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POKYNY PRO AUTORY

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Kaláb J. (1995): Changes in milk production during the sexual cycle. In: Hekel K. (ed.): Lactation in Cattle. Academic Press, London. 876–888.

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Evaluation of bull growth at a cattle progeny testing station in relation to parents' genotype

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ABSTRACT: A decrease in live weight during the fattening period was found in progenies of Czech Pied sires with higher share of dairy breeds. Lower average daily gain in specific phases of fattening (birth-150 days, birth-500 days, 150–500 days of age) was recorded in sons of C2 sires (86 g, 1 050 g, 1 116 g, respectively) as compared with progenies of C1 sires (912 g, 1 076 g, 1 146 g, resp.). A higher share of dairy breeds was also associated with worse parameters of meat efficiency. Lower weight of dressed carcass (308.43 kg) and lower dressing percentage (55.59%) were found in progenies of C2 sires as compared with the respective values (317.33 kg and 55.89%) recorded in progenies of C1 sires. On the contrary, kidney fat and kidney fat proportion of C2 sire progenies (7.067 kg and 1.259%, resp.) were higher than the values found in C1 sire progenies (7.013 kg and 1.216%, resp.).

Keywords: Czech Pied cattle; bulls; meat production; growth; heritability; genetic correlation; phenotypic correlation

At present, increased concern is attributed to beef breeds of cattle. These breeds are used in productive systems based on grazing as well as in various forms of commercial crossing. In spite of the very intensive use of beef breeds of cattle most animals will be produced in Czech Pied and Black Pied herds in the nearest future. Correct orientation and proper selection require, however, adequate and up-to-date information on milk and meat efficiency of the cattle population in this country. At present, a pure breeding system using sires – products of inland improvement program – is applied in Czech Pied herds (Urban *et al.*, 1997). Sires of phylogenetically associated breeds from Germany, Austria, Switzerland, France are used in the framework of a unique improvement program to a certain limited extent (Pinďák and Vetýška, 1993).

Adequate growth parameters of bulls fattened to higher slaughter weights, higher dressing percentage and meat quality, adequate meat : bone ratio, and lower incidence of health disorders can be mentioned as merits of Czech Pied cattle (Pinďák and Vetýška, 1993).

In Bavaria, ADG amounting to 1 300 g (bulls) and 950–1 100 g (heifers), dressing percentage 60%, and meat yield 70% have been outlined as target standards for Pied cattle (Putz and Wiedenmann, 1993, 1994).

Effective and profitable cattle breeding is aimed at production of animals guaranteeing the maximum potential profit under existing conditions as well as in the nearest future (Putz and Wiedenmann, 1994).

Improvement of Austrian and Bavarian Pied cattle is focused on an increase in milk efficiency and stability of meat efficiency (the ratio of milk efficiency : meat efficiency being 60 : 40) – Putz and Wiedenmann (1993).

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Simmental breed is very appreciated with regard to maternal position in hybridization programs because of its excellent milkiness, adequate conformation, muscling, resistance and adaptability to various climatic conditions (Coombs and Lutchman, 1994).

Breeding values for net gain, final live weight (at the end of the fattening period) and ADG in the testing period are the principal criteria used for classification of fattening performance and carcass value at cattle progeny testing stations. Selection is based on the results of testing. Development and muscling of progenies are considered, too (Pinďák and Vetýška, 1993).

Significant improvement of milk production and adequate meat production was achieved in recent years. This fact resulted in a relatively high increase in the milk efficiency potential associated with negative impact on beef production (Bartoň *et al.*, 1996a). Adequate conditions during the rearing period and fattening period are necessary for improvement of growth ability and meat efficiency (Šubrt *et al.*, 1996).

Teslík *et al.* (1995) studied efficiencies of Czech Pied (C) and Black Pied (N) bulls fattened intensively up to 530 kg of live weight. Better muscling resulting in higher weight of dressed carcass (303.4 kg), higher dressing percentage (57.77%) and net gain (579 g) were found in C-bulls as compared to N-bulls (289.36 kg, 56.00%, and 548 g, resp.).

Similar trends were found by Bartoň *et al.* (1996a) in C-bulls and N-bulls fattened to 575 kg of live weight. C-bulls had higher weight of dressed carcass (by 5.3 kg: 337.09 kg), dressing percentage (by 1.6%: 58.95%), and net gain (by 2.5%: 519 g) as compared to N-bulls.

The concept of Czech Pied cattle improvement (outlined in 1993) envisages the use of phylogenetically associated cattle breeds (Mikšík *et al.*, 1996). Simmental cattle (including regional types e.g. Deutsche Fleckvieh, Slovak Pied, Hungarian Pied and other populations used as dual-purpose populations in most cases) is recommended for improvement of dual-purpose productive type presenting good beef quality (Trojan and Safarová, 1987; Hampel, 1994).

The objectives of the study were estimates of genetic parameters based on growth traits and meat efficiency of bulls and comparison of specific progeny sets (differentiated according to sire's genotype, dam's genotype, sire's genotype × dam's genotype interaction, sire's RBV for corrected net gain).

MATERIAL AND METHODS

In total, 2 008 bulls from a cattle progeny testing station (CPTS) born in the period 1994–1997 and slaughtered until 1999 year were included in the study.

Methodical principles of progeny testing at CPTS were respected at the purchase of bulls (age: max. 4 weeks, 14–17 sons). An all-in all-out system was applied. The age variation of the set did not exceed ±7 days. Sons of one sire were included in three sets at minimum. A pre-fattening period (until 150 ± 7 days of age) was followed by the proper test of fattening performance (151 ± 7 days to 500 ± 10 days of age). Since March 1, 1999, the testing period was extended to 530 ± 10 days (according to methodical modifications). The testing period was completed by slaughter.

Dressed carcass weight was determined according to valid methodology at CTPS.

The formulation of feed ration corresponded to minimum average daily gains in the rearing (pre-fattening) period (950 g) and in the testing period (1 300 g).

The following parameters were studied:

- weight of animals at: the time of purchase
  start of testing period (150 ± 10 days of age)
  end of testing period (500 ± 10 days of age)
- at slaughter (hot carcass): weight of half-carcasses without kidney and kidney fat
  weight of kidney fat
  quality grade (standard classification)

Basic statistical characteristics and parameters were calculated for all studied sets. Data were processed and evaluated by multifactorial analysis of variance using procedures of GLM program SAS v.6.12.

The following model was used for data processing:

$$y_{ijkl} = \mu + RNS_i + A_j + B_k + \beta\,(x - \bar{x}) + e_{ijkl}$$

where:
y_{ijkl} = observed parameter
μ = mean value
RNS_i = fixed effect: year of birth and set of the tested bull
A_j = fixed effect of sire's genotype
B_k = fixed effect of dam's genotype
$\beta\,(x - \bar{x})$ = regression on slaughter age
e_{ijkl} = residual error

Fixed effect of the year of birth was included in the model as an alternative. Interactions of these fixed effects were studied with regard to a more detailed analysis of variance between sire's genotype and dam's genotype. The tested population was classified according to:

– sire's and dam's genotype (C1 = 75% and more, C2 = 51–74%, C3 = 25–50% share of Czech Pied breed)
– interaction between sire's genotype and dam's genotype (1st group: C1 sire, C1 dam, 2nd group: C1 sire, C2 dam, 3rd group: C2 sire, C1 dam, 4th group: C2 sire, C2 dam, 5th group: C2 sire, C3 dam)

Breeding values (BV) and relative breeding values (RBV) of sires and dams were taken over from documentation of the Czech Pied Cattle Breeding Association (www.plemdat.cz).

The chosen set (1 022 head) of bulls with known relative breeding values (RBV) for corrected net gain (CNG) – mean RBV and standard deviation of CNG being 101.44% and 15.6, respectively – was classified according to sire's RBV:

1st group: RBV < $x - s_x$
2nd group: RBV = $x \pm s_x$
3rd group: RBV > $x + s_x$

Statistical program Harvey-1987 was used for correction of specific effects and estimates of genetic parameters using multifactorial analysis of variance and covariance. The following model equation was used:

$$y_{ijk} = \mu + a_i + A_j + \beta\,(x - \bar{x}) + e_{ijk}$$

where: y_{ijk} = estimate of trait
μ = mean value
a_i = random sire's effect
A_j = fixed effect: year of bull's birth
$\beta\,(x - \bar{x})$ = regression on slaughter age
e_{ijk} = residual error

RESULTS AND DISCUSSION

Meat efficiency characterizing the total population of Czech Pied cattle is affected directly by cattle breeders who select sires proved by progeny testing.

Progeny testing for meat efficiency is carried out at cattle progeny testing stations. Basic statistical characteristics of a set tested at one of these stations are presented in Table 1.

The sires of fattened bulls had the following breeding values: –23.69 kg milk, 1 225 kg protein, 101.45% RBV for CNG. Breeding values of bulls' dams: –33.91 kg milk, –1.678 kg protein. Low breeding values of dams are associated with principles of testing mating: breeders prefer dams with lower milk efficiency (or dams with reproductive disorders) to top-producing dams. Average weight of fattened bulls amounted to 166.31 kg (start of testing: 150 days of age) and to 567.03 kg (slaughter: 500 days of age). The following average daily gains were calculated from these values: 911 g (birth-150 days) and 1 075 g (birth-500 days). ADG in the testing period (150–500 days of age) amounted to 1 146 g.

Average dressed carcass weight 317.11 kg and dressing percentage 55.90% were determined in fattened bulls. According to Barton *et al.* (1996 b) dressing percentage of Czech Pied bulls (58.9%) is higher (by 2.5%) as compared to Black Pied bulls (56.4%).

Weight of kidney fat averaged 7.18 kg, kidney fat proportion amounted to 1.25%. In total, 1.4% carcasses were classified by E 1 (élite) grade, 92.8% by A 1 grade, and 5.8% by B 1 grade.

Estimates of heritability coefficients (h^2) for growth parameters and their phenotype and genetic correlations are shown in Table 2. Relationships were established according to Šafus *et al.* (1998) by means of genotype and phenotype correlation coefficients – it was necessary to eliminate systematic environmental effects. The highest heritabilities were found in ADG and in 150-day weight (h^2 = 0.589). Heritability of ADG in the testing period amounted to 0.416. Veseth *et al.* (1993) and Hirooka *et al.* (1996) reported h^2 = 0.47 and h^2 = 0.22, respectively.

The values h^2 = 0.343 and h^2 = 0.263 were calculated for dressed carcass weight and dressing percentage, h^2 = 0.453 and h^2 = 0.424 were found in kidney fat and kidney fat proportion. Reynolds *et al.* (1991) reported h^2 = 0.32 for dressing percentage of beef breeds.

Correlations r_g = 0.146 and r_{xy} = 0.360 were associated with 150-day weight × 500-day weight relationship. As for the relationships between ADG in the testing period and dressed carcass weight and kidney fat, the following values were found: r_g = 0.897, r_{xy} = 0.927, r_g = 0.182 and r_{xy} = 0.500, respectively. These values document a higher risk of fat deposition in body cavities connected with growth rate of dual-purpose cattle.

Table 1. Growth parameters of bulls at testing stations (CPTS)

Parameters	Basic statistical characteristics					
	n	$\bar{x}$	$s_{\bar{x}}$	v (%)	min.	max.
Breeding values (BV) of sire						
BV of milk production (kg)	253	**–23.69**	373.25	–	–937.0	+1 505.0
BV of milk protein (kg)	253	**+1.22**	12.71	–	–33.00	+56.00
RBV of corrected net gain (%)	253	**101.45**	15.69	15.47	72.00	152.00
Breeding values (BV) of dam						
BV of milk production (kg)	1 584	**–33.91**	179.58	–	–584.0	+667.0
BV of milk protein (kg)	1 586	**–1.678**	5.65	–	–19.2	+21.8
Growth parameters and meat efficiency traits of tested bulls						
150-day weight (kg)	2 008	**166.31**	18.67	11.23	92.00	291.00
500-day weight (kg)	2 008	**567.03**	56.30	9.92	300.00	750.00
Average daily gain (from birth to 150 days) (g)	2 008	**911**	126	13.83	413	1 752
Average daily gain (from birth to 500 days) (g)	2 008	**1 075**	113	10.51	537	1 423
Average daily gain (from 150 to 500 days) (g)	2 008	**1 146**	148	12.91	469	1 613
Dressed carcass weight (kg)	2 008	**317.11**	33.24	10.48	166.00	424.00
Carcass yield (%)	2 008	**55.90**	1.07	12.91	43.80	67.10
Weight of kidney fat (kg)	2 008	**7.18**	3.03	42.20	1.00	19.00
Proportion of kidney fat (%)	2 008	**1.25**	0.48	38.40	0.07	4.00

Positive correlations were also found between 500-day weight and kidney fat (r_g = 0.165 and r_{xy} = 0.540), between kidney fat and dressed carcass weight (r_g = 0.196 and r_{xy} = 0.543), and between kidney fat and dressing percentage (r_g = 0.300 and r_{xy} = 0.231).

Data compiled in Table 3 illustrate evident differences between progeny sets classified according to sire's genotype. Sire's breeding value for milk production and relative BV for corrected net gain amounted to +17.10 kg and to 102.42%, resp. (C1 progeny) and to –105.17 kg and 93.04%, resp. (C2 progeny).

150-day and 500-day weights of tested bulls amounted to 166.64 kg and 567.52 kg (sons of C1 sires) and to 164.27 kg and 554.44 kg, resp. (sons of C2 sires). Reduced weights in the individual phases of fattening period found in bulls with higher share of dairy breeds in sire's blood are associated with adequate reduction of ADG from birth to 150 and 500 days and ADG in the testing period (896 g, 1 050 g, 1 116 g, resp. in C2 progeny, 912 g, 1 076 g, 1 146 g, resp. in C1 progeny). Steinwidder *et al.* (2002) found average daily gain 1 519 g in Simmental bulls fattened to final weight 640 kg.

As for meat efficiency traits, a higher share of dairy breeds reduced the weight of dressed carcass and dressing percentage to 308.43 kg and 55.59% (C2 progeny) as compared to 317.33 kg and 55.89%, resp. (C1 progeny) and slightly increased the intensity of fat deposition expressed by kidney fat and kidney fat proportion (7.067 kg and 1.259%, resp. in C2 progeny as compared to 7.013 kg and 1.216%, resp. in C1 progeny).

