost svalu *longissimus lumborum*, procentuální obsah svaloviny a tuku v řezu nízkého roštěnce

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ABSTRACT: Bioelectrical impedance analysis was tested on 54 beef carcasses for prediction of their composition – weight of *longissimus lumborum* muscle, ratio of muscle tissue and fat in the cross-section of loin. A four-electrode method of measurement with planispheric elastic electrodes coated with Cu-foil of the surface area about 30 cm^2 was used for measurements of BIA. To use a bioimpedance analyzer, developed for measurements of resistance and reactance at frequencies of 1 kHz, 10 kHz and 100 kHz, as a fully automatic measuring system for on-line measurements on slaughter lines, it was connected to PC. Relatively high correlations were found between *longissimus lumborum* muscle weight (MLL) and BIA values. Specific values of resistance (100Rp/D) and reactance (100Xcp/D) measured at frequency of 100 kHz show a high correlation $r = 0.907$ and $r = 0.906$, so they are good predictors for the estimation of this muscle weight. The variables derived from reactance 100Xcp (100Xcp/L ...$r = 0.816$ and L^2/100Xcp.... $r = 0.836$) show the highest dependence on the muscle tissue area. To make up the regression equation of estimation of carcass composition a stepwise regression analysis was used. Loin weight was exactly estimated by the model with coefficient of determination $r^2 = 0.88$ and correlation coefficient $r = 0.94$. The best regression equation for the estimation of relative ratio of muscle tissue (% muscle) and relative fat ratio by VIA shows satisfactory coefficients of determination $r^2 = 0.72$ and $r^2 = 0.63$. These are the best coefficients of direct estimation of adipose tissue ratio in beef carcasses achieved until now.

Keywords: bioelectrical impedance; beef carcass; resistance; reactance; video image analysis

ABSTRAKT: Na 54 jatečně upravených tělech skotu byla zkoušena metoda bio-impedanční analýzy za účelem odhadu jejich složení – hmotnosti svalu *longissimus lumborum*, poměru svalové tkáně a tuku na řezu nízkého roštěnce. K měření bioelektrické impedance byla použita čtyřelektrodová metoda s plošnými pružnými elektrodami opatřenými na povrchu měděnou fólií o ploše 30 cm^2 (150 × 20 mm). Abychom využili bioimpedanční analyzér vyvinutý pro měření rezistence a reaktance při frekvencích 1 kHz, 10 kHz a 100 kHz jako plně automatický měřicí systém pro on-line měření na jatkách, propojili jsme jej s PC. Byla nalezena poměrně vysoká korelace mezi

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hmotností svalu *longissimus lumborum* (MLL) a BIA veličinami. Měrné hodnoty rezistence (100Rp/D) a reaktance (100Xcp/D) naměřené při frekvencích 100 kHz vykazují vysokou korelaci $r = 0.907$ a $r = 0.906$ a jsou tak dobrými prediktory pro odhad hmotnosti tohoto svalu. Nejvyšší závislosti k ploše svaloviny vykazují veličiny odvozené z reaktance 100Xcp (100Xcp/L ...$r = 0.816$ a L^2/100Xcp.... $r = 0.836$). Pro nalezení regresní rovnice odhadu složení jatečně upravených těl skotu byla použita step-wise regresní analýza. Přesný odhad hmotnosti roštěnce byl docílen u modelu s koeficientem determinace $r^2 = 0.88$ a koeficientem korelace $r = 0.94$. Nejlepší regresní rovnice odhadu relativního poměru svalové tkáně a relativního poměru tuku vykazuje uspokojivé koeficienty determinace $r^2 = 0.72$ a $r^2 = 0.63$. Jsou to nejlepší doposud dosažené koeficienty přímého odhadu tukové tkáně jatečně upravených těl skotu.

Klíčová slova: bioelektrická impedance; jatečně upravené tělo skotu; rezistence; reaktance; analýza obrazu

Techniques for simple, non-destructive and repeatable assessment of the absolute and relative fat-free mass, fat and water content of animals are used both in medical and animal science. Bioelectrical impedance analysis (BIA) developed for estimating the body composition in human subjects (Lukaski *et al.*, 1985, 1986; Lukaski, 1987; Segal *et al.*, 1988; Jaeger *et al.*, 1999; Fijter *et al.*, 2000) was tested in animals (Jenkins *et al.*,1988; Swantek and Lukaski, 1991; Marchello *et al.*, 1992, 1994; Kushner, 1992; Swantek *et al.*, 1992; Thiele, 1993). Recently BIA has been shown to be able to predict skeletal muscle mass in farm animals, e.g. 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; Jenkins *et al.*, 1988).

Evaluation of the quality of carcasses is important for their objective grading to ensure correct relations between livestock producers and meat processors when animals are sold and purchased. Simultaneously, assumptions for further destination of meat according to their composition are set up, i.e. retail meat and raw material for meat products.

In the case of retail meat the proportion of muscle tissue and the size of individual lean cuts are important criterions for culinary preparation. However, the fat content is mostly important for meat used for further production, thus the carcass grading includes the estimation of fat content.

The methods for determining the human body composition are offered in an exhaustive description by Lukaski (1987). The publication includes both traditional and new methods, including BIA, applied in human medicine to estimate fat-free mass (FFM/kg), total body water, extracellular water and protein, etc. The same topic is dealt with in papers by Lukaski *et al.* (1986) and Thomas *et al.* (1992). Among the fundamental literature sources, it was Lukaski *et al.* (1985), who described the methods of tetrapolar impedance analysis and its application for the estimation of fat-free mass of human body. There are no papers dealing with direct determination of body fat by BIA in a satisfactory way. The achieved correlations between body fat and electrical values, published by Lukaski *et al.* (1985), are low: the correlation between body fat and Rs is $r = 0.45$ and for L^2/Rs is $r = 0.49$. These values are determined on the basis of calculations from an absolute estimation of FFM and subsequent calculation from the known body weight.