Higher growth parameters and lower fatness rate in C1 progeny as compared to C2 progeny

Table 2. Estimated heritability coefficients (on diagonal), phenotypic correlations (above diagonal) and genetic correlations (below diagonal) of growth parameters in bulls at CPTS

Parameter (n = 2 008)	150-day weight (kg)	500-day weight (kg)	Average daily gain (from birth to 150 days) (g)	Average daily gain (from birth to 500 days) (g)	Average daily gain (from 150 to 500 days) (g)	Dressed carcass weight (kg)	Carcass yield (%)	Weight of kidney fat (kg)	Proportion of kidney fat (%)
150-day weight (kg)	**0.589**	0.360	0.978	0.359	0.039	0.361	0.148	0.218	0.165
500-day weight (kg)	0.146	**0.335**	0.358	1.000	0.942	0.986	0.323	0.540	0.329
Average daily gain (from birth to 150 days) (g)	0.976	0.133	**0.589**	0.358	0.027	0.360	0.152	0.218	0.166
Average daily gain (from birth to 500 days) (g)	0.141	1.000	0.129	**0.334**	0.943	0.986	0.324	0.540	0.329
Average daily gain (from 150 to 500 days) (g)	–0.278	0.903	–0.305	0.905	**0.416**	0.927	0.292	0.500	0.293
Dressed carcass weight (kg)	0.135	0.992	0.130	0.992	0.897	**0.343**	0.475	0.543	0.336
Carcass yield (%)	–0.022	0.494	0.025	0.497	0.463	0.601	**0.263**	0.231	0.177
Weight of kidney fat (kg)	–0.028	0.165	–0.050	0.164	0.182	0.196	0.300	**0.353**	0.955
Proportion of kidney fat (%)	–0.90	–0.061	–0.105	–0.062	–0.012	–0.028	0.194	0.424	**0.424**

correspond to the meat efficiency characterizing dual-purpose Czech Pied cattle (as compared to dairy breeds). Differences in growth parameters of progenies classified according to dam's genotype (Table 4) are less expressive.

As for sires of bulls – sons of C1 dams, BV for milk and milk protein amounted to –63.70 kg and –0.70 kg, resp. as compared to +14.02 kg and +2.79 kg, resp. (sires of bulls – sons of C 3 dams).

ADG in the testing period was 1 134 g (progeny of C1 dams), 1 140 g (progeny of C2 dams) and 1 108 g (progeny of C3 dams). Dressed carcass weight amounted to 313.59 kg (sons of C1 dams), and to 306.35 kg (sons of C3 dams). Polách *et al.* (2000) found average daily gain 974 g in progeny C1 and 940 g in progeny C2. Progeny C2 also had the highest dressed carcass weight (343 kg).

The lowest fatness parameters were found in progeny of C3 dams (6.18 kg kidney fat, 1.10% kidney fat), the highest in progeny of C2 dams (7.26 kg kidney fat, 1.28% kidney fat proportion).

It is evident that the shares of improvement dairy breed in dam's blood do not affect the good growth rate of their sons negatively.

Table 5 illustrates differences between sets formed according to sire's genotype × dam's genotype interactions. Compiled data correspond to data presented by Suchánek *et al.* (1990). The cited authors found a gradual reduction of differences between specific groups (namely in growth parameters) reflecting the progressive process of improvement.

The highest sire's RBV for corrected net gain (101.76%) was found in the 2nd group of bulls (progeny of C1 sires and C2 dams), the lowest value (91.65%) in the 3rd group (progeny of C2 sires and C1 dams). The highest dam's BV for milk production (70.79 kg) was recorded in the 5th group (progeny of C2 sires and C3 dams), the lowest

Table 3. Growth parameters and meat efficiency traits of bulls at CPTS as related to sire's genotype

Parameter		Genotype of sire		
		C_1	C_2	*t*-test
Breeding values (BV) of sire				
	n	1 784	224	
BV of milk production (kg)	$\mu + a_i$	**+17.10**	**–105.17**	9.13 ++
	$s_{\mu + a_i}$	17.70	36.42	
	n	1 754	209	
BV of milk protein (kg)	$\mu + a_i$	**+2.82**	**–2.01**	12.21 +++
	$s_{\mu + a_i}$	0.61	1.24	
	n	893	129	
RBV of corrected net gain (%)	$\mu + a_i$	**102.42**	**93.04**	15.86 +++
	$s_{\mu + a_i}$	1.37	2.41	
Growth parameters and meat efficiency traits		n = 1 784	n = 224	*t*-test
150-day weight (kg)	$\mu + a_i$	**166.64**	**164.27**	0.73
	$s_{\mu + a_i}$	0.76	1.38	
500-day weight (kg)	$\mu + a_i$	**567.52**	**554.44**	5.10 +
	$s_{\mu + a_i}$	2.41	4.40	
Average daily gain (from birth to 150 days) (g)	$\mu + a_i$	**912**	**896**	0.92
	$s_{\mu + a_i}$	5	9	
Average daily gain (from birth to 500 days) (g)	$\mu + a_i$	**1 076**	**1 050**	5.10 +
	$s_{\mu + a_i}$	4	8	
Average daily gain (from 150 to 500 days) (g)	$\mu + a_i$	**1 146**	**1 116**	7.67 ++
	$s_{\mu + a_i}$	6	12	
Dressed carcass weight (kg)	$\mu + a_i$	**317.33**	**308.43**	6.05 +
	$s_{\mu + a_i}$	1.45	2.64	
Carcass yield (%)	$\mu + a_i$	**55.89**	**55.59**	5.24 +
	$s_{\mu + a_i}$	0.12	0.22	
Weight of kidney fat (kg)	$\mu + a_i$	**7.013**	**7.067**	0.04
	$s_{\mu + a_i}$	0.12	0.22	
Proportion of kidney fat (%)	$\mu + a_i$	**1.216**	**1.259**	0.06
	$s_{\mu + a_i}$	0.020	0.036	

(–92.95 kg) in the 3rd group (progeny of C2 sires and C1 dams). The highest 150-day weight (167.88 kg) and the highest ADG (birth-150 days) (923 g) were recorded in progeny of C2 sires and C2 dams, the lowest ones (163.80 kg and 896 g) were found in progeny of C2 sires and C3 dams.

Progenies of C1 sires and C2 dams were characterized by the highest 500-day weight and highest dressed carcass weight (568.69 kg, 318.61 kg, resp.), and highest ADG from birth to 500 days and highest ADG in the testing period (1 078 g, 1 149 g, resp.). The corresponding lowest values were found in progenies of C2 sires and C3 dams (548.48 kg, 305.25 kg, 1 038 g, 1 098 g). The highest dressing percentage (56.01%) was calculated in progenies of C1 sires and C2 dams, the

Table 4. Growth parameters and meat efficiency traits of tested bulls as related to dam's genotype

Parameter	Tests		Groups according to genotype of dam		
			C_1	C_2	C_3
Breeding values (BV)					
Sire's BV of milk production (kg)		n	1 162	643	51
		$\mu + a_{ii}$	**–63.70**	**–71.09**	**+14.02**
		$s_{\mu + a_i}$	18.37	22.24	59.57
	F-test: 0.61; t-test:				
Sire's BV of milk protein (kg)		n	1 252	682	39
		$\mu + a_i$	**–0.70**	**–0.90**	**+2.79**
		$s_{\mu + a_i}$	0.62	0.76	2.03
	F-test: 1.12; t-test:				
Sire's RBV of corrected net gain (%)		n	676	320	26
		$\mu + a_i$	**96.69**	**97.72**	**98.32**
		$s_{\mu + a_i}$	1.48	1.68	3.64
	F-test: 0.21; t-test:				
Dam's BV of milk production (kg)		n	971	575	38
		$\mu + a_i$	**–68.74**	**–8.52**	**–13.49**
		$s_{\mu + a_i}$	9.25	11.68	40.78
	F-test: 4.66^{++}; t-test: $C_1 : C_2^{+++}$				
Parameters of meat efficiency and growth			n = 1 162	n = 643	n = 51
150-day weight (kg)		$\mu + a_i$	**165.37**	**165.72**	**162.95**
		$s_{\mu + a_i}$	0.75	0.85	2.47
	F-test: 1.25; t-test:				
500-day weight (kg)		$\mu + a_i$	**561.96**	**564.39**	**550.51**
		$s_{\mu + a_i}$	2.38	2.71	7.86
	F-test: 1.39; t-test:				
Average daily gain (from birth to 150 days) (g)		$\mu + a_i$	**904**	**907**	**887**
		$s_{\mu + a_i}$	5	6	16
	F-test: 1.13; t-test:				
Average daily gain (from birth to 500 days) (g)		$\mu + a_i$	**1 065**	**1 070**	**1 041**
		$s_{\mu + a_i}$	5	5	16
	F-test: 1.38; t-test:				
Average daily gain (from 150 to 500 days) (g)		$\mu + a_i$	**1 134**	**1 140**	**1 108**
		$s_{\mu + a_i}$	6	7	21
	F-test: 0.92; t-test:				
Dressed carcass weight (kg)		$\mu + a_i$	**313.59**	**315.30**	**306.35**
		$s_{\mu + a_i}$	1.43	1.62	4.72
	F-test: 1.49; t-test:				
Carcass yield (%)		$\mu + a_i$	**55.77**	**55.83**	**55.61**
		$s_{\mu + a_i}$	0.04	0.05	0.14
	F-test: 1.21; t-test:				
Weight of kidney fat (kg)		$\mu + a_i$	7.21	7.26	6.18
		$s_{\mu + a_i}$	0.12	0.14	0.40
	F-test: 2.90^{+}; t-test: $C_2 : C_3^{++}$ $C_1 : C_3^{+}$				
Proportion of kidney fat (%)		$\mu + a_{ii}$	1.27	1.28	1.10
		$s_{\mu + a_i}$	0.02	0.02	0.06
	F-test: 2.63^{+}; t-test: $C_2 : C_3^{++}$ $C_1 : C_3^{+}$				

Table 5. Growth parameters of tested bulls as related to sire's genotype × dam's genotype interaction

Breeding value of sire		C_1		C_2			
Breeding value of dam		C_1	C_2	C_1	C_2	C_3	*F*-test
Parameter	Group	1	2	3	4	5	
Sire's RBV of corrected net gain (%)	n	520	291	60	38	6	
	$\mu + a_i$	**101.74**	**101.76**	**91.65**	**93.68**	**91.76**	0.33
	$s_{\mu + a_i}$	1.23	1.35	2.25	2.70	6.30	
Dam's BV of milk production (kg)	n	947	443	103	68	7	
	$\mu + a_i$	**–44.53**	**–9.13**	**–92.95**	**–7.91**	**+70.79**	4.27 [+]
	$s_{\mu + a_i}$	5.90	8.48	17.60	21.77	67.30	
t-test: 1 : 2 [+++] 3 : 2 [+++] 3 : 1.4 [++] 3 : 5 [+]							
Growth parameters and meat efficiency traits		n = 1 049	n = 563	n = 113	n = 80	n = 13	*F*-test
150-day weight (kg)	$\mu + a_i$	**165.85**	**166.38**	**165.97**	**167.88**	**163.80**	0.16
	$s_{\mu + a_i}$	0.56	0.76	1.69	2.02	4.98	
500-day weight (kg)	$\mu + a_i$	**566.02**	**568.69**	**561.51**	**556.67**	**548.48**	0.71
	$s_{\mu + a_i}$	1.72	2.30	5.15	6.13	15.15	
Average daily gain (from birth to 150 days) (g)	$\mu + a_i$	**907**	**913**	**905**	**923**	**896**	0.31
	$s_{\mu + a_i}$	4	5	11	14	34	
Average daily gain (from birth to 500 days) (g)	$\mu + a_i$	**1 073**	**1 078**	**1 064**	**1 054**	**1 038**	0.72
	$s_{\mu + a_i}$	3	5	10	12	30	
Average daily gain (from 150 to 500 days) (g)	$\mu + a_i$	**1 144**	**1 149**	**1 133**	**1 111**	**1 098**	1.23
	$s_{\mu + a_i}$	5	6	14	16	40	
Dressed carcass weight (kg)	$\mu + a_i$	**316.85**	**318.61**	**313.29**	**310.44**	**305.25**	0.71
	$s_{\mu + a_i}$	1.03	1.38	3.08	3.67	9.07	
Carcass yield (%)	$\mu + a_i$	**55.96**	**56.01**	**55.77**	**55.72**	**55.64**	0.42
	$s_{\mu + a_i}$	0.03	0.04	0.09	0.11	0.28	
Weight of kidney fat (kg)	$\mu + a_i$	**7.16**	**7.14**	**7.03**	**7.22**	**6.84**	0.88
	$s_{\mu + a_i}$	0.09	0.12	0.27	0.32	0.80	
Proportion of kidney fat (%)	$\mu + a_i$	**1.246**	**1.247**	**1.237**	**1.285**	**1.218**	1.03
	$s_{\mu + a_i}$	0.014	0.019	0.043	0.052	0.128	

lowest one (55.64%) in progenies of C2 sires and C3 dams.

The lowest kidney fat and kidney fat proportion (6.84 kg, 1.218%, resp.) were found in progenies of C2 sires and C3 dams, the highest ones (7.22 kg and 1.285%) were recorded in progenies of C2 sires and C2 dams.

The mentioned data confirm the findings of Teslík *et al.* (1996): increasing milk production is associated with more intensive fat deposition

Table 6. Growth parameters and meat efficiency traits of tested bulls as related to sire's RBV for corrected net gain

Parameter		Groups formed according to sire's RBV for CNG		
		1 > 88%	2 88–115%	3 < 115%
		n = 237	n = 577	n = 208
Sire's RBV of corrected net gain (%)	$\mu + a_i$	**83.70**	**101.16**	**123.59**
	$s_{\mu + a_i}$	0.57	0.34	0.55
F-test: 1 275 +++	*t*-test: 1 : 2.3 +++ 2 : 3 +++			
Growth and meat efficiency traits				
150-day weight (kg)	$\mu + a_i$	**165.07**	**164.05**	**167.94**
	$s_{\mu + a_i}$	1.37	0.82	1.34
F-test: 5.94 ++	*t*-test: 2 : 3 +			
500-day weight (kg)	$\mu + a_i$	**543.18**	**565.00**	**596.08**
	$s_{\mu + a_i}$	4.32	2.59	4.22
F-test: 39.12 +++	*t*-test: 1 : 2.3 +++ 2 : 3 +++			
Average daily gain (from birth to 150 days) (g)	$\mu + a_i$	**902**	**896**	**920**
	$s_{\mu + a_i}$	9	5	9
F-test: 2.71	*t*-test:			
Average daily gain (from birth to 500 days) (g)	$\mu + a_i$	**1 027**	**1 070**	**1 133**
	$s_{\mu + a_i}$	9	5	8
F-test: 39.24 +++	*t*-test: 1 : 2.3 +++ 2 : 3 +++			
Average daily gain (from 150 to 500 days) (g)	$\mu + a_i$	**1 080**	**1 146**	**1 225**
	$s_{\mu + a_i}$	11	7	11
F-test: 41.89 +++	*t*-test: 1 : 2.3 +++ 2 : 3 +++			
Dressed carcass weight (kg)	$\mu + a_i$	**303.09**	**315.92**	**335.34**
	$s_{\mu + a_i}$	2.58	1.55	2.52
F-test: 40.99 +++	*t*-test: 1 : 2.3 +++ 2 : 3 +++			
Carcass yield (%)	$\mu + a_i$	**55.76**	**55.90**	**56.25**
	$s_{\mu + a_i}$	0.08	0.05	0.08
F-test: 10.86 +++	*t*-test: 1 : 3 +++ 2 : 3 +++			
Weight of kidney fat (kg)	$\mu + a_i$	**6.87**	**6.52**	**7.44**
	$s_{\mu + a_i}$	0.22	0.13	0.22
F-test: 6.49 ++	*t*-test: 2 : 3 +++			
Proportion of kidney fat (%)	$\mu + a_i$	**1.26**	**1.14**	**1.23**
	$s_{\mu + a_i}$	0.04	0.02	0.04
F-test: 4.74 ++	*t*-test: 1 : 2 ++ 2 : 3 +			

in the tissues of body cavities and body organs, increasing meat production is related to higher proportions of subcutaneous, intramuscular and internal fat.

Growth rate and meat efficiency of bulls tested at CPTS classified according to sire's RBV for CNG are presented in Table 6. Average sire's RBV for CNG amounted to 83.70% (1st group), 101.16% (2nd group) and to 123.59% (3rd group).

Increasing sire's RBV for CNG was associated with adequate increase in growth ability in fattened sons because the growth rate verified in tested sons is the basis for reverse calculation of sire' RBV for CNG. The lowest 150-day weight and the lowest ADG (birth-150 days) – 164.05 kg and 896 g, resp. – were recorded in bulls with mean sire's RBV for CNG. The highest respective values (167.94 kg and 920 g) were found in bulls – sons of sires with the highest RBV.

The lowest 500-day weight and dressed carcass weight (543.18 kg and 303.9 kg, resp.) were found in bulls – sons of sires with the lowest RBV for CNG, the highest ones (596.8 kg and 335.4 kg, resp.) in progenies of sires with the highest RBV.

The highest ADG in the testing period (1 225 g) was recorded in sons of sires with the highest RBV for CNG, the lowest one (1 080 g) in sons of sires with the lowest RBV.

The highest dressing percentage (56.25%) as well as the highest kidney fat (7.44 kg) were determined in progenies of sires with the highest RBV for CNG. Frickh *et al.* (2002) found the highest dressing percentage in Simmental bulls 57.1%.

The lowest proportion of kidney fat (1.14%) was found in sons of sires with mean RBV, the highest kidney fat proportions (1.26% and 1.23%) were recorded in progenies of sires with the lowest and the highest RBV for CNG, respectively.

The genetic potential of Czech Pied cattle guaranteeing significant improvement of meat efficiency is utilizable under adequate breeding conditions. Nutrition deficiency in the pre-fattening and fattening periods results in very low growth intensity reducing carcass value parameters not only in Czech Pied cattle, but also in progenies of imported breeding animals.

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ABSTRAKT

Hodnocení růstu býků na stanici kontroly výkrmnosti skotu ve vztahu ke genotypu rodičů

Do sledování bylo zahrnuto 2 008 býků českého strakatého skotu ze SKVS poražených do roku 1999, tj. narozených v průběhu let 1994 až 1997. Při posuzování genetických parametrů byly zjištěny nejvyšší hodnoty heritability průměrných denních přírůstků a hmotnosti ve 150 dnech věku h^2 = 0,589. Koeficient dědivosti průměrného denního přírůstku zjištěného v období testu představoval hodnotu h^2 = 0,416. U hmotnosti jatečně opracovaného těla a jatečné výtěžnosti byly zaznamenány hodnoty h^2 = 0,343, resp. h^2 = 0,263 a u ukazatelů stupně protučnění (hmotnosti a podílu ledvinového loje) pak hodnoty h^2 = 0,353, resp. h^2 = 0,424. Mezi hmotností ve 150 dnech věku a hmotností v 500 dnech věku byly zjištěny hodnoty genetických a fenotypových korelací r_g = 0,146 a r_{xy} = 0,360. Vztahy mezi průměrným denním přírůstkem v testu a HJOT, respektive hmotností ledvinového loje vykázaly hodnoty r_g = 0,897 a r_{xy} = 0,927, resp. r_g = 0,182 a r_{xy} = 0,500. Výše uvedené vztahy potvrzují obecně známou skutečnost většího rizika ukládání tuku v tělních dutinách se zvyšující se intenzitou růstu kombinovaných plemen skotu. Snížením hmotností v jednotlivých fázích výkrmu u skupiny s vyšším podílem jednostranně mléčných plemen v krvi otce se adekvátně snižují i hodnoty průměrných denních přírůstků do 150 dnů věku a následně i průměrný denní přírůstek v období zkoušky výkrmnosti (896 g, resp. 1 116 g u skupiny C2) oproti 912 g, resp. 1 146 g u skupiny C1. Při posuzování ukazatelů masné užitkovosti se vlivem vyššího podílu jednostranně dojných plemen na jedné straně snížila hmotnost jatečně opracovaného těla a jatečná výtěžnost na 308,43 kg, resp. 55,59 % u skupiny býků s otcem C2 v porovnání se skupinou býků s otcem C1, kteří vykázali 317,33 kg hmotnosti jatečně opracovaného těla a 55,89 % jatečné výtěžnosti, a na druhé straně se mírně zvyšuje intenzita ukládání tuku daná hmotností a podílem ledvinového loje 7,067 kg a 1,259 % u býků s otcem plemenné příslušnosti C2 v porovnání se 7,013 kg, resp. 1,216 % u skupiny býků s otcem C1. U skupin diferencovaných dle úrovně RPH otce pro KNP dosáhli nejnižší hmotnosti v 500 dnech věku a HJOT 543,18 kg, resp. 303,9 kg býci s nejnižší úrovní RPH otce pro korigovaný netto přírůstek (83,70 %) a nejvyšší 596,08 kg, resp. 335,34 kg pak vykázali synové býků s nejvyšší úrovní RPH otce (123,59 %). Avšak u skupiny synů otců s nejvyšší úrovní RPH pro korigovaný netto přírůstek byla zjištěna také nejvyšší hmotnost ledvinového loje (7,44 kg).

Klíčová slova: český strakatý skot; býci; masná užitkovost; růst; heritabilita; genetické korelace; fenotypové korelace

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Effect of chemical preservation with anhydrous ammonia on composition and degradability of crude protein in alfalfa hay

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ABSTRACT: The paper deals with effects of anhydrous ammonia and storage on chemical composition and degradability of crude protein (CP) in alfalfa hay. In comparison with untreated control, it was found out that in hay with a high moisture content (30%) the application of anhydrous ammonia at the dose of 1.35% of DM weight of hay resulted in an increase in the content of CP ($P > 0.05$). Statistically significant differences ($P < 0.05$) were observed in contents of ammonia in control and treated hay (0.086 vs. 0.115 %), and in the values of formol titration (0.26 vs. 0.34 %). Content of crude fibre and dry matter was not influenced by ammoniation. Rumen degradability of CP was lower ($P < 0.05$) in control hay than in ammonia-treated hay (68.31 vs. 71.87%).

Keywords: alfalfa hay; anhydrous ammonia; crude protein; degradability

The feeding value of hay is influenced by a number of agrotechnical and technological factors. Fodder preservation and, especially hay making is considerably dependent on climatic conditions. Frequent rainfalls during the period of forage drying always result either in great losses of dry matter and nutrients or even in a complete degradation of the final product. The average annual losses often make as much as 12 to 18% but after a longer period of drying they can be even remarkably higher. Johnson *et al.* (1983) mentioned that, as compared with good climatic conditions, the losses of crude protein (CP) and dry matter (DM) increased to as much as 43.3% and more than 32.6%, respectively, if fodder was preserved in periods of rainy weather. In general, however, it is well known that the addition of a suitable chemical preservative usually results in an improvement of both nutritive value and quality of hay. Such an improvement is caused not only by a reduction of nutrient losses but also by a certain nutritive value of the additive itself (Birnkammer, 1980). Worldwide, the ammonia treatment is considered as a promising method of preservation of high moisture native hay not only due to the reduction of total preservation costs but also because of an increase in the content of CP. Many authors reported an increase in CP content in ammonia-treated hay and straw (Birnkammer, 1980; Richter *et al.*, 1980; Winther *et al.*, 1983; Lines *et al.*, 1996 and others). Using ammonia at the dose of 3 to 4% of dry matter of harvested forage, Gibb and Bauer (1988) increased the content of CP in dry matter of grass hay from 8.38 to 15.13% and Coombs *et al.* (1989) from 11.3 to 19.4%. Mason *et al.* (1989) published similar results. According to Ballet *et al.* (1998), ammonia treatment improved digestibility and increased the content of CP in all investigated hay samples. The results of more authors indicated that ammonia at the dose of 1 and 2% of hay weight was adequate while at the dose of only 0.5% it was not so. Knapp *et al.* (1975), and Lacey *et al.* (1983) as well, observed that the treatment of alfalfa hay with anhydrous ammonia at the dose of 1% of the weight of forage containing 32% of water prevented moulding, heating and losses of digestible nutrients. In

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ruminants, the treatment of grass forage and/or wet straw with anhydrous ammonia can improve digestibility of nutrients (Streeter and Horn, 1980; Winther *et al.*, 1983 and others). This increase in digestibility of alkaline-treated fodder is associated with hydrolysis of esteric bounds existing between sugars present in cell walls on the one hand and phenolytic polymers on the other. At the same time, ammonia treatment also reduces concentrations of hemicellulose and crude fibre (CF) so that it also markedly influences the overall digestibility of forage (Buettner *et al.*, 1982; Van Soest *et al.*, 1984). These results also indicate that the efficiency of fodder ammoniation increases with the increasing content of water and higher doses of anhydrous ammonia.

The efficiency of hay preservation and storage can be evaluated not only on the basis of the content and digestibility of nutrients but also according to the extent of ruminal degradation of nutrients and the intake of feed by animals. Many authors tested the effect of hay ammoniation on the dry matter intake (Horton *et al.*, 1979; Shin *et al.*, 1985; Mason *et al.*, 1989 and others). As a rule, all these authors observed an increase in the intake of ammoniated hay by 6 to 48%. Brand *et al.* (1989) studied the in situ degradability of CP in ammoniated oat straw and observed increased values in comparison with in untreated control. After feeding meadow hay treated with 3% of ammonia, Benhamed and Dulphy (1985) observed an *in situ* increase in degradability of CP from 55.4 to 61.2%. Erasmus *et al.* (1990) also observed a markedly higher degradability of CP in ammonia-treated hay.

Lines *et al.* (1996) mentioned that the treatment of bales of alfalfa hay with 2% of ammonia (calculated on the basis of DM content) resulted in an increase of nitrogen from 3.26 to 4.16% on the one hand and in a change in CP degradability on the other. Data published by Mason *et al.* (1989) also indicate that a higher dose of anhydrous ammonia (3.5% DM) improved both the degradability of cell walls and the in vitro digestibility of organic matter.

Kováčová (2001) studied ruminal degradability and intestinal digestibility of CP and organic matter in alfalfa hay, ground extracted soybean and crushed maize and found that the ruminal degradability of CP was influenced not only by the rate of passage of feed through rumen but also by protein composition and CF content. The lowest values of efficient degradability of organic matter were found in alfalfa hay (49.5%).

The aim of this study was to evaluate effects of anhydrous ammonia and period of storage on composition of native alfalfa hay and on the level of degradability of CP.

MATERIAL AND METHODS

To evaluate qualitative changes occurring after the application of anhydrous ammonia during the process of drying, the alfalfa (*Medicago sativa* L.) stand was harvested at the stage of full flowering. Harvested swaths were turned three times and then, at the average DM content of 71 to 72% stored into a hayshed. Experimental forage was harvested from the area of 50 hectares and the average yield of green fodder was 25.6 tons per hectare. Immediately after storage, the experimental batch of alfalfa hay was treated with anhydrous ammonia at the dose of 0.97% of original hay weight. Anhydrous ammonia was applied to stored hay by means of an injector mounted on a fan so that its application was relatively homogeneous. The pressure tank containing anhydrous ammonia was weighed before and after the application so that it was possible to estimate the total amount of applied ammonia. To reach a stable DM content of 85%, experimental and control batches of hay were ventilated under identical conditions for two weeks. The stored hay was sampled at intervals of 1, 7, 14, 28, and 56 days after the application at 5 points and the samples were analysed to estimate the content of CP and ammonia and to determine values of formol titration and CP degradability. Crude protein and total ammonia were determined according to Kjeldahl (N × 6,25) and Conway methods, respectively (AOAC, 1980). Formol titration was determined by titration of hay extract (in 0.1 N NaOH) up to pH of 8.5. Prior to titration, the hay extract was neutralised with formaldehyde (FT value = amount of NaOH × 0.017 × f NaOH). NH_2 groups of amino acids were blocked by formaldehyde and free carboxyl groups were titrated by NaOH. The content of crude fibre (CF) was determined by using Fibertec system on a Tecator 1020. Effective degradability of CP was estimated by nylon bag method. Samples for the estimation of CP degradability were obtained from the middle of the haystack between days 1, 14 and 56 after the end of chemical treatment. Bags (pore size 42 μm) of the internal size 5 × 10 cm containing 1 g of milled sample (mesh size 2 mm) were fixed to a carrier (Třináctý *et al.*, 1996) and incubated in the rumen of fistulated dairy cows. Samples were incubated for 0; 2; 4; 8; 16; 24 and 48 hours. The sample of zero time interval was only rinsed for 15 minutes, i.e. without any subsequent incubation. After the incubation, the bags were rinsed for 15 minutes under tap water and dried in an oven overnight at the temperature of 60°C. The value of effective degradability (considering the dilution rate $k = 0.06$) was calculated according to Orskov and McDonald (1979).