Needle electrodes in various modifications are frequently used for BIA estimation of the body composition of livestock and their carcasses. The concept differs whether living animals or their carcasses are used or for the particular species of tested animals. Electrodes are used in tetrapolar arrangement, when the supply conductors of drive circuits are separated from the measuring one. It is a more exact principle of measurement that helps to eliminate the polarization effect and electrode contact resistance, thus enabling to carry out measurements within the potential linear course (Lukaski *et al.*, 1985; Swantek and Lukaski, 1991; Bohuslávek, 2000; Bohuslávek *et al.*, 2000). Needle electrodes offer satisfactory results of laboratory and experimental measurements, e.g. Swantek and Lukaski (1991) tested a possibility of FFM estimation in living market swine and pork carcasses in this way. The best regression model of FFM estimation achieved $r^2 = 0.84$. Measurements with needle electrodes carried out by Jenkins *et al.* (1995) demonstrated a possibility of BIA application for the FFM estimation in a heterogeneous population of cattle. Regression equation for estimating the carcass fat-free soft tissue (kg) in cattle was deduced on the basis of measured electrical properties, body length and carcass weight; it demonstrates very good accuracy for estimation with $r^2 = 0.942$. During tests of the BIA method suitability for estimation of beef carcass conformation carried out at a high-performance abattoir line (Bohuslávek, 2002b) some imperfections of needle electrodes occurred (difficulty of exactly placing the electrodes, undesirable contact with bones, damage). They provided worse results in the estimation of quality parameters (the conformation due to EU standards).

Attempts to estimate the values of absolute or relative fat content by BIA brought about only poor results. For example Thiele (1993) described experiments with needle electrodes to estimate total body water (TBW) and fat content in the body of slaughter pigs. The best regression model for fat content prediction showed a lower determination coefficient $r^2 = 0.53$. Hegarty *et al.* (1998) tested the use of multi-frequency impedance analysis for prediction of the chemical composition of lamb carcasses. In the equation for the estimation of fat content the low determination coefficient $r^2 = 0.35$ was achieved between L^2/Z_{50} and fat. At the same time the multi-frequency impedance Zc caused no improvement (Z_{50}....impedance at frequency 50 KHz, L...carcass length).

Video Image Analysis (VIA) of loin cross-section is used to determine the values of fat and meat content. There exist several methods for the evaluation of the section in individual images. The section area is usually evaluated between two lines; one follows the external border of vertebra, the other is different in individual papers. German authors (Branscheid *et al.*, 1999) use a tangent to the external border of ribs whereas in Japanese ones (Nade *et al.*, 2001) this line links the end of vertebra and *musculus ilocostalis*.

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 a slaughter line. Using electrical values obtained from BIA the weight of *musculus longissimus lumborum et thoracis* and absolute and relative proportions of muscle tissue and fat in the cross-section between the 8th and 9th ribs evaluated by VIA method is estimated.

MATERIAL AND METHODS

Description of the carcass collection

The measuring system was verified at an abattoir in Kostelec near Jihlava, where 54 beef carcasses (young bulls, cows, heifers) were measured during a part of the shift. Measurements were carried out on left half-carcasses. The physical and electrical characteristics for carcasses of the group of evaluated animals ($n = 54$) are summarized in Table 1.

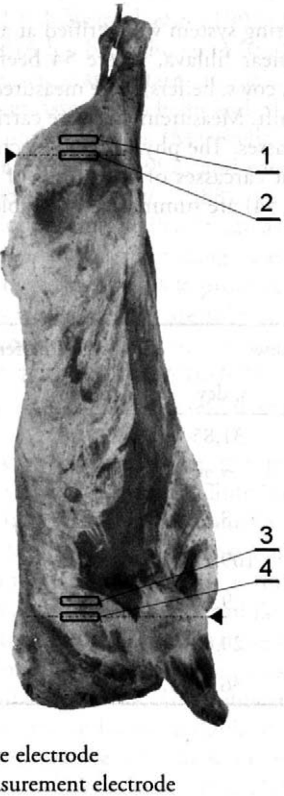
Table 1. Characteristics of the group of evaluated animals ($n = 54$)

Category	40 young bulls		10 cows		4 heifers	
	mean	s. dev.	mean	s. dev.	mean	s. dev.
CW (kg)	395.00	44.12	264.40	31.85	296.20	18.75
Carcass Length (cm)	273.50	9.08	265.50	7.29	253.00	7.26
1Rp (ohm)	112.02	9.83	166.62	8.67	151.12	12.47
100Xcp (ohm)	283.17	47.70	513.34	109.15	417.98	40.76
100Rp (ohm)	70.73	6.82	108.85	9.60	98.90	8.15
MA (cm²)	169.71	29.15	101.83	20.88	140.14	17.41
TA (cm²)	215.03	33.8	167.10	36.71	236.22	36.73

CW = carcass weight (kg)
1Rp = resistance at frequency 1 kHz
100Xcp = reactance at frequency 100 kHz
MA = area of muscle cross-section between 8th and 9th ribs
TA = total area of cross-section between 8th and 9th ribs
100Rp = resistance at frequency 100 kHz

Description of measuring method and device

A four-electrode method of measurement with flat elastic electrodes coated with Cu-foil of the surface area about 30 cm^2 was used for measurement of BIA. A newly developed (at the author's workplace) impedance analyzer enabled measurements of impedance and phase angle at three frequencies (1 kHz; 10 kHz and 100 kHz). The alternating current 5 mA only could be used for measurements on carcasses of animals. The mechanical concept of telescopic electrode adapter including means of measurement of their distance was identical to the experiments described by Bohuslávek (2002b). Simple anatomic definition allowed placement of electrodes and enabled fast attendance and good contact of electrodes. The electrodes were situated from the external side of left half-carcasses. All electrodes were placed on the vertical lines going through the heel tendon (*tendo calcaneus*). The upper measuring electrode was placed on the horizontal line going through the broadest part 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 from measuring electrodes (Figure 1). A scheme in Figure 1 shows their exact position. The measuring instrument was charged from NiMh batteries and communicated with central computer through Irda interface. Due to this matter the galvanic selection from grid was simply provided and higher resistance against the interference was assured. The program of central computer used only two frequencies (1 kHz and 100 kHz) for measurements. This program automatically archived transmitted data from the analyzer (impedance, angle) and manually inserted data into PC (number of measured piece, distance of electrodes and piece) into ASCII table and Excel format.



1, 4 = drive electrode
2, 3 = measurement electrode

Figure 1. Placement of electrodes on the carcass surface

Reference values – obtained during dissection of beef carcasses

The images of cross-sections between the 8th and 9th rib were taken after cooling by digital camera Olympus 2020 Zoom; constant distance, calibration and camera axis perpendicularity to the section plane was provided by special equipment.

The dorsal parts – loins (caudally from the 8th rib) incl. backbone were cut from the beef carcasses and weighed (SV). These parts were deboned and weighed again (S). Finally all other tissues (adipose etc.) were removed from the *longissimus lumborum et thoracis* muscles and these muscles were weighed too (MLLT). These weight values were correlated with electrical properties. The left and right parts (loins and MLL) were measured in parallel to check out the asymmetry of both sides (hindquaters) – corresponding indices were L – left, R – right.

Output values of the analyzer

Measured impedance and phase angle were calculated for statistical analysis on the real and imaginary part of impedance – resistance and reactance. Calculated values correspond to serially arranged RC circuit (Rs, Xcs) as it follows from the measurement principle of the analyzer. While modelling the biological tissue, the intracellular and intercellular space, as a model system, can be replaced by parallel

RC circuits with corresponding conductivity and permittivity. The surrogate circuit of larger tissue can be created from a parallel chain of RC circuit, which makes a global circuit in parallel form again. The simplest biological equivalent model is a single resistor and capacitor in parallel. All BIA measurements assume an equivalent series model and must be transformed to their parallel equivalent. The transformation is shown in the series to parallel transformation frame. Therefore the values of serial circuit need to be calculated according to the relationship in Figure 2 for resistance and reactance of parallel circuit (Rp, Xcp). No cited author mentions this calculated relationship.

The software LUCIA 3.52 performed the image processing analysis

The software LUCIA 3.52 performed the image processing analysis of cross-sections between the 8th and 9th ribs. The areas of bones and surroundings were avoided using image arithmetic's functions in individual pictures. The parts corresponding to fat and muscle were thresholded and converted to binary image. The binary image was cleared and the total area of cross-section, area of muscle tissue and area of fat tissue were measured. These areas expressed in pixels were converted to cm^{-2} using calibration by means of known 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-sections of samples were calculated.

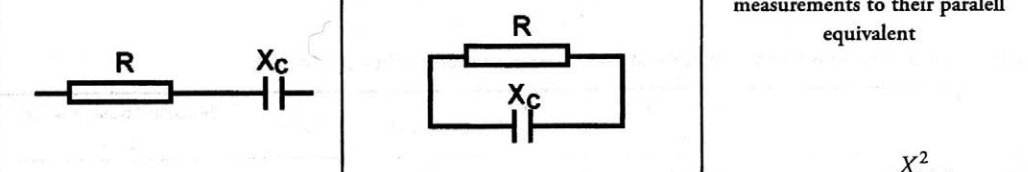
Processing of results, statistical evaluation

Data obtained from the impedance analysis were replenished by calculating values, for examples the "D^2/R_p, L^2/R_p as electric volume (Lukaski *et al.*, 1985, 1986; Nyboer *et al.*, 1943; 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. The results of experimental measurements were processed using the WINSTAT application. Firstly, higher correlations between reference values (weights of dissected loin and results of VIA of cross-sections between the 8th and 9th rib) and data from the impedance analysis were looked for. Consequently, the regression equation for estimation of *musculus lumborum et thoracis* (MLLT) and ratio (%) areas of muscle and fat obtained from VIA cross-sections between the 8th and 9th rib were looked for as well. Estimation formulae were calculated by multiple stepwise regression analysis.

RESULTS AND DISCUSSION

The investigation of correlations between BIA variables was carried out on two groups of reference values. The first group was represented by the weights of parts received by dissection of left half-carcasses: SV, S, MLL. The results of analysis are shown in Table 2 and they represent the highest achieved correlations of selected values. According to an assumption deduced from foregoing meas-

Resistance and capacitance in series	Resistance and capacitance in parallel	Parallel transformation of series measurements to their paralell equivalent



$Z^2 = X_c^2 + R^2$	$\frac{1}{Z^2} = \frac{1}{X_c^2} + \frac{1}{R^2}$ $Z = \frac{X_c R}{\sqrt{X_c^2 R^2}}$	$R_{(par)} = R_{(ser)} + \frac{X^2_{c\,(ser)}}{R_{(ser)}}$ $X_{c(par)} = X_{c(ser)} + \frac{R^2_{(ser)}}{X_{c(ser)}}$

Figure 2. The transformation the series to parallel transformation frame

urements (Lukaski, 1987; Hegarty *et al.*, 1998; Bohuslávek, 2000b) the highest correlation was achieved between the carcass weight and the variable $D^2/100Rp$, which represent so called electrical content. The correlation coefficient $r = 0.892$ is the highest value achieved by the author up to now. A relatively very high correlation degree was found between *longissimus lumborum* muscle weight (MLL) and BIA variables. The specific values of resistance (100Rp/D) and those of reactance (100Xcp/D) measured at the frequency of 100 kHz show high correlations $r = 0.907$ and $r = 0.906$, and thus they are good predictors for the estimation of the weight of this muscle. Volume quantity ($D^2/100Xcp$) calculated from the reactance proves similar values. During the estimation of specific values better results were achieved by the conversion on electrode distance (D) in comparison with carcass length (L), see 100Xcp/D and 100Xcp/L.