Results were evaluated by means of analysis of variance using the software Statgraphic (ver. 5.0).

RESULTS AND DISCUSSION

The values of CP content in control and ammoniated alfalfa hay obtained in this trial were published by Doležal *et al.* (2000). Immediately before treatment the harvested alfalfa hay DM content of 71.85% contained 19.50%, 26.15% of, and 3.41% of CP, CF and water-soluble sugars, respectively. The average DM contents in control and ammoniated hay were 80.53% and 82.78%, respectively (Table 1). The ammoniation of stored hay resulted in an insignificant increase in the content of CP (20.22%). The control hay sample contained 19.99% of CP. It was found out that the place and the day of sampling did not show a significant effect on the values under study. This relatively small increase in CP content (i. e. by 5.0%) was lower than the values mentioned by Birnkammer (1980), Winther *et al.* (1983), Moore *et al.* (1985), Gibb and Bauer (1988), Coombs *et al.* (1989) and other authors who used higher concentrations of anhydrous ammonia for preservation of high moisture hay. This also indicated that the rate of ammonia absorption into stored hay was lower than expected and that its greater proportion obviously escaped into the atmosphere because the stored hay was dried with cold air 20 hours after ammoniation. Birnkammer (1980) mentioned that out of 80% of absorbed gaseous ammonia, altogether 42% were bound chemically and approximately 35% were in water-soluble form. On the other hand, Scholz (1982) observed that ammonia was absorbed up to 54%. An increased absorption of ammonia in plant material and, thus also an improved nutritive value of treated hay (due to the supplementation of amidic nitrogen) is dependent on the humidity of treated hay and the dose of ammonia. Effects of anhydrous ammonia on the content of NH_4^+ are presented in Table 1. These data indicate that in ammoniated hay the average concentration of $N\text{-}NH_4^+$ was higher than in untreated control. This difference was significantly higher during the whole study period ($P < 0.05$). Knapp *et al.* (1974) wrote that the N retention ranged from 60 to 80% in treated hay while Grotheer *et al.* (1985) mentioned the value of 67.2%. In our study, it was found out that, as compared with untreated control, the retention of NH_3-N was 85.60% because ammoniation resulted in an effective enrichment of 1 kg of hay by 7.98 g NH_3-N. This value was higher than that mentioned by Buettner *et al.* (1982), who found that only 57% of supplied total N was

Table 1. The content of ammonia and DM in control and ammoniated alfalfa hay during the period of drying and storage

Days after treatment	Ammonia content in control hay (%)	Ammonia content in treated hay (%)	Dry matter content in control hay (%)	Dry matter content in treated hay (%)
1	0.067[a]	0.116[b]	72.47	71.90
7	0.086	0.118	76.64[a]	82.96[b]
14	0.080	0.120	84.81	84.81
28	0.096	0.090	83.85	86.64
56	0.100	0.133	84.87	87.58
Average	0.086[a]	0.115[b]	80.53[a]	82.78[b]

Differences between values marked with different letters in the same row are significant ($P < 0.05$)

fixed. According to Winther *et al.* (1983), about 28 to 47% and 25 to 55%, respectively, of supplied ammonia were bound into water present in hay and released into the atmosphere. Thus a high concentration of NH_3-N was caused more probably by the amount of applied ammonia and not by the degree of proteolytic degradation of plant protein. An increasing concentration of ammonia is always associated with an increase in the proportion of water-soluble ammonia.

Average values of formol titration in ammoniated and control hay samples, as measured during the whole storage period, are presented in Table 2. As the results of this experiment indicate, ammoniation of wet alfalfa hay increased the value of this parameter significantly ($P < 0.05$). As compared with control, the value of formol titration in ammoniated hay was increased by 30.8%. It also corresponds with our earlier finding (Doležal *et al.*, 1988) that there is a very close correlation between the ammonia treatment and the value of formol titration. It is also known that the value of formol titration (estimated according to the Sorensen) is often influenced by the application of preservatives. It is quite obvious that ammoniation increased the amount of released N-amino acids and, thus the level of free amino acids. The value of formol titration, which indicates the content of free amidic N, is together with the content of ammonia and the degree of proteolysis another supplementary indicator that is suitable for the evaluation of chemically treated feeds.

Average contents of CF in control and ammoniated hay are presented in Table 3. If compared with data published by other authors (Birnkammer, 1980; Winther *et al.*, 1983) there was no significant decrease in CF in ammoniated hay. However, as mentioned in our earlier study (Doležal *et al.*, 1988), there was a decrease in the content of CF in hay DM by as much as 8.36% against control after the application of 1% of ammonia in a model experiment with high moisture alfalfa hay. A different concentration of CF in ammoniated hay was probably caused by a relatively small amount of applied ammonia and also a low degree of absorption. Due to a low content of water in hay (with 70% of DM) there were not suitable conditions for the establishment of chemical bonds. This small difference in the content of CF was probably also the cause of insignificant differences in the level of CP degradability in alfalfa hay. The course of ruminal degradation of CP in individual hay samples (expressed as the loss of CP in %) is presented in Table 4. These data indicate that practically after all time intervals the degradability of CP was faster in ammoniated hay than in control. When calculating the effective value of CP degradability according to Orskov *et al.* (1979) the average values for control and ammoniated hay were (56th day) 68.73% and 69.90%, resp. (Table 5). A difference in the values on 14th day was statistically significant ($P < 0.05$). Our results corresponded with data published in literature (Benhamed and Dulphy, 1985; Erasmus *et al.*, 1990). Smaller differences in the level of CP

Table 2. Results of formol titration in control and ammoniated alfalfa hay during the period of drying and storage

Days after treatment	Formol titration in	
	control hay (%)	treated hay (%)
1	0.27 [a]	0.43 [b]
7	0.26 [a]	0.33 [b]
14	0.29	0.34
28	0.24	0.30
56	0.26	0.29
Average	0.26[a]	0.34[b]

Differences between values marked with different letters in the same row are significant ($P < 0.05$)

Table 3. The content of crude fibre in non-treated and ammoniated alfalfa hay during the period of drying and storage

Days after treatment	Crude fibre content (%DM) in	
	control hay	treated hay
1	29.79	30.73
7	26.25	25.09
14	29.77	31.08
28	26.40	27.55
56	26.96	28.19
Average	27.83	28.53

Differences between values marked with different letters in the same row are significant ($P < 0.05$)

Table 4. The course of ruminal degradation of crude protein samples in various time intervals of incubation (expressed as a loss of CP in %)

Time (h)	Control alfalfa hay				Ammoniated alfalfa hay			
	day of sampling			average	day of sampling			average
	1st	14th	56th	(%)	1st	14th	56th	(%)
0	33.19	29.65	31.87	31.87	37.37	34.37	33.05	34.93
1	36.39	34.35	35.10	35.28	42.47	39.05	36.92	39.48
3	39.03	36.75	39.98	38.59	45.75	47.55	42.66	45.32
6	68.12	58.96	58.18	61.75	63.96	74.23	65.85	68.01
12	80.37	78.13	81.23	79.91	82.65	83.81	80.21	82.22
24	83.64	83.01	85.39	84.01	85.94	86.44	84.00	85.46
48	84.33	82.52	86.36	84.40	85.74	86.98	84.82	85.85

Table 5. Effective degradability of CP in alfalfa hay sampled from the central part of storage room (k = 0.06)

Collection of samples (day)	Control hay (%)	Ammoniated hay (%)
1	69.68	71.52
14	66.53[a]	74.18[b]
56	68.73	69.90
Average	68.31[a]	71.87[b]

Differences between values marked with different letters in the same row are significant ($P < 0.05$).

degradability of both variants were obviously associated with a lower dose of ammonia and a shorter exposition. However, our values of CP degradability were lower than those published by Kováčová (2001), who found the values of CP degradability in hay and alfalfa within the range of 48.6 and 75.1%. It is obvious that in ammoniated hay a higher degree of CP degradability was caused by a higher level of quickly soluble fractions of CP and, especially by a higher concentration of NH_3-N in ammoniated hay. This effect of quickly soluble CP fractions also corresponded with data published by Kováčová (2001). However, the effect of CF on ruminal degradability of CP was not demonstrated.

CONCLUSION

As compared with untreated control, the application of ammonia to wet alfalfa hay resulted in a statistically significant increase in ammonia content and values of formol titration ($P < 0.05$). Due to drying and storage, the values of formol titration decreased continually in both experimental variants. The average content of CF was higher in the experimental batch of hay (by 2.5%); however, this difference was statistically insignificant.

As far as the values of rumen degradation of CP were concerned, there were significant ($P < 0.05$) differences between both experimental variants. As compared with control, the values of rumen degradability of CP in ammoniated hay were higher by 5.20% on average. This higher CP degradability obviously resulted from a higher content of quickly soluble CP fractions in experimental samples of hay.

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ABSTRAKT

Vliv chemického ošetření bezvodým amoniakem na složení a degradovatelnost dusíkatých látek vojtěškového sena

Byl zjišťován vliv přídavku bezvodého amoniaku a faktor skladování na chemické složení a degradovatelnost N-látek ve vojtěškovém seně. Vojtěška setá (*Medicago sativa* L.) byla sklízena ve stadiu butonizace, při průměrném obsahu sušiny 71 až 72 % byla naskladněna do seníku a pokusná varianta byla ošetřena bezvodým amoniakem v dávce 0,97 % z hmotnosti sena. Vzorky sena k analýzám byly odebírány v 1. 7., 14., 21., 28. a 56. dni po ošetření. Ve vzorcích byl stanoven amoniak, formolová titrace, obsah sušiny, N-látek, vlákniny a metodou nylon bag byla stanovena degradovatelnost N-látek. Bylo zjištěno, že konzervace vojtěškového sena s vyšší vlhkostí (vlhkost asi 30 %) bezvodým amoniakem v dávce 1,35 % v přepočtu na sušinu sena vedla ke zvýšení obsahu N-látek ve srovnání s neošetřenou kontrolní variantou. Statisticky významné rozdíly ($P < 0,05$) byly nalezeny v obsahu amoniaku u kontrolního a ošetřeného sena (0,086 vs. 0,115 %), a formolové titrace (0,26 vs. 0,34 %) mezi oběma variantami sena ve prospěch pokusného zásahu. Obsah vlákniny a sušiny nebyl přídavkem amoniaku v podmínkách našeho pokusu ovlivněn ($P > 0,05$). Bachorová efektivní degradabilita N-látek byla u kontrolního sena nižší ($P < 0,05$) než u ošetřeného (68,31 vs. 71,87 %).

Klíčová slova: vojtěškové seno; bezvodý amoniak; dusíkaté látky; degradovatelnost

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The effect of calcium salts of fatty acids on nutrient digestibility and nitrogen, calcium and phosphorus balance in piglets

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ABSTRACT: A balance trial on 12 weaning piglets weighing from 8.1 to 17.9 kg was conducted to study the effect of dietary calcium salts of fatty acids (Ca-sFA)[1] on nutrient digestibility and N, Ca and P balance. Apparent digestibility of nitrogen, fat, nitrogen-free extract (NFE), fiber, organic matter, ash, Ca, P and balance of N, Ca and P were determined. Piglets were divided into 4 groups according to dietary contents of rapeseed oil and Ca-sFA. The diet for piglets in Group 1 (A0) contained 1.4% of rapeseed oil, in Group 2 (B2) an isocaloric supplement in the form of 1.8% Ca-sFA, in Group 3 (B3) 3.6% of Ca-sFA and in Group 4 (B4) 5.4% of Ca-sFA. The effect of supplementation of diets for early weaned piglets with Ca-sFA on apparent digestibility of N, fiber, organic matter and Ca was not significant. Apparent digestibility of fat increased with increasing Ca-sFA supplement. It was higher by 6.9% in Group 4 than in Group 2 ($P < 0.01$). Coefficients of apparent digestibility of NFE were higher by 1.9% and 2.4%, respectively, in piglets of Group 1 than in Groups 3 and 4, ($P < 0.01$). The values of apparent digestibility of ash increased significantly with higher dietary Ca-sFA contents ($P < 0.05$–0.01) and they ranged from 31.4 (B2) to 60.7% (B4). The apparent digestibility coefficients of phosphorus were significantly higher by 11.4% in Group 3 and by 11.3% in Group 4 in comparison with Group 1 ($P < 0.01$). Nitrogen utilization of ingested and digested N was significantly lower by 6.92% and 6.4%, respectively, in piglets of Group 2 than in Group 4 ($P < 0.05$). The retention of crude protein and Ca in g/day was not influenced significantly. A significant increase in the utilization of digested ($P < 0.05$) and ingested calcium ($P < 0.01$) was found. Phosphorus utilization of ingested P increased from 5.6 to 10.9% with increasing content of dietary Ca-sFA ($P < 0.05$–0.01) and of digested P decreased by 0.5–3.5% ($P < 0.05$). Phosphorus retention increased by 0.25 g in piglets of Group 3 in comparison with piglets of Group 1 ($P < 0.05$).

Keywords: piglets; calcium salts of fatty acids; nutrient digestibility; N, Ca and P balance

Calcium salts of fatty acids (Ca-sFA), which are less easily soluble in the fore stomach, are often used as an energy source in the diets for ruminants. They are saponified free fatty acids – transformed to hardly soluble salts. Higher amounts of this energy source do not have any negative effects on the rumen microbial population like unstabilized fat. Many papers were published dealing with the use of fatty acid salts in dairy cow feeding and with their effect on lactation (e.g. Schauff *et al.*, 1992; Garcia-Bojalil *et al.*, 1998). Salts of fatty acids were used to supplement energy to a diet for horses (Tomczynski *et al.*, 1994). Ca-salts of fatty acids were tested in diets for broiler chicks (Zhadan *et al.*, 1983). Feed conversion improvement was reported in these trials. The findings are in agreement with the results of our trials (Mendlík *et al.*, 1999), in which a 4.18% decrease in feed consumption per unit weight gain was found. The first trials with pigs were carried out by Zhadan *et al.* (1983), who reported a weight gain increase by 7.7%. Dressing percentage in their trials was higher by 4% but sensory characteristics of meat were worse. Salts of fatty acids are highly stable under current storage conditions; as this feed

[1]trademark Bovipal, Setuza, a.s., Ústí nad Labem

is in a loose form, it can easily be admixed into the compound feed without any special equipment but their lower palatability for their intensive odor should be pointed out.