Correlations of the BIA variables and calculated values of the second group obtained by the VIA of the images of the cross-sections between the 8th and 9th rib are summarized in the Table 3. Relative and absolute VIA variables are calculated from the threshold and segmented objects (areas) of the muscle tissue, fat and bones. The variables derived from reactance 100Xcp (100Xcp/L ...$r = 0.816$ and $L^2/100Xcp$.... $r = 0.36$) show the highest dependence on 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

Table 2. The correlations between BIA variables and physical reference values

	Left half-carcass (kg)	SV (kg)	S (kg)	MLL (kg)
D^2/1Xcp (cm²/ohm)	0.828	0.809	0.775	0.864
100Xcp/L (ohm/m)	–0.739	–0.818	–0.796	–0.903
100Xcp/D (ohm/m)	–0.753	–0.832	–0.810	–0.907
100Rp/D (ohm/m)	–0.850	–0.841	–0.779	–0.906
L^2/100Rp (cm²/ohm)	0.884	0.763	0.686	0.846
D^2/100Rp (cm²/ohm)	0.892	0.785	0.707	0.850
D^2/100Xcp (cm²/ohm)	0.823	0.809	0.772	0.906

SV = loin incl. backbone
S = loin without backbone
MLL = *longissimus lumborum et thoracis* muscle
L = length of carcass
D = distance of electrodes

Table 3. The correlations between BIA variables and reference values obtained by VIA

	Muscle (cm²)	Fat (cm²)	% muscle	% fat	Muscle/(muscle + fat) (%)
100Rp/L (ohm/m)	–0.810	0.484	–0.743	0.634	–0.671
100Xcp/L (ohm/m)	–0.816	0.382	–0.688	0.557	–0.592
L^2/100Rp (cm²/ohm)	0.796	–0.516	0.746	–0.652	0.685
1Xcp/100Xcp (ohm/m)	0.575	–0.595	0.726	–0.691	0.715
D^2/100Xcp (cm²/ohm)	0.783	–0.476	0.737	–0.630	0.664
L^2/100Xcp (cm²/ohm)	0.836	–0.498	0.761	–0.651	0.685

Table 4. Regression models for beef carcasses (n = 54)

Model No.	Dependent variables	Independent variables	Equations	r^2/r**	RSD*
1	MLL (kg)	1Rp/D 100Xcp/D 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 L^2/100Rp 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 L^2/100Rp 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 = standard error of estimation
r^2/r** = coefficient of correlation/determination

frequency 100 kHz will be good predictors of the estimation of muscle tissue ratio in the carcass.

Regression analysis was aimed to find the best regression model (equation) for estimating selected references values – loin 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 4. MLL weight is more exactly estimated by model No. 1 where coefficient of determination r^2 = 0.88 and coefficient of 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), as mentioned by Bohuslávek (2002a), 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 = 0.72. The best equation for the estimation of the relative fat ratio by VIA is represented by model No. 3 with the coefficient of determination r^2 = 0.63 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 $P < 0.005$.

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 favorable.

REFERENCES

Bohuslávek Z. (2000): Estimation of EUROP-Conformation and Fatness of Beef Carcasses by Bioelectrical Impedance Analysis., CIGR Electronic Journal, www.agen.tamu.edu/cigr, Vol. II, 1–10.

Bohuslávek Z. (2002a): Analysis of the commercial grades for beef carcasses, Czech J. Anim. Sci., *47*, 112–118.

Bohuslávek Z.(2002b): Estimation of beef carcasses conformation carried out at a high-performance abattoir line, based on an impedance method. Czech J. Anim. Sci., *47*, 155–159.

Bohuslávek Z., Augustini C., Branscheid W. (2000b): Estimation of EUROP – conformation and fatness of beef carcasses by bioelectrical impedance analysis. Scientia Agric. Bohemica, *31*, 55–64.

Brandscheid W., Dobrowolski A., Spindler M., Augustini Ch. (1999): Application of video image analysis in grading of cattle. Fleischwirtchaft Int., 12–15.

Cosgrove J.R.J., King W.B., Brodie D.A., (1988): A note on the use of impedance measurements for the prediction of carcass composition in lambs. Anim. Prod., *47*, 311–315.

Fijter C.W., Geers A.B., Donker A.J.M. (2000): The impact of equations on calculation of lean body mass by bioelectrical impedance analysis in RTD patients. International J. Artific. Organs, *23*, 168–172.

Hegarty R.S., McPhee M.J., Oddy V.H (1998): Prediction of the chemical composition of lamb carcasses from multi-frequency data. Brit. J. Nutr., *79*, 169–176.

Jaeger J., Ravinda R.L. (1999): Dry weight and body composition in hemodialysis: A proposal for an index of fluid removal. Semin. Dialysis, *12*, 164–174.

Jenkins T.G., Leymaster K.A., Turlington L.M. (1988): Estimation of fat-free soft tissue in lamb carcasses by use of carcass and resistive impedance measurements. J. Anim. Sci., *66*, 2174–2179.

Jenkins T.G., Leymaster K.A., McNeil M.D (1995): Development and evaluation of a regression equation of prediction for fat free soft tissue in heterogenous populations of cattle. J. Anim. Sci., *73*, 3627–3632.

Kushner R.F. (1992): Bioelectrical impedance analysis a review of principles and applications. J. Am. Coll. Nutr., *11*, 199–209.

Lukaski C.H., (1987): Methods for the assessment of human body composition: traditional and new. Am. J. Clin. Nutr., *46*, 537–556.

Lukaski C.H., Johnson E.P., Bolonchuk W.W. (1985): Assessment of fat free using bioelectrical impedance measurements of the human body. Am. J. Clin. Nutr., *41*, 810–817.

Lukaski C.H., Bolonchuk W.W., Hall C.B., Siders W.A. (1986): Validation of tetrapolar bioelectric impedance method to assess human body composition. J. Appl. Physiol., *60*, 1327–1332.

Marchello M.J., Slanger W. D. (1992). Use o bioelectrical impedance to predict leanness of Boston butts. J. Anim. Sci., *70*, 3443–3450.

Marchello M.J., Slanger W.D. (1994): Bioelectrical impedance can predict skeletal muscle and fat-free skeletal muscle of beef cows and their carcasses. J. Anim. Sci., *72*, 3118–3123.

Nade T., Karnuah A.B., Masuda Y., Hirabara S., Fujita K. (2001): Estimation of carcass composition from the cross-section at ribloin of Japanese Black steers by Computer Image Analysis. Anim. Sci. J., *72*, 313–320.

Nyboer J., Bagno S., Nims L.F. (1943): The electrical impedance plethysmograph and electrical volume recorder. Waschington DC: National Research Council, Report No.149.

Segal Kr., van Loan M., Fitgerald P.T., Hodgon J.A. (1988) : Lean body mass estimation by bioelectrical impedance analysis. Am. J. Clin. Nutr., *47*, 7–14.

Thiele S. (1993): Untersuchungen zur Schaetzung des Koerperwasser- und Fettgehaltes von Schweinen mittels der bioelektrischen Resistanz und Reaktanzanalyze. Diss., Berlin, Journal Nr. 1664, s. 127.

Thomas B.J., Cornish B.H., and Ward L.C. (1992) : Bioelectrical impedance analysis for measurement of body fluid volumes: a review. J. Clin. Engr., *17*, 505–510.

Swantek P.M., Lukaski H.C. (1991): Bioelectrical impedance: a nondestructive method to determine fat-free mass of live market swine and pork carcasses. J. Anim. Sci., *70*, 169–177.

Swantek P.M., Creschaw J.D., Marchello M.J., Lukaski H.C. (1992): Bioelectrical impedance a non-destructive method to determine fat-free mass of live market swine and pork carcasses. J. Anim. Sci., *70*, 169–177.

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Meat performance and meat quality in different genotypes of F_1 generation gilts

Masná užitkovost a kvalita masa odlišných genotypů prasniček F_1 generace

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ABSTRACT: The results of carcass evaluation and analytical examination as well as the sensory properties of meat were studied in gilts of hybrid combinations of Large White × Landrace (LWxL) and Norway Landrace × Landrace (NL×L), n = 2×10 animals. The average slaughter live weight was 114 kg in the LW×L group and 110 kg for NL×L. The proportion of valuable lean cuts was significantly higher in the NL×L group (51.66%) than in LW×L gilts (46.84%). SEUROP classification of meatiness, using the two-point method, showed that the NL×L gilts had a significantly higher proportion of lean mean (58%), being included in class E, as compared with the LW×L gilts (class U, 51% lean meat). A significant difference between the LW×L and NL×L cross combinations was recorded in the proportion of fatty parts in the dressed carcass: 16.80% vs. 9.85%. The LW×L gilts had the highest content of intramuscular fat (19.18 g/kg) whereas in the NL×L gilts this parameter was close to the critical low values (15.98 g/kg). The NL×L hybrid combination had a significantly higher value (5.27%) of shrinkage loss within 24 hours if compared with LW×L (3.07%). There were observed no deviations in pH_{24} that remained within the range of standard pork. The results of sensory evaluation, except juiciness, were better for the LW×L gilts.

Keywords: pig; hybrid combinations; meatiness; intramuscular fat

ABSTRAKT: Posuzovali jsme výsledky jatečného hodnocení, analytického šetření a senzorických vlastností masa prasniček plemenné kombinace bílé ušlechtilé × landrase (BU×L) a norská landrase × landrase (NL×L) při n = 2×10 ks. Průměrná jatečná živá hmotnost byla 114 kg u BU×L a 110 kg pro NL×L. Podíl hlavních masitých částí (51.66 %) byl zjištěn u souboru NL×L signifikantně vyšší oproti prasničkám BU×L (46.84 %). Při posouzení zmasilosti klasifikací SEUROP na základě dvoubodové metody měly prasničky NL×L významně vyšší podíl libové svaloviny (58 %) při zařazení do třídy E ve srovnání s prasničkami BU×L (třída U, 51 % libového masa). V podílu tučných částí na JUT se projevila významná diference mezi BU×L (16.80 %) a Nl×L (9.85 %). Nejvyšší hodnoty obsahu intramuskulárního tuku vykázaly prasničky BU×L (19.18 g/kg), zatímco u NL×L se tento ukazatel blíží kritickým nízkým hodnotám (15.98 g/kg). Hybridní kombinace NL×L dosáhla významně vyšší hodnoty (5.27 %) odkapu šťávy za 24 hodin oproti BU×L (3.07 %), nebyly zaznamenány odchylky v hodnotách pH_{24}, které se pohybovaly v rozmezí platných pro standardní vepřové maso. Při senzorickém hodnocení bylo maso prasniček BU×L, s výjimkou šťavnatosti, hodnoceno jako lepší.

Klíčová slova: prase; hybridní kombinace; zmasilost; intramuskulární tuk

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Pig breeders and producers seek to achieve efficient production of slaughter pigs with high meat performance. Selection is practised not only in sire breeds but also on the side of the dam in breeding programmes for carcass conformation. To be selected for the dam position, gilts must meet great requirements for the reproduction potential while supporting the tendency of lowering the backfat thickness. However, as Gráčik *et al.* (2001) asserts, breeding for higher meatiness of dam-side breeds involves higher numbers of gilts to be excluded because of disorders in the reproduction cycle. Great attention is paid to fat content in slaughter animals in order to reduce the content of intra- and intermuscular fat, subcutaneous fat and visceral fat. Although intramuscular fat has a positive influence on the sensory properties of meat, selection for high meatiness reduces it below 2%, which affects the quality of pork: meat loses much of its palatability, juiciness and tenderness. Vries and Wal (1993) found that the proportion of intramuscular fat decreased by 0.07% with every percent of increase in the proportion of lean meat. Schwörer (1988) recorded a range of 0.9–2.7% for the proportion of intramuscular fat in the Belgian Landrace breed and 2.4–4.5% in the Duroc breed. According to Fernandez *et al.* (1999), who examined the effect of intramuscular fat in hybrid pigs (Duroc × Landrace and Tia Meishan × Landrace) on the sensory properties and consumer acceptability of pork, the content of intramuscular fat should not exceed 3.5%. Krška *et al.* (1999) studied performance and carcass value parameters and meat quality in dam and sire breeds of pigs slaughtered at an average live weight of 100 kg. They proved the existence of highly significant differences between the dam and sire breeds as to the total proportions of muscle, valuable lean cuts, ham meat (with bone) in the half-carcass, average backfat thickness and the area of *the musculus longissimus lumborum et thoracis* (MLLT).