The objective of this paper was to determine the effect of Ca-sFA supplement on nutrient digestibility of diets for piglets.

MATERIAL AND METHODS

A balance trial was conducted in RIAN Pohořelice on 12 piglets of the hybrid combination L × LW weighing from 8.1 to 17.9 kg. Piglets were weaned at the age of 28 days and transported to experimental pigsties. They were placed in one pen and

Table 1. Composition of experimental diets (g/kg)

Ingredient	Diet designation			
	A0	B2	B3	B4
Fish meal	35	35	35	35
Soybean meal	225	225	226	229
Barley	423	423	405	386.5
Wheat	203	203	203	203
Corn	49	49	49	49
Premix Lys HCl (60%)	5	5	6	6.7
Premix Thr (20%)	5	5	6	7
Premix Met (20%)	5	5	6	6
Monocalcium phosphate	10	10	10	10
Sodium phosphate, monobasic	5	5	5	5
Feeding limestone	15	11	7	2.8
Rapeseed oil	14	–	–	–
Fatty acids Ca salts	–	18	36	54
Premix of feed additives*	6	6	6	6
Crude protein	214.9	214.9	214.4	214.3
MEp MJ	13.0	13.0	13.4	13.7
Lys	13.3	13.3	13.8	14.1
Thr	8.9	8.9	9.0	9.2
Met	4.5	4.5	4.7	4.7
Crude fiber	38.2	38.2	37.4	36.7
Fat	33.9	33.9	47.7	61.4
Crude ash	62.7	61.2	59.8	58.3
Nitrogen-free extract	527.6	527.6	517.2	506.3
Ca	9.5	9.6	9.6	9.6
Digestible P	4.8	4.8	4.8	4.8

*1 kg of premix contained: vitamin A 1 800 000 i.u., vitamin D2 400 000 i.u., vitamin E 4 000 mg, vitamin K3 300 mg, vitamin B1 300 mg, vitamin B2 600 mg, vitamin B6 400 mg, vitamin B12 5 mg, niacin 2 500 mg, calcium pantothenate 1 500 mg, folic acid 50 mg, choline chloride 80 000 mg, $CaCO_3$ 250 g/kg, Cu 5 000 mg/kg, Fe 27 000 mg/kg, Zn 24 000 mg/kg, Mn 8 000 mg/kg, Co 134 mg/kg, I 120 mg/kg, Se 40 mg/kg received the same diet. After one-week adaptation period they were divided into 4 groups and housed in balance cages. The animals received the experimental diets (Table 1). The diet for Group 1 (A0) contained 1.4% of low erucic rapeseed oil, for Group 2 (B2) 1.8% of Ca-sFA, for Group 3 (B3) 3.6% of Ca-sFA and for Group 4 (B4) 5.4% of Ca-sFA. Energy content of the diet for Group 1 was the same as that for Group 2. Calcium salts of fatty acids were prepared from fatty acids resulting from the refining process of low erucic rapeseed oil. Lime saponification at an elevated temperature followed by washing and fluid drying were the next steps of the treatment of fatty acids. Calcium salts of fatty acids contain 80 g Ca and 820 g fat per 1 g. The composition of fatty acids was as follows: C 14:0 1.5%, C 16:0 18%, C 18:0 30%, C 18:1 33%. C 18:2 10%, C 18:3 2.3% and C 22:1 0.11%. Feed was offered *ad semi-libitum*, water was available *ad libitum*. A 7-day preliminary period was followed by five successive five-day balance periods. Feed consumption of piglets was recorded daily. Fecal collection was also carried out every day; feces were preserved with HCl and stored in a refrigerator. Feces collected for the whole balance period were mixed, weighed and lyophilized. Urine was collected every day, its amount was prepared and proportional samples were taken. An amount of excreted urine for the whole balance period was determined and a mixed sample was taken. Feces, feed and mixed sample of urine were analyzed by standard methods of the Association of Official Analytical Chemists (AOAC, 1984). Apparent digestibility of nitrogen, fat, NFE, Ca and P was calculated from nutrient intake and fecal nutrient excretion. Utilization of ingested and digested nutrients was calculated on the basis of nitrogen, Ca and P retention that was determined from a difference between nutrient intake and fecal and urinary nutrient excretion. Data were subjected to analysis of variance (Snedecor and Cochran, 1969) with differences between means assessed using the least significant difference test.

RESULTS

Table 2 shows apparent digestibility coefficients of nitrogen and values of N-balance. N digestibility was not significantly influenced in the balance period. Digestibility ranged from 84.8 to 86.9%. Nitrogen utilization of ingested and digested N significantly increased with increasing Ca-sFA supplement ($P < 0.05$). Nitrogen utilization of ingested and/or digested N was higher by 1.42% and 1.2%, respectively, in the rapeseed oil group than in the group with an isocaloric levels of Ca-sFA. Protein retention was not significantly influenced and ranged from 38.3 to 41.4 g/day.

Table 3 shows digestibility coefficients of fat, NFE, fiber, organic matter and ash. Apparent digestibility of fat ranged from 74.8 to 81.7% in the balance period. Fat digestibility significantly increased with increasing content of Ca-sFA ($P < 0.01$). There was no significant difference between the energy sources, i.e. between Group 1 and Group 2. Apparent digestibility coefficients of NFE were in the range of 88.1 and 90.5% in the whole balance period. NFE digestibility significantly ($P < 0.01$) decreased with increasing dietary Ca-sFA content. Apparent digestibility of fiber, ranging from 46.6 to 50.8%, was not significantly influenced in the experimental period. Organic matter digestibility values between 87 and 88.2% were in the range of natural variability. The values of ash digestibility significantly increased with higher dietary Ca-sFA content ($P < 0.01$), ranging from 31.4 to 60.7%.

Values of apparent digestibility of calcium and calcium balance are shown in Table 4. The values from 46.1 to 53.9% were in the range of natural variability and tended to increase with higher calcium supplement in the form of fatty acid salts. Utilization of ingested ($P < 0.01$) and digested calcium ($P < 0.01$) also increased with higher content of calcium in the form of fatty acid salts. Ca deposition was not influenced and ranged from 1.61 to 1.78 g/day.

Table 5 shows apparent digestibility values of phosphorus and phosphorus balance. Apparent digestibility of phosphorus ranged from 42.6 to 54.0%; it increased significantly ($P < 0.01$) with increasing Ca-sFA supplement. Utilization of ingested phosphorus was influenced significantly ($P < 0.01$) but utilization of digested phosphorus decreased with increasing Ca-sFA supplement ($P < 0.05$). The range of phosphorus retention values was from 1.19 to 1.44 g/day ($P < 0.05$).

DISCUSSION

Li and Sauer (1994) reported that digestibility of amino acids was not influenced by fat supple-

Table 2. Protein digestibility and N balance*

	Group diet**			
	A0	B2	B3	B4
Protein digestibility (%)				
Balance 1	83.0 ± 1.19	84.7 ± 2.33	89.1 ± 2.49	87.8 ± 2.49
Balance 2	84.3 ± 0.50	85.8 ± 1.05	86.1 ± 1.27	87.5 ± 1.27
Balance 3	86.5 ± 0.94	83.6 ± 1.30	86.4 ± 1.51	87.7 ± 1.51
Balance 4	86.4 ± 1.19	85.5 ± 1.21	82.2 ± 2.13	85.2 ± 2.13
Balance 5	86.9 ± 0.19	84.4 ± 1.78	81.7 ± 3.05	86.4 ± 3.05
Balance 1–5	85.4 ± 0.53	84.8 ± 0.64	85.1 ± 1.11	86.9 ± 0.55
N utilization of N uptake (%)				
Balance 1	48.0 ± 3.45	49.8 ± 3.06	63.6 ± 8.84	61.5 ± 9.64
Balance 2	53.2 ± 1.66	50.1 ± 0.24	53.3 ± 2.37	60.5 ± 2.95
Balance 3	50.1 ± 1.92	52.2 ± 1.62	47.1 ± 1.32	54.0 ± 2.53
Balance 4	50.6 ± 4.16	49.2 ± 1.02	44.6 ± 1.20	52.4 ± 1.31
Balance 5	56.3 ± 0.86	49.6 ± 0.73	54.7 ± 1.78	58.1 ± 0.16
Balance 1–5	51.6^{ab} ± 1.28	50.2^{a} ± 0.69	52.6^{ab} ± 2.39	57.1^{b} ± 2.10
N utilization of digested N (%)				
Balance 1	57.8 ± 3.40	58.7 ± 2.12	70.9 ± 7.82	69.7 ± 9.50
Balance 2	63.1 ± 1.61	58.5 ± 0.91	61.8 ± 1.90	69.2 ± 3.85
Balance 3	57.9 ± 1.73	62.4 ± 0.98	54.7 ± 2.20	61.5 ± 2.10
Balance 4	58.5 ± 4.30	57.6 ± 1.97	54.4 ± 2.78	61.4 ± 0.96
Balance 5	64.8 ± 0.94	58.8 ± 0.37	67.0 ± 1.20	67.2 ± 0.37
Balance 1–5	60.4^{ab} ± 1.29	59.2^{a} ± 0.70	61.7^{ab} ± 2.31	65.6^{b} ± 2.08
Protein retention (g/day)				
Balance 1–5	40.7 ± 3.94	38.3 ± 3.05	39.3 ± 3.72	41.4 ± 3.78

Capital letters designate highly significantly different values at $P < 0.01$
Small letters designate significantly different values at $P < 0.05$
*mean ± standard error of the mean ($n = 3$)
**A0 – 1.4% rapeseed oil, B2 – 1.8%, B3 – 3.6%, B4 – 5.4% Ca salts of fatty acids

ment but they established a linear relationship between ileal digestibility of amino acids and increasing supplements of fat in the diet. Even if we determined apparent N digestibility in our experiment, we observed the same relationship, that was propably associated with a change in the ratio of energy to lysine, the first limiting dietary amino acid. Nitrogen digestibility in piglets of Group 3 was lower than that in piglets of Group 1 but the utilization of ingested or digested N was higher.

In pigs weighing 35 kg Jorgensen *et al.* (2000) found digestibility values of fat ranging from 88

Table 3. Nutrient digestibility*

	Group diet**			
	A0	B2	B3	B4
Fat digestibility (%)				
Balance 1	79.5 ± 4.62	76.3 ± 3.37	84.0 ± 3.21	83.3 ± 2.75
Balance 2	77.5 ± 2.26	76.1 ± 3.97	75.0 ± 2.79	84.0 ± 0.23
Balance 3	80.9 ± 1.85	70.9 ± 4.26	78.7 ± 2.53	81.0 ± 2.14
Balance 4	79.5 ± 3.74	72.8 ± 3.18	75.6 ± 3.31	80.1 ± 0.66
Balance 5	81.9 ± 0.89	77.6 ± 3.34	71.4 ± 5.73	80.9 ± 0.31
Balance 1–5	79.9^{AB} ± 1.20	74.8^{A} ± 1.53	76.9^{AB} ± 1.80	81.7^{B} ± 0.76
Nitrogen-free extract digestibility (%)				
Balance 1	89.1 ± 0.58	90.1 ± 0.89	90.6 ± 2.25	88.8 ± 2.03
Balance 2	90.3 ± 0.23	89.7 ± 0.66	88.6 ± 0.84	88.0 ± 0.10
Balance 3	91.0 ± 0.29	90.0 ± 0.83	89.7 ± 0.28	89.3 ± 0.13
Balance 4	91.2 ± 0.52	90.0 ± 0.24	87.3 ± 0.27	87.0 ± 0.20
Balance 5	90.8 ± 0.40	90.1 ± 0.79	86.8 ± 1.28	87.4 ± 0.31
Balance 1–5	90.5^{Aa} ± 0.26	90.0^{ABa} ± 0.27	88.6^{BCb} ± 0.60	88.1^{Cb} ± 0.45
Crude fiber digestibility (%)				
Balance 1	47.8 ± 3.40	52.5 ± 5.58	57.9 ± 9.26	53.8 ± 8.38
Balance 2	51.7 ± 1.71	50.2 ± 1.72	46.1 ± 3.88	49.7 ± 3.74
Balance 3	52.0 ± 1.29	47.0 ± 3.10	53.5 ± 3.23	54.1 ± 0.86
Balance 4	51.6 ± 2.91	46.8 ± 3.49	40.2 ± 3.15	40.0 ± 4.03
Balance 5	50.8 ± 2.66	48.0 ± 5.90	35.3 ± 7.18	43.7 ± 3.90
Balance 1–5	50.8 ± 1.04	48.9 ± 1.71	46.6 ± 3.14	48.1 ± 2.47
Organic matter digestibility (%)				
Balance 1	86.7 ± 0.90	88.1 ± 1.32	89.7 ± 2.38	88.0 ± 2.11
Balance 2	87.8 ± 0.10	88.0 ± 0.80	87.0 ± 1.01	87.3 ± 0.30
Balance 3	88.8 ± 0.48	87.4 ± 0.72	88.2 ± 0.68	88.2 ± 0.38
Balance 4	88.9 ± 0.77	88.0 ± 0.58	85.3 ± 0.82	85.8 ± 0.37
Balance 5	88.8 ± 0.35	88.0 ± 1.12	84.5 ± 1.87	86.5 ± 0.37
Balance 1–5	88.2 ± 0.32	87.9 ± 0.36	87.0 ± 0.76	87.2 ± 0.45
Crude ash digestibility (%)				
Balance 1	39.6 ± 2.30	32.0 ± 1.42	46.6 ± 1.78	61.9 ± 2.04
Balance 2	38.6 ± 1.13	32.0 ± 1.67	41.6 ± 1.55	62.4 ± 0.17
Balance 3	40.3 ± 0.92	29.8 ± 1.79	43.7 ± 1.40	60.1 ± 1.59
Balance 4	39.6 ± 1.87	30.6 ± 1.33	41.9 ± 1.84	59.5 ± 0.49
Balance 5	40.8 ± 0.44	32.6 ± 1.40	39.6 ± 3.18	60.1 ± 0.23
Balance 1–5	39.8^{Bb} ± 0.60	31.4^{Aa} ± 0.64	42.7^{Bc} ± 1.00	60.7^{Cd} ± 0.53

Capital letters designate highly significantly different values at $P < 0.01$

Small letters designate significantly different values at $P < 0.05$

*mean ± standard error of the mean ($n = 3$)

**A0 – 1.4% rapeseed oil, B2 – 1.8%, B3 – 3.6%, B4 – 5.4% Ca salts of fatty acids

Table 4. Calcium digestibility and balance*

	Group diet**			
	A0	B2	B3	B4
Calcium digestibility (%)				
Balance 1	27.2 ± 2.45	40.0 ± 6.79	57.5 ± 11.63	46.5 ± 9.71
Balance 2	42.0 ± 4.83	46.0 ± 6.16	50.4 ± 1.77	46.0 ± 8.15
Balance 3	51.8 ± 1.70	45.4 ± 5.12	53.0 ± 0.26	56.7 ± 4.21
Balance 4	53.8 ± 3.56	53.1 ± 2.58	58.9 ± 2.06	52.8 ± 3.93
Balance 5	55.9 ± 1.89	52.8 ± 4.41	49.5 ± 4.32	51.6 ± 2.36
Balance 1–5	46.1 ± 3.07	47.5 ± 2.37	53.9 ± 2.37	51.1 ± 2.51
Ca utilization of Ca uptake (%)				
Balance 1	16.7 ± 3.98	35.5 ± 6.90	52.0 ± 13.58	44.1 ± 10.41
Balance 2	32.0 ± 4.71	40.5 ± 3.37	42.1 ± 3.68	41.8 ± 6.75
Balance 3	42.3 ± 0.39	41.6 ± 4.97	47.4 ± 0.48	55.4 ± 4.15
Balance 4	45.7 ± 4.20	49.9 ± 0.33	55.8 ± 2.15	51.8 ± 4.00
Balance 5	54.2 ± 2.26	51.8 ± 3.95	48.0 ± 4.63	50.7 ± 2.27
Balance 1–5	38.2^{a} ± 3.69	43.7^{ab} ± 2.34	49.1^{b} ± 2.82	49.3^{b} ± 2.68
Ca utilization of digested Ca (%)				
Balance 1	60.5 ± 11.39	88.9 ± 7.05	88.4 ± 4.81	93.8 ± 2.43
Balance 2	75.6 ± 2.88	89.3 ± 5.67	83.6 ± 7.10	90.9 ± 1.43
Balance 3	81.8 ± 3.53	91.9 ± 4.59	89.6 ± 1.11	97.6 ± 0.62
Balance 4	84.7 ± 2.29	94.4 ± 4.04	94.8 ± 0.43	98.1 ± 0.58
Balance 5	96.9 ± 0.79	98.1 ± 0.74	96.7 ± 1.05	98.3 ± 0.54
Balance 1–5	79.9^{A} ± 3.83	92.5^{B} ± 2.06	90.6^{B} ± 1.93	96.1^{B} ± 0.90
Calcium retention (g/day)				
Balance 1–5	1.61 ± 0.26	1.74 ± 0.21	1.78 ± 0.18	1.75 ± 0.19

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Small letters designate significantly different values at $P < 0.05$
* mean ± standard error of the mean ($n = 3$)
**A0 – 1.4% rapeseed oil, B2 – 1.8%, B3 – 3.6%, B4 – 5.4% Ca salts of fatty acids

to 93%: digestibility of rapeseed oil with higher content of unsaturated fatty acids was higher than digestibility of coconut oil with higher content of saturated fatty acids. Cera *et al.* (1988b) in their experiments on piglet, determined the digestibility of corn oil with higher content of unsaturated fatty acids in piglets in the range of 79–89% and digestibility of animal fats in the range 67–84%. The values achieved in our trial (74.8–81.7%) are at the lower boundary of this range; it can likely be explained by worse digestibility of fat in young piglets. However, Cera *et al.* (1990) described higher apparent digestibility of fat within 2 weeks after piglet weaning in coconut oil with higher content of saturated fatty acids than in soybean oil with higher content of unsaturated fatty acids. Mahan (1991), Cera *et al.* (1988a) or Lawrence and Maxwell (1983) reported a positive effect of coconut or soybean oil supplement to compound feed for weaned piglets on their performance. Li *et al.* (1990) drew attention to a positive effect of the combination of soybean and coconut oil on ileal digestibility of fatty acids and on basic performance characteristics. It is to conclude from the results of

Table 5. Phosphorus digestibility and balance*

	Group diet**			
	A0	B2	B3	B4
Phosphorus digestibility (%)				
Balance 1	27.0 ± 3.90	43.3 ± 4.37	58.4 ± 11.85	48.9 ± 6.63
Balance 2	40.4 ± 4.20	49.2 ± 4.15	53.7 ± 1.97	52.0 ± 5.07
Balance 3	48.5 ± 1.24	48.1 ± 5.49	53.8 ± 1.37	60.4 ± 0.75
Balance 4	46.8 ± 4.12	51.5 ± 2.14	56.0 ± 1.75	53.8 ± 2.70
Balance 5	50.2 ± 1.80	50.4 ± 2.14	48.0 ± 5.11	53.6 ± 2.51
Balance 1–5	42.6[A] ± 2.59	48.5[AB] ± 1.65	54.0[B] ± 2.42	53.9[B] ± 1.83
P utilization of P uptake (%)				
Balance 1	26.7 ± 3.91	42.0 ± 4.58	58.2 ± 11.89	47.6 ± 7.44
Balance 2	40.1 ± 4.23	48.9 ± 4.12	51.4 ± 0.36	51.5 ± 5.31
Balance 3	48.3 ± 1.24	47.8 ± 5.47	53.5 ± 1.40	56.6 ± 1.75
Balance 4	46.6 ± 4.15	51.3 ± 2.12	55.5 ± 1.80	51.1 ± 2.77
Balance 5	50.1 ± 1.81	50.0 ± 2.21	47.8 ± 5.14	51.5 ± 1.96
Balance 1–5	42.4[Aa] ± 2.60	48.0A[Bab] ± 1.72	53.3[Bb] ± 2.42	51.7A[Bb] ± 1.81
P utilization of P digested (%)				
Balance 1	99.0 ± 0.16	96.9 ± 1.69	99.5 ± 0.13	96.7 ± 2.66
Balance 2	99.4 ± 0.16	99.4 ± 0.10	96.0 ± 3.61	98.9 ± 0.56
Balance 3	99.4 ± 0.04	99.4 ± 0.09	99.5 ± 0.07	93.8 ± 4.01
Balance 4	99.5 ± 0.10	99.5 ± 0.03	99.2 ± 0.24	95.1 ± 1.91
Balance 5	99.7 ± 0.03	99.2 ± 0.24	99.5 ± 0.16	96.3 ± 1.62
Balance 1–5	99.4[a] ± 0.08	98.9[ab] ± 0.40	98.7[ab] ± 0.71	95.9[b] ± 1.08
Phosphorus retention (g/day)				
Balance 1–5	1.19[a] ± 0.14	1.37[ab] ± 0.13	1.44[b] ± 0.12	1.39[ab] ± 0.13

Capital letters designate highly significantly different values at $P < 0.01$
Small letters designate significantly different values at $P < 0.05$
*mean ± standard error of the mean ($n = 3$)
**A0 – 1.4% rapeseed oil, B2 – 1.8%, B3 – 3.6%, B4 – 5.4% Ca salts of fatty acids

these trials that fat supplement has a positive effect on production traits of piglets while digestibility of fat with higher content of unsaturated fatty acids is linearly dependent on increasing age. Coefficients of apparent digestibility of NFE decreased with increasing content of dietary Ca-sFA. It is suggested that fat retention is preferred to saccharide digestion.

Maynard *et al.* (1979, cit. by McDowell 1992) states that irrespective of the forms in which Ca and P are ingested, their absorption is dependent on their solubility at the point of contact with the absorption membranes. The values of apparent digestibility of calcium in piglets determined in our trial tended to increase with its higher amount in the form of fatty acid salts. McDowell (1992) reported the same finding: Ca-sFA are insoluble Ca forms that are assimilated with difficulty, yet a certain amount of fat seems to favor the absorption of this element. This effect was likely to contribute to better utilization of Ca from ingested and digested Ca.

The coefficients of phosphorus digestibility showed the same trend as those of Ca digestibility, and they increased with increasing Ca-sFA supplement. Utilization of P from ingested P also increased with higher Ca-sFA supplement. An opposite dependence was observed in the utilization of digested P: it is probably connected with urine phosphorus excretion while the Ca : P ratio was maintained in all diets for piglets.

It is to conclude from the results of this trial that Ca-sFA can be used as an energy source for piglets.

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ABSTRAKT

Vliv solí vápníku mastných kyselin na stravitelnost živin a bilanci dusíku, vápníku a fosforu u selat

V bilančním pokusu s 12 odstavenými selaty o hmotnosti od 8,1 do 17,9 kg byl sledován vliv vápenatých solí mastných kyselin (Ca-sMK)[1] v krmných směsích na stravitelnost živin a bilanci N, Ca a P. Byla stanovena bilanční stravitelnost dusíku, tuku, BNLV, vlákniny, organické hmoty, popelu, Ca, P a bilance N, Ca a P. Selata byla roz-

[1]obchodní značka Bovipal a.s., Setuza, Ústí nad Labem

dělena do čtyř skupin podle obsahu řepkového oleje a Ca-sMK v krmných směsích. Směs pro selata ve skupině 1 (A0) obsahovala 1,4 % řepkového oleje, ve skupině 2 (B2) alikvotní podíl energie v 1,8 % Ca-sMK, ve skupině 3 (B3) 3,6 % Ca-sMK a ve skupině 4 (B4) 5,4 % Ca-sMK. Bilanční stravitelnost N, vlákniny, organické hmoty a Ca nebyly zařazením Ca-sMK do krmných směsí pro časný odstav selat statisticky významně ovlivněny. Bilanční stravitelnost tuku se s vyšším přídavkem Ca-sMK zvyšovala. U skupiny B4 byla vyšší o 6,9 % než u skupiny B2 ($P < 0,01$). Koeficienty bilanční stravitelnosti BNLV byly u selat skupiny A0 vyšší o 1,9 % resp. 2,4 % než u skupiny B3, resp. B4 ($P < 0,01$). Hodnoty bilanční stravitelnosti popelu se s vyšším obsahem Ca-sMK v krmných směsích statisticky významně zvyšovaly ($P < 0,05$–$0,01$) a byly v rozmezí od 31,4 (B2) do 60,7 % (B4). Koeficienty bilanční stravitelnosti fosforu byly statisticky významně vyšší u skupiny B3 o 11,4 % a u skupiny B4 o 11,3 % ve srovnání se skupinou A0 ($P < 0,01$). Využití dusíku z přijatého a ze stráveného bylo signifikantně nižší u selat skupiny B2 o 6,92 % a o 6,4 % než u selat skupiny B4 ($P < 0,05$). Ukládání NL a Ca v g/den nebylo signifikantně ovlivněno. Statisticky významně se zvyšovalo využití stráveného ($P < 0,05$) a přijatého vápníku ($P < 0,01$). Využití fosforu z přijatého se zvyšovala z 5,6 na 10,9 % s rostoucím obsahem Ca-sMK v dietě ($P < 0,05$–$0,01$) a ze stráveného fosforu se snižovalo o 0,5–3,5 % ($P < 0,05$). Ukládání fosforu se zvýšilo u selat skupiny B3 o 0,25 g ve srovnání se selaty skupiny A0 ($P < 0,05$).

Klíčová slova: selata; vápenaté soli mastných kyselin; stravitelnost živin; bilance N, Ca a P

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Food and nutritive value of gut contents of rudd (*Scardinius erythrophthalmus* L.) from Vrana Lake, Cres Island, Croatia

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ABSTRACT: Gut contents of rudd, *Scardinius erythrophthalmus* L. (age group 3+), which represents a dominant fish species in the oligotrophic karstic Vrana Lake, Cres Island, Croatia, were examined. Benthic micro- and macroalgae (Cyanobacteria, Dinophyceae, Bacillariophyceae, Chlorophyceae, Xanthophyceae) constituted the major food items of the species while macrophytes (mostly *Potamogeton*), zooplankton (Cladocera and Copepoda) and detritus were also recorded. Over the period of study, diatomaceous Bacillariophyceae were observed in all samples, contributing up to 79% of dietary intake during February. An increased variation of food in gut contents, associated with elevated gut lipid and protein presence, was observed in May and June. During this period, total energy or nutritive values were increased when compared with other months.

Keywords: oligotrophic lake; herbivory; food; biochemical composition; rudd *Scardinius erythrophthalmus*

Rudd (*Scardinius erythrophthalmus* L.) is a cyprinid fish that inhabits Croatian rivers of the Black Sea and Adriatic Sea watersheds (Lelek, 1989). As a limnophilic species, rudd are frequently observed in slow flowing and stagnant waters that contain submersed vegetation. As a littoral species, rudd influences the abundance of vegetation in many European lakes (e.g. Holčik, 1967; Johansson, 1987; Eklöv and Hamrin, 1989; Lodge, 1991; VanDonk and Otte, 1996) by enhancing water phosphate concentrations, which stimulates epiphytic algal growth (Hansson *et al.*, 1987). The food of rudd changes with age and growth. Throughout their life, rudd feed on zooplankton, detritus, phytoplankton and macrophytes (e.g. Prejs, 1973, 1984; Niederholzer and Hofer, 1980; Ravera and Jamet, 1991; Martyniak *et al.*, 1996; Garcia-Berthou and Moreno-Amich, 2000). However, little is known about the chemical composition (e.g. protein and lipid) and nutritive value of rudd diet under natural conditions.

Food quality may be more important than food quantity with respect to both growth and reproduction in animal populations. Ecological limitation studies performed on primary consumers, particularly zooplankton, were focused on elemental limitation (Hessen, 1992; Sommer, 1992; Sterner *et al.*, 1992). The elemental limitation approach with zooplankton may, however, reflect limitation of one or more biochemical compounds (Müller-Navarra, 1995). Comparison of various compounds, such as certain fatty acids (the main constituents of lipids) may be far more important as key factors than for example amino acids (the main constituents of proteins). For phytoplankton, at the base of the food chain, lipid content and fatty acid composition are highly variable, species-specific and dependent upon conditions supporting growth (Shifrin and Chisholm, 1981; Roessler, 1990). In contrast, protein content and amino acid composition in phytoplankton taxa show significantly lower variation (e.g. Ahlgren *et al.*, 1992). In fish, the importance of protein and lipid quality is of high importance and long chained fatty acids are critical for the growth, development and survival of early larval stages of many species (e.g. Watanabe *et al.*, 1983).

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The objective of the present studies was to examine the biochemical composition of the gut contents from rudd inhabiting an oligotrophic lake. In addition, the study comprised an investigation of the food nutritive value and how it varied over a year long cycle.