Aware of the above trends, the authors wanted to compare, evaluate and define the meat performance and meat quality of gilts of LW×L and NL×L hybrid combinations.

MATERIAL AND METHODS

Gilts of two hybrid combinations (Large White × Landrace [LW×L] and Norway Landrace × Landrace [NL×L]) were subjected to slaughter evaluation, analytical examination and sensory evaluation of meat. The obtained results were processed and examined. The gilts chosen and examined for the evaluation and comparison of meat performance and meat quality included only those normally intended as potential dams that are exclusively used in the Czech Republic in reproduction stocks for final hybrid production. The animals were subjected to a fattening test, involving 60 gilts, using standard commercial diets: A-series compound feeds in loose consistence, where the levels of digestible proteins, lysine and energy were adequate to the nutrient requirements of animals in the weight categories of fattened pigs (A1 – 179.6 g/kg crude protein and 13 ME/MJ energy; A2 – 152.7 g/kg crude protein and 12.9 ME/MJ energy; A3 – 140.6 g/kg crude protein and 12.8 ME/MJ energy). Gilts of both hybrid combinations enjoyed the same conditions of feeding, housing and tending during the fattening period and handling before and after slaughter. When the fattening test was completed, representative groups of 10 gilts of each hybrid combination were slaughtered at an average live weight of 110–115 kg. The right sides of pork were subjected to *post-mortem* examination to determine carcass parameters. For chemical analyses and sensory evaluation, average samples were taken from the *musculus longissimus lumborum et thoracis* and backfat in order to evaluate the quantitative and qualitative traits.

Quantitative traits

1. Proportions of the individual lean cuts (ham, shoulder, spare rib, loin) and the total proportion of lean cuts in the half-carcass (%).
2. Proportion of lean meat, determined by the two-point method, with SEUROP classification. Two linear dimensions (in mm) were measured in the half-carcass in the medial plane: muscle (M) depth in the lumbar area as the shortest connecting line from the upper (dorsal) edge of the spinal canal to the front (cranial) end of *musculus gluteus medius*; and backfat thickness (S) – in the lumbar area together with skin at the site of the lowest layer over the mid part of *musculus gluteus medius* at the place of its greatest arching. Muscle percentage is calculated by inserting the values in the following equation (in Matoušek *et al.*, 1997):

$$Y = 76.6722 - 1.0485\,M + 0.00794\,M^2 - 0.002884\,S^2 + 9.0151\,\ln\,(M/S)$$

where: Y = percentage of lean meat
S = backfat thickness, incl. skin, (mm)
M = muscle depth (mm)
ln = natural logarithm

3. Percentage of fatty parts (intestinal fat, fat of ham with skin, backfat) in the half-carcass.
4. Average backfat thickness in cm, measured behind the second and last thoracic and first croup vertebra.
5. Meat : fat ratio.
6. Area of the *musculus longissimus lumborum et thoracis* measured between the second and fourth rib (cm^2).

Qualitative traits

1. Nutritive values:
   – levels of dry matter, protein (N × 6.25), fat in meat, cholesterol, hydroxyproline, connective tissue and energy value.
2. Technological properties:
   – meat colour (reflectance), pH_{24}, (pH Meter Orion 0250A3), shrinkage loss in 24 hours.
3. Sensory properties:
   – sensory evaluation (expert commission of the Czech Agricultural and Food Inspection Authority), including evaluation of sensory properties of muscle (flavour, taste, juiciness, texture, profile), determined by the rank test and the triangle test, following Draft International Standard ISO/DIS 8587.

The results were processed by means of the SAS statistical programme with *t*-test procedure.

RESULTS AND DISCUSSION

The average slaughter live weight was 114 kg for LW×L and 110 kg for NL×L, the average weight of the gilt half-carcass being 44.2 kg (LW×L) and 43.4 kg (NL×L). The carcass parameters are given in % of the half-carcass (Table 1), together with selected statistical parameters. Evaluation of the proportions of valuable lean cuts in the dressed carcass shows a low variability of these values, conforming to the requirements for standardisation of the product within the framework of EU standards. The NL×L combination had a higher proportion of ham (20.15%) and loin (12.33%) in the half-carcass ($P \leq 0.01$ and $P \leq 0.001$), as compared with the LW×L gilts (18.27 and 9.96%, respectively). No significant differences were found in the proportions of shoulder and spare rib. The total proportion of valuable lean cuts was significantly higher ($P \leq 0.001$) in the NL×L group (51.66%) than in the LW×L group (46.84%). Demo *et al.* (1995) evaluated the quality of dressed carcasses of pig hybrids bred for a higher proportion of lean cuts (SLOVHYB-1); after the pigs were slaughtered at 110 kg, they found that the pigs had a 51.3 to 56.9% proportion of lean cuts; at the same time they confirmed the finding (Gregor and Scholz, 1993) that meat quality (especially meat colour and proportion of bound water) worsens with higher proportions of lean cuts. Evaluation of meatiness in hybrid combinations (SLOVHYB 1, SLOVHYB 2) at a live weight of about 105 kg (Demo and Poltársky, 1997) showed the proportion of total lean cuts to amount to about 50.3% and 54.4%, respectively. Demo (1994), who examined a group of hybrid pigs at an average slaughter weight of about 112 kg, found a lean cut proportion of 48.8% and noted that the proportion of lean cuts declined (1–2%) with slaughter weights increasing by 10 kg. In the evaluation of meatiness by the SEUROP classification, using the two-point method, the NL×L gilts had a higher ($P \leq 0.001$) proportion of lean muscle (58%), with inclusion in class E, than the LW×L gilts, which were included in class U and had 51% lean meat. The differences found between the proportion of muscle determined by the two-point method and that determined by calculation confirm the finding published by Matoušek *et al.* (2000): among 732 pigs of different purebred populations these differences were up to 4.5%.