MATERIAL AND METHODS

Vrana Lake (44°21' N and 14°21' E; Figure 1) as a monomictic, oligotrophic cryptodepression bottom is 62 m below mean sea level, whose surface is 13 m above mean sea level. The average area of the water surface is 5.75 km^2. The lake is fed by run-off water from the lake basin only, without any other surface inflow (Petrik, 1957, 1960). The lake's catchment area is unpopulated and covered with Mediterranean vegetation. In shallow waters of the northern and southern parts of the Lake, vegetation comprises *Phragmites communis* Trin. and *Typha angustifolia* L. At greater depths, *Scirpus* sp. predominates while a zone of submersed vegetation lies still deeper, comprising *Potamogeton perfoliatus* L. and large beds of *Potamogeton pectinatus* L. with sporadic *Myriophyllum spicatum* L. This vegetation is observed at 7 m, where it is replaced by beds of the alga *Chara* (down to 30 m depth). Characeae predominate the flora of Vrana Lake (Golubić, 1961).

Due to its exceptionally pure water the Lake is abundant in fish, including chub (*Leuciscus cephalus* L.), tench (*Tinca tinca* L.), pike (*Esox lucius* L.) and rudd (*Scardinius erythrophthalmus* L.). The latter species predominates accounting approximately for 75% of the total fish population. The most numerous are rudd of the age-group 3+ (about 61%) (Scheibel, 1998).

The gut contents of 140 rudds in the 3+ class were examined. The fish were collected in February, May, June, August and November by seining of the littoral zone of the lake (Figure 1). Average specimen weight was 440.38 ± 30 g, mean FL was 252.0 ± 8.8 mm. Gut contents were removed from individual fishes and prior to qualitative microscopic analyses, diluted (1 : 10) using distilled water.

Natural components of fish food were determined by using standard keys for aquatic organisms: Hindak *et al.* (1978), Kerovec (1986). The obtained data were expressed in terms of percentage presence of all detected organisms (Holden and Raitt, 1974) and assigned according to the formula:

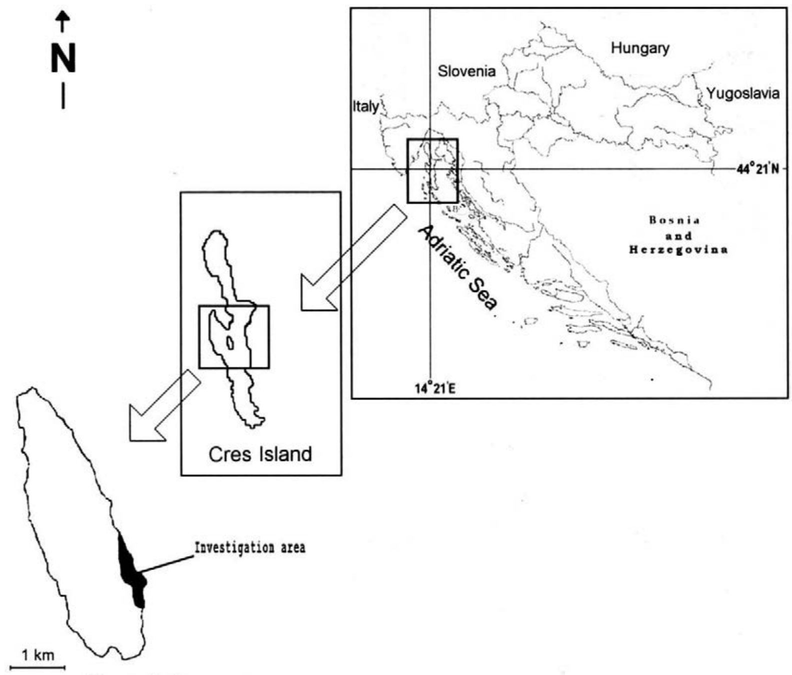

Figure 1. Study site

$$F.O. (\%) = fi / \Sigma f \times 100$$

where: F.O.(%) = percentage of the frequency of occurrence
fi = frequency of one nutritive category
Σf = total frequency of all nutritive categories

To determine basic biochemical composition, gut contents were homogenized in a grinder, and the quantities of protein, lipid, ash and moisture were determined. The protein quantity (N × 6.25) was measured by a micro-Kjeldahl method (boric acid was used as a receiver solution and hydrochloric acid as a titrant; Kjeltec Auto 1030 Analyzer). Lipids were determined following extraction with trichloroethylene using a Soxtec Tecator system. Ash was assessed following incineration in a muffle furnace at 525°C for 6 hours. Percent moisture was calculated following sample drying at 105°C for 24 h. Based on protein and lipid quantities the nutritive value was calculated using Rubner factors (Schormüller, 1974): 4.1 for proteins and 9.3 for lipids. Protein and lipid values were multiplied by 4.184 to estimate energy value (kJ). Effects of food types and biochemical composition were compared by one-way ANOVA.

RESULTS AND DISCUSSION

In Vrana Lake, rudd (*Scardinius erythrophthalmus* L.) was the most abundant fish species. Its food indicated that it was strictly littoral. This observation is similar to the findings of other authors in different European lakes (Eklöv and Hamrin, 1989; Horppila *et al.*, 2000). Rudd of the 3+ age group were found to consume primarily aquatic plant material (~97%) in Vrana Lake. Of particular significance in the diet of the species were algae that were absent or of lesser importance in other species present in the lake. Although several lake species of Europe consume plant material, herbivory is particularly important to rudd, roach and ide (*Leuciscus idus* L.) (Prejs and Jackowska, 1978; Niederholzer and Hofer, 1980). Although more common in tropical or subtropical fish (Okeyo, 1989), herbivory in rudd adults is considered extremely important in certain populations that consume a wide variety of aquatic plants and algae (e.g. Holčik, 1967; Ravera and Jamet, 1991). Macrophytes usually dominate the food of rudd (% biomass = 65–95; Prejs, 1984). However, in Vrana Lake, this was not observed, with the major component of the diet being made up of microalgae (Figure 2).

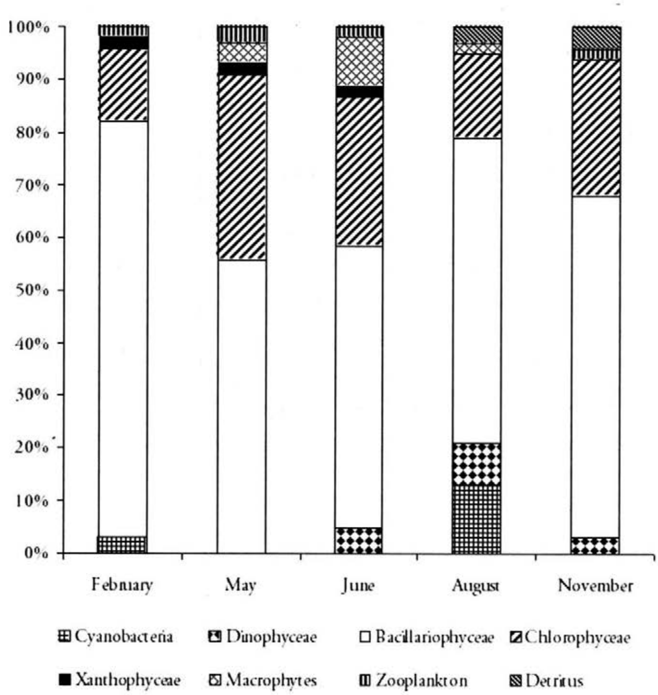

Figure 2. The food of rudd gut contents (%) in February, May, June, August and November (1997)

Rudd from other localities were observed to feed upon animal prey intensively including the larvae of small littoral chironomids and others including Gammarus, Asellus and caddis larvae (Martyniak *et al.*, 1996; Garcia-Berthou and Moreno-Amich, 2000). However, in Vrana Lake the prevalence of invertebrates (zooplankton) was low (≤ 3% of the diet) throughout the periods of investigation, suggesting that these small prey items could be taken incidentally with plant material rather than actively ingested.

The guts of examined rudd contained approximately 85% of epiphytic and benthic microalgae with the Bacillariophyceae (diatoms) representing the highest proportion (56–79%; Figure 2). Apart from benthic micro- and macroalgae (Cyanobacteria, Dinophyceae, Xanthophyceae and Chlorophyta) and macrophytes (mostly *Potamogeton*) the only invertebrates recorded were zooplanktonic (Figure 2), representing the Cladocera and Copepoda. Detritus accounted for up to 4% of the diet.

The biochemical composition of rudd gut contents varied significantly over the period of investigation (Figure 3). Percent mean protein values showed an increasing trend in spring (May) reaching the maximum in June (Figure 3). Diatoms, which dominated during the period of investigation, did not differ significantly in protein. Over the same period, macroalgae of Chlorophyta (e.g. *Mougeotia* sp. and *Chara* sp.) and macrophytes amounted to 4–10% of gut contents between May an June. However, there existed differences ($P < 0.05$) between these plant groups, corresponding to their percent mean protein values.

Consumer-mediated recycling is known to be extremely important for nutrient turnover, especially within closed systems such as lakes (e.g., Vanni and Layne, 1997; Attayde and Hansson, 2001). Clearly, rudd is of high importance to Vrana Lake in this respect. Rudd, and especially the 3+ age group, presumably has a controlling influence on lake macrophyte and phytoplankton community dynamics.

During late summer (August), when a decrease in mean protein values was observed in gut contents (4.71%) (Figure 3), an increased presence of Cyanobacteria (13%), Dinophyceae (8%) and detritus (3%) was observed, when compared with other months studied (Figure 2). However, these algal groups did not differ in the mean protein content, generally being considered as low-grade food (Cyanobacteria in particular, DeMott and Müller-Navarra, 1997). The highest lipid values (1.30%) were recorded during spring (May) and were somewhat lower in June (1.11%) (Figure 3),

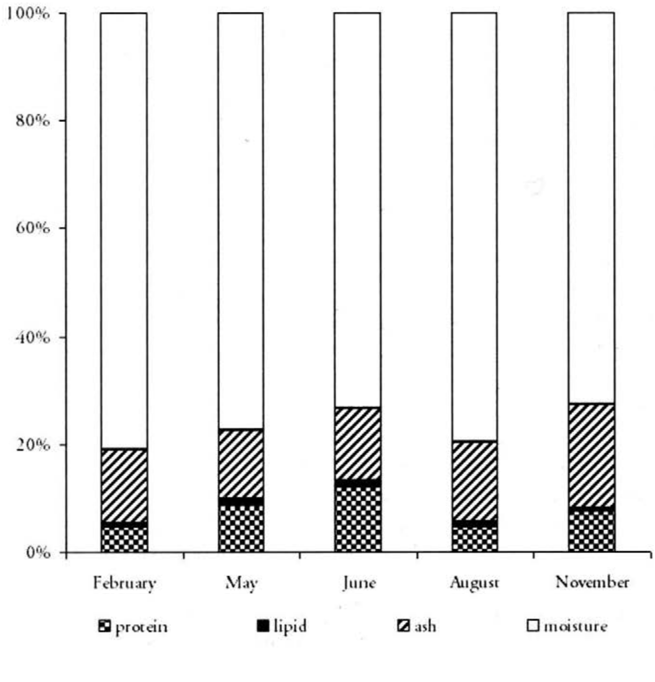

Figure 3. Mean values of biochemical composition (%) of the gut contents of the rudd (n = 10) in February, May, June, August and November (1997)

Table 1. Total energetic value of the gut contents of the rudd (Σ) and protein and lipid proportions in % (n = 10)

Sampling time	Σ	Protein		Lipids	
		kJ	%	kJ	%
February	101.88	81.65	80.14	20.23	19.86
May	198.79	148.21	74.56	50.58	25.44
June	252.30	209.11	82.88	43.19	17.12
August	113.49	80.80	71.20	32.69	28.80
November	149.86	131.57	87.80	18.29	12.20

correlating with increased dietary diversity in the gut (Figure 2). In contrast, the lowest mean lipid values were found during February (0.52%) and November (0.47%). During this period the gut contents of rudd were qualitatively more uniform, consisting mainly of diatoms (Figure 2). They showed no significant difference compared with lipid values since they were probably represented by the species containing no or small quantities of fatty acids. Percent mean ash values were approximately similar during the whole period of investigation (from 12.80 % to 14.82%) except for November when an increase in percent ash values in gut contents (19.58%) was observed (Figure 3). In terms of gut contents composition, moisture exhibited the least variation; from 80.82% in February to 73.28% in June.

Assessment of rudd gut contents in terms of nutritive value (Σ; Table 1) illustrated that it was enhanced between May and June, corresponding to the elevated levels of proteins and lipids in the gut samples (Figure 3). Nutritive values depend upon the quantity and types of fatty acids and amino acids contained in different food items (e.g., Ahlgren *et al.*, 1992; Müller-Navarra, 1995). However, while diatoms are often considered high-quality food, this was not observed in the present study, perhaps because the predominant species consisted of differing polyunsaturated fatty acids (PUFA) or highly unsaturated fatty acids (HUFA) (e.g. Fredrickson *et al.*, 1986). Many authors point to the importance of the total sum of fatty acids and amino acids as a factor of food quality determination rather than individual fatty acids and amino acids (e.g. Lürling and Van Donk, 1997). Our results are in agreement with those obtained in earlier investigations into the composition and nutritive values of rudd gut contents (Garcia-Berthou and Moreno-Amich, 2000).

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ABSTRAKT

Potrava a nutriční hodnota obsahu trávicího ústrojí u perlína (*Scardinius erythrophthalmus* L.) z jezera Vrana na ostrově Kres v Chorvatsku

Byl studován obsah trávicího ústrojí perlína *Scardinius erythrophthalmus* (věkové skupiny 3+), který představuje dominantní rybí druh v oligotrofním krasovém jezeře Vrana na ostrově Kres v Chorvatsku. Hlavní potravní složku tohoto druhu tvořily bentické mikro- a makrořasy (Cyanobacteria, Dinophyceae, Bacillariophyceae, Chlorophyceae, Xanthophyceae), a dále byla zjištěna makrofyta (převážně *Potamogeton*), zooplankton (Cladocera a Copepoda) a detrit. V průběhu sledovaného období byly ve všech vzorcích zjištěny rozsivky Bacillariophyceae, které v únoru tvořily až 79 % přijímané potravy. Větší variabilita obsahu trávicího ústrojí spojená se zvýšeným obsahem tuků a bílkovin byla nalezena v květnu a červnu. V tomto období došlo ve srovnání s ostatními měsíci ke zvýšení celkového energetického obsahu nebo nutriční hodnoty.