A significant ($P \leq 0.001$) difference was recorded in the proportion of fatty parts in the dressed carcass (16.80% for LW×L and 9.85% for NL×L), which also substantially influenced the meat : fat ratio to the detriment of the LW×L combination. In this study, the proportions of separable fat are somewhat lower than those published by other authors. In Hungary, the proportions of valuable lean cuts, muscle and fat in purebred and hybrid populations were studied by Radnóczi and Fésüs (1993), who recorded a range of 23.4 to 31.0% for separable fat, 45.9 to 54.2% for lean cuts and 52.7 to 58.7% for muscle. The meat : fat ratio 1 : 0.19 was lower ($P \leq 0.001$) in the NL×L group,

Table 1. Average values of carcass parameters

Parameter	Hybrid combination LW × L			NL × L			t-test
	$\bar{x}$	$s_{\bar{x}}$	v (%)	$\bar{x}$	$s_{\bar{x}}$	v (%)	
		n = 10			n = 10		
Slaughter weight (kg)	114	3.84	3.37	110	2.01	1.83	**
Weight of cold right half-carcass (kg)	44.2	2.77	6.27	43.4	1.88	4.40	–
Proportions of lean cuts							
ham (%)	18.27	1.07	5.88	20.15	1.16	5.75	**
shoulder (%)	10.16	1.06	10.42	10.80	0.50	4.63	–
spare rib (%)	8.44	0.49	5.80	8.38	0.51	6.13	–
loin (%)	9.96	1.09	10.90	12.33	0.73	5.89	***
Proportion of valuable lean cuts (%)	46.84	1.96	4.19	51.66	2.18	4.21	***
Proportion of lean meat (%)	51	1.72	3.38	58	3.23	5.59	***
Classification by SEUROP		U			E		
Proportion of fatty parts (%)	16.80	2.40	14.27	9.85	1.37	13.91	***
Meat : fat ratio	1 : 0.36	1 : 0.05	1 : 14.29	1 : 0.19	1 : 0.03	1 : 18.04	***
Proportion of bacon (%)	13.92	1.00	7.21	17.01	1.00	5.85	***
MLLT area (cm)^2	44	5.46	12.42	52	2.27	4.36	***
Average back fat thickness (cm)	2.7	3.03	11.10	1.9	2.14	11.56	***

* $P \leq 0.05$
** $P \leq 0.01$
*** $P \leq 0.001$

i.e. about 20% of fat for each part of muscle, whereas in the LW×L group the ratio was 1 : 0.36, i.e. about one-third of fat for each cut of meat. The LW×L gilts had a higher fat deposition ability: they had higher ($P \leq 0.001$) backfat thickness (2.7 cm) than the NL×L gilts with 1.9 cm. The proportion of fatty parts and backfat thickness were highly variable in both groups of gilts. The percent proportion of bacon is an important parameter of the dressed half-carcass: it was higher ($P \leq 0.001$) in the NL×L combination than in the LW×L combination (17.01 and 13.92%, respectively). Similar relations were recorded in the area of the *musculus longissimus lumborum et thoracis*: 52 cm^2 for NL×L, 44 cm^2 for LW×L.

Meat quality is determined by its aggregate nutritive, technological, sensory and hygienic properties. The most important for the consumer are meat colour, proportion of intramuscular fat, water holding capacity, tenderness and pH (Hovenier *et al.*, 1993). Evaluation of the complete analysis of muscle samples (the MLLT) and backfat, with focus on selected quantitative traits, is illustrated in Table 2. As shown by the analysis, there is a high variability in the levels of fat and cholesterol, shrinkage loss, loss of colour and – in the case of the NL×L genotype – also in the content of hydroxyproline and connective tissue. The LW×L gilts showed the highest values of intramuscular fat for their meat (19.18 g/kg) whereas in the NL×L gilts this parameter was close to its critical low level (15.98 g/kg), affecting the sensory properties from the consumer's and culinary point of view. The low content of intramuscular fat in the animals under study may be a manifestation of the general rule that gilts usually have less fat in their meat than barrows (Koucký and Ševčíková, 2001). These values correspond to those published by Mikule *et al.*

Table 2. Parameters of chemical and technological properties of meat

Parameter	Hybrid combination						*t*-test
	LW × L			NL × L			
	$\bar{x}$	$s_{\bar{x}}$	*v* (%)	$\bar{x}$	$s_{\bar{x}}$	*v* (%)	
Dry matter (g/kg)	264.22	5.09	1.93	257.31	3.77	1.47	**
Crude protein (g/kg)	231.19	3.55	1.54	227.13	4.01	1.76	*
Fat (g/kg)	19.18	5.40	28.16	15.98	3.53	22.08	–
Cholesterol (g/kg)	0.47	0.06	12.82	0.41	0.02	4.69	*
Hydroxyproline (g/kg)	0.58	0.04	7.41	0.73	0.12	17.46	**
Connective tissue (g/kg)	4.68	0.35	7.41	5.81	1.01	17.34	**
Energy value (MJ/kg)	4.65	0.19	4.04	4.46	0.13	3.01	*
Meat colour (reflectance) (%)	19.67	3.87	19.69	18.22	2.95	16.18	–
Shrinkage for 24 hours (%)	3.07	0.62	20.28	5.27	1.58	30.01	**
pH_{24}	5.51	0.09	1.61	5.44	0.04	0.82	*

* $P \leq 0.05$
** $P \leq 0.01$
*** $P \leq 0.001$

Table 3. Sensory evaluation

Parameter	Hybrid combination					
	LW × L			NL × L		
	$\bar{x}$	$s_{\bar{x}}$	*v* (%)	$\bar{x}$	$s_{\bar{x}}$	*v* (%)
Flavour	5.5	0.18	3.26	5.4	0.19	3.44
Taste	5.4	0.22	4.00	5.1	0.23	4.44
Texture	5.1	0.27	5.24	5.0	0.49	9.68
Juiciness	4.3	0.35	8.09	4.6	0.35	7.71
Over-all profile	5.1	0.20	3.97	5.0	0.30	6.03

(2001): in the evaluation of pig breeds used in dam and sire positions in breeding programmes in the Czech Republic, there was a range of 0.54 to 1.94% in this parameter. Dry matter and crude protein contents and cholesterol levels were generally more or less balanced within each group, but taking gilts alone, they were lower ($P \leq 0.05$) in the NL×L gilts (257.31 g/kg; 227.13 g/kg and 0.41 g/kg, respectively) than in the LW×L gilts (264.22 g/kg; 231.19 g/kg and 0.47 g/kg, respectively). A reverse tendency was recorded in hydroxyproline and connective tissue. Meat colour (reflectance) and shrinkage loss for 24 hours varied considerably. Shrinkage loss for 24 hours was much higher ($P \leq 0.01$) in the NL×L combination (5.27%) than in the LW×L combination (3.07%). According to many authors, shrinkage loss ranges from 1.9% to 8%. Matoušek *et al.* (1997) evaluated meat quality in the final hybrids of various genotypes of pigs. With lean meat proportion of 52.3%, the determined values (reflectance 22.02, shrinkage loss 4.74%, intramuscular fat 2.39%) were as required for normal meat quality. Significant variances were recorded in pH_{24}: the values remained within the range for standard pork, but the pH_{24} for the LW×L combination (5.51) was higher ($P \leq 0.05$) than that for the NL×L combination (5.44).

In the sensory properties of meat (Table 3) as the key indicator for the consumer, the meat of the LW×L gilts was better (except juiciness) in both the over-all profile and the individual properties (flavour, taste, texture). The results of sensory evaluation were insignificant. Intramuscular fat as a trait positively influencing the sensory properties of meat was low in the NL×L combination and as such it was probably responsible for the lower sensory and consumer quality in this combination.

REFERENCES

Demo P. (1994): Hodnotenie jatočných tiel ošípaných podľa podielu cenných mäsových častí pomocou regresných rovníc. Živoč. Výr., *39*, 629–642.

Demo P., Poltársky J., Lagin L., Pavlič M. (1995): Hodnotenie kvality jatočne opracovaných tiel hybridov ošípaných šľachtených na zvýšený podiel mäsových častí. Živoč. Výr., *40*, 277–281.

Demo P., Poltársky J. (1997): Objektivizácija hodnotenia zmäsilosti ošípaných pomocou podielu chudej svaloviny. Živoč. Výr., *42*, 33–39.

Fernandez X., Monin G., Talmant A., Mourot J., Lebret B. (1999): Influence of intramuscular fat content on the quality of pig meat – 2. Consumer acceptability of *m. longissimus lumborum*. Meat Sci., *53*, 67–72.

Gregor G., Scholz A. (1993): Evaluation of intramuscular fat-content in the *longissimus dorsi* muscle by video image-analysis and discussion of objectives in pig breeding. Arch. Tierzucht – Arch. Anim. Breeding, *36*, 383–395.

Gráčik P., Buchová B., Poltársky J., Fľak P., Hetényi L. (2001): Improvement of meat efficiency in mother types of pigs in relation to their reproductive performance. Czech J. Anim. Sci., *46*, 105–110.

Hovenier R., Kanis E., Asseldonk T., Van-Westerink N.G. (1993): Breeding for pig meat quality in halothane negative populations – review. Pig News Inform., *14*, 17N–25N.

Koucký M., Ševčíková S. (2001): Stanovení diferencí ve vybraných znacích jakosti u odlišných jatečných partií prasat. In: Mezinárodní konference Aktuální poznatky v oblasti jakosti zemědělské a potravinářské produkce, Brno, 115–117.

Krška P., Bahelka I., Demo P., Lukáčová A. (1999): Vplyv genotypu a intenzity rastu na jatočnú hodnotu a kvalitu mäsa ošípaných. Czech J. Anim. Sci., *44*, 49–53.

Matoušek V., Kernerová N., Václavovský J., Vejčík A. (1997): Analýza kvality masa u hybridní populace prasat. Živoč. Výr., *42*, 511–515.

Matoušek V., Kernerová N., Vejčík A., Jirotková D. (2000): Hodnocení podílu svaloviny u čistokrevných populací prasat. In: XXVII. Mezinárodní seminář o jakosti potravin a potravinových surovin, Brno, s. 6.

Mikule V., Čechová M., Sládek L. (2001): Obsah intramuskulárního tuku u čistokrevných plemen prasat používaných v hybridizačných programech ČR. In: XXVII. Mezinárodní seminář o jakosti potravin a potravinových surovin, Brno, s. 25.

Radnóczi L., Fésüs L. (1993): Pig production in Hungary. Pig News Inform., *14*, 113a–117N.

Schwörer D. (1988): Berücksichtigung des intramuskulären Fettes in der Schweinezucht. In: Schweine-Worshop, February 24–25, Kiel, Germany, 82–94.

Vries A.G., De Wal P.G. Van Der (1993): Breeding for pork quality. Pork quality: genetic and metabolic factors. In: Papers OECD Workshop in Helsinki, Finland. CAB International, 58–75.

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