Klíčová slova: oligotrofní jezero; býložravost; potrava; biochemické složení; perlín *Scardinius erythrophthalmus*

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Assessment of meat efficiency in nutria (*Myocastor coypus*)

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ABSTRACT: The aim of this paper was to characterise objectively meat efficiency in nutrias kept on an experimental farm and to assess dressing percentage and carcass composition in dependence on sex and age. Standard nutrias in the period of fur maturity were chosen for the experimental observation, namely a group of young males and females at the age of eight months and a group of old males and females at the age of three years. After the animals were killed by the cervical dislocation and skinned, the following parameters of meat efficiency were assessed in the individual age categories and sexes: live weight (g), carcass with head (g), dressed carcass (g), head (g), dressing percentage with head (%), dressing percentage without head (%), edible parts (g), edible viscera (g), liver (g), kidneys (g), heart (g), spleen (g), lungs (g) and non-edible parts (g). The results were processed mathematically and statistically by two-way variance analysis of sex × age interaction. The average live weight of animals was 4 788.39 g, dressing percentage 64.22%, weight of edible parts 3 084.32 g, edible viscera 252.21 g, liver 169.00 g, and non-edible parts 1 704.07 g. We found significant and highly significant correlations in most of the studied parameters that manifested themselves more markedly in young animals.

Keywords: nutria; partial slaughter traits

Nutrias have a specific place in fur animal breeding. They produce not only valuable fur but also meat which is suitable for human nutrition. Although nutrias have been bred in our conditions for almost 80 years, their meat has not been appreciated duly until now. One of the reasons is the lack of objective information about meat efficiency, technological and culinary properties of their meat.

Slaughter characteristics of nutrias are quite high and dressing percentage amounts to 50–55%, depending on fatness of animals and on their age and sex to a certain extent (Skřivan *et al.*, 1976). Kostroň and Kukla (1971) reported that the weight of boned meat from the carcass ranged from 87.94 to 90.25%. Petričevič *et al.* (1987) gave dressing percentage without head 55–57%, Barta *et al.* (1984) from 51.12 to 55.64%, Hermann and Müller (1991) gave dressing percentage with head 67.6%. Kovalski (1987) analysed meat efficiency in nutrias of various weight categories, and on the basis of his research he reported the slaughter percentage from 56.8 to 61.0%. He mentioned the weight of liver 109.6 g, 123.7 g, 152.0 g and 190.8 g in males of average live weight 3 490 g, 4 430 g, 5 325 g and 6 186 g, resp. In females of the weight 3 434 g, 4 440 g, 5 210 g and 6 136 g the liver weight was 104 g, 129 g, 145 g and 219 g, respectively. The values of edible parts in males of the given weight categories were as follows: 1 982.7 g, 2 605.4 g, 3 163.1 g and 4 268.3 g, in females they were 2 019.3 g, 2 588.6 g, 3 053.1 g and 3 759.1 g. Some parameters of meat efficiency and live weights of nutrias of different age categories are given in Table 1 (Barta *et al.*, 1984). Skřivan *et al.* (1976) reported the weight of edible viscera 5–7%, liver weight from 80 to 300 g, heart from 10 to 30 g and kidneys from 20 to 40 g.

MATERIAL AND METHODS

The aim of this work was to characterise objectively meat efficiency in nutria kept on an experi-

Table 1. Some parameters of meat efficiency and live weight in nutrias (Barta *et al.*, 1984)

Parameters	8 months of age		3 years of age	
	males	females	males	females
Live weight (g)	4 859	3 948**	7 117	6 515**
Carcass processed at slaughterhouses (g)	2 573	1 942**	3 557	3 360
Dressing percentage without head (%)	55.64	51.12**	52.36	53.82
Head (g)	398.00	317.00**	640.80	530.80**
Heart (g)	15.96	19.22	32.54	26.76**
Liver (g)	104.06	96.98	204.36	138.94**
Kidneys (g)	28.60	22.74	56.52	48.40
Lungs (g)	23.98	20.20	39.72	30.90**

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

mental farm and to assess dressing percentage and carcass composition in dependence on sex and age.

The experiments were performed at an Experimental Farm for Fur-bearing Animals of RIAP Nitra with standard nutrias. The animals were kept in one-storey cages with pools in a hall. They received full-value nutrition according to the valid standard (Mertin *et al.*, 1994). They were fed pelleted feed mixture KK (AC Čataj), and they received green lucerne (in spring-summer period) and fodder beet (in autumn-winter period) as saturation supplements. The nutritional value of feed mixture was as follows: crude proteins 17.73%, fat 3.12%, fibre 13.50%, metabolizable energy 10.46 MJ/kg. The animals drank water from the pools. For the experimental observation animals in the period of fur maturity were chosen, namely a group of young animals at the age of eight months (males n = 18, females n = 19), and a group of old animals at the age of three years (males n = 5, females n = 14). These age categories represent slaughter nutrias for the food industry. Nutrias achieve their first fur maturity at the age of eight months and they are killed for fur, and the nutrias at the age of three years are culled as breeding animals and they are skinned (Barta *et al.*, 1984). We applied the balanced body development and live weight of animals as the main criterion for selection of animals. After the animals were killed by the cervical dislocation and skinned, the following parameters of meat efficiency were assessed in the individual age categories and sexes: live weight (g), carcass with head (g), dressed carcass (g), head (g), dressing percentage (%), dressing percentage without head (%), edible parts (g), edible viscera (g), liver (g), kidneys (g), heart (g), spleen (g), lungs (g) and non-edible parts (g). Weights were determined by digital scales with accuracy of 1 g. Dressing percentage (DP) was calculated after the formula:

$$\text{DP (\%)} = \frac{\text{weight of edible parts of body}}{\text{live weight of animals}} \times 100$$

The results were processed mathematically and statistically by two-way variance analysis of sex × age interaction (Grofík and Fľak, 1990).

RESULTS AND DISCUSSION

Arithmetical means and standard errors of the studied parameters of meat efficiency in nutria are given in Tables 2–4 according to age categories, at the age of eight months (Table 2), at the age of three years (Table 3) and the age categories in total (Table 4).

The results of two-way variance analysis of sex × age interaction (Table 5) of the studied parameters of meat efficiency in nutria show the statistically significant and highly significant differences between sex and age.

The analysis of differences between the sexes in the studied parameters of meat efficiency in nutria showed significant differences on the level of significance α = 0.01 in individual groups of age

Table 2. Arithmetical means (M) and standard errors (SE) of meat efficiency in nutrias at the age of eight months

Parameters	Males (n = 18)		Females (n = 19)		Total (n = 37)	
	M	SE	M	SE	M	SE
Live weight (g)	4 688.89	52.32	4 068.42	48.40	4 370.27	62.47
Carcass with head (g)	3 025.17	52.51	2 572.32	52.33	2 792.62	52.53
Carcass processed at slaughterhouses (g)	2 427.17	40.21	2 012.05	42.77	2 214.00	45.13
Head (g)	383.56	8.57	316.79	10.33	349.27	8.67
Dressing percentage (%)	64.53	0.63	63.19	0.80	63.84	0.52
Dressing percentage without head (%)	51.68	0.48	49.45	0.71	50.54	0.47
Edible parts (g)	3 025.17	52.51	2 573.89	52.00	2 793.43	52.35
Edible viscera (g)	214.78	8.45	245.05	12.35	230.32	7.87
Liver (g)	134.50	7.29	172.00	12.27	153.76	7.79
Kidneys (g)	25.83	1.01	22.68	1.21	24.22	0.82
Heart (g)	16.72	1.30	15.79	1.64	16.24	1.04
Spleen (g)	5.78	0.42	5.42	0.39	5.59	0.28
Lungs (g)	31.94	1.32	29.16	1.89	30.51	1.17
Non-edible parts (g)	1 663.72	28.34	1 494.53	30.62	1 576.84	24.98

categories, i.e. in the group of eight months old animals and in the group of three years old animals, in the parameters as follows: live weight, carcass with head, dressed carcass, head, edible parts, kidneys, non-edible parts, and on the level of significance $\alpha = 0.05$ for the lungs. Higher values were recorded in males. No significant differences in other parameters were found and the obtained values were approximately on the same level except for liver, the weight of which was higher in females but the differences were not statistically significant.

We observed highly significant differences between males and females of the studied age categories during the analysis of parameters of meat efficiency in dependence on age in the following parameters: live weight, carcass with head, dressed carcass, head, edible parts, edible viscera, liver, kidneys, heart, spleen and non-edible parts. Higher values were found in males except for liver.

We found statistically highly significant sex × age interactions in parameters of the weight of head and kidneys. The interaction was caused by markedly higher values of these parameters in males at the age of three years. As these are parameters that would not influence the total carcass value significantly, we will pay only little attention to them.

Dressing percentage is a transparent parameter of evaluation of meat efficiency in nutrias from the practical aspect. As no differences between the sexes (sex × age) were found, we can state that dressing percentage in males and females is approximately on the same level in the studied age categories (in eight months old animals 63.84 ± 0.52%, in three years old ones 64.96 ± 0.74%, in age categories totally 64.22 ± 0.43 %, dressing percentage without head 50.54 ± 0.47%, 51.40 ± 0.90, 50.83 ± 0.43%, resp.). If we compare our results we must state that dressing percentage without head ranged from 49.45 to 51.68% and it is somewhat lower compared with the results of the cited authors. Our results approach the results of Skřivan *et al.* (1976) 50–55%, and Barta *et al.* (1984) 51.12–55.64%,

Table 3. Arithmetical means (M) and standard errors (SE) of meat efficiency in nutrias at the age of three years

Parameters	Males (*n* = 5)		Females (*n* = 14)		Total (*n* = 19)	
	M	SE	M	SE	M	SE
Live weight (g)	6 200.00	170.29	5 389.29	161.14	5 602.63	150.32
Carcass with head (g)	4 098.00	134.68	3 491.07	139.64	3 650.79	124.12
Carcass processed at slaughterhouses (g)	3 159.40	94.25	2793.71	131.44	2 889.95	105.61
Head (g)	621.60	18.87	405.79	11.48	462.58	24.34
Dressing percentage (%)	66.06	0.43	64.57	0.98	64.96	0.74
Dressing percentage without head (%)	50.94	0.13	51.57	1.23	51.40	0.90
Edible parts (g)	4 098.00	134.68	3 491.07	139.64	3 650.79	124.12
Edible viscera (g)	308.00	27.65	290.14	12.58	294.84	11.51
Liver (g)	190.40	24.05	201.64	11.94	198.68	10.54
Kidneys (g)	46.60	1.03	29.43	1.67	33.95	2.17
Heart (g)	26.80	3.25	22.86	1.56	23.89	1.44
Spleen (g)	7.40	0.40	7.43	0.73	7.42	0.54
Lungs (g)	36.80	1.53	30.21	1.41	31.95	1.29
Non-edible parts (g)	2 102.00	39.60	1 898.21	51.08	1 951.84	43.91

Table 4. Arithmetical means (M) and standard errors (SE) of meat efficiency in nutrias in total

Parameters	Males (*n* = 23)		Females (*n* = 33)		Total (*n* = 56)	
	M	SE	M	SE	M	SE
Live weight (g)	5 017.39	143.04	4 628.79	136.20	4 788.39	101.91
Carcass with head (g)	3 258.39	106.23	2 962.09	103.39	3 083.79	76.85
Carcass processed at slaughterhouses(g)	2 586.35	73.99	2 343.67	90.74	2 443.34	63.10
Head (g)	435.30	22.29	354.55	10.85	387.71	12.27
Dressing percentage (%)	64.86	0.51	63.78	0.62	64.22	0.43
Dressing percentage without head (%)	51.52	0.38	50.35	0.68	50.83	0.43
Edible parts (g)	3 258.39	106.23	2 963.00	103.23	3 084.32	76.76
Edible viscera (g)	235.04	11.86	264.18	9.60	252.21	7.64
Liver (g)	146.65	8.90	184.58	8.95	169.00	6.84
Kidneys (g)	30.35	2.00	25.55	1.14	27.52	1.10
Heart (g)	18.91	1.49	18.79	1.29	18.84	0.97
Spleen (g)	6.13	0.36	6.27	0.42	6.21	0.28
Lungs (g)	33.00	1.15	29.61	1.23	31.00	0.89
Non-edible parts (g)	1 759.00	45.09	1 665.79	44.69	1 704.07	32.51

Table 5. Two-way analysis of variance of sex and age interaction for meat efficiency in nutrias

Parameters		Sex (P)	Age (V)	Interaction ($P \times V$)	SEE
		$f_P = 1$	$f_V = 1$	$f_{P.V} = 1$	$f_e = 52$
Live Weight	MS	5395673.135	21126857.114	95343.030	133552.371
	F	40.401**	158.192**	0.714	
Carcass with head	MS	2958603.825	10448531.431	62536.759	109456.317
	F	7.030**	95.458**	0.571	
Carcass processed at slaughterhouses	MS	1605961.606	6037363.569	6435.874	85428.221
	F	18.799**	70.672**	0.750	
Head	MS	210348.684	281747.062	58520.674	1731.292
	F	121.498**	162.738**	33.802**	
Dressing percentage	MS	20.916	22.145	0.065	9.974
	F	2.097	2.220	0.007	
Dressing percentage without head	MS	6.729	5.005	21.396	9.991
	F	0.674	0.501	2.142	
Edible parts	MS	2949794.446	1043970.643	63825.046	109231.254
	F	27.005**	90.504**	0.584	
Edible viscera	MS	406.199	50393.946	6102.722	2270.765
	F	0.179	22.192**	2.688	
Liver	MS	6258.609	19276.285	1816.146	2023.710
	F	3.093	9.525**	0.897	
Kidneys	MS	1087.744	1993.744	517.958	25.831
	F	42.109**	77.183**	20.051**	
Heart	MS	62.620	774.379	23.868	40.332
	F	1.553	19.200**	0.592	
Spleen	MS	0.284	34.706	0.391	3.969
	F	0.071	8.745**	0.099	
Lungs	MS	231.390	92.070	38.022	41.627
	F	5.559*	2.212	0.913	
Non-edible parts	MS	366463.471	1867431.482	3151.753	20630.514
	F	17.763**	90.518**	0.153	

$F_{0.05}$ (1.52) = 4.034*; $F_{0.01}$ (1.52) = 7.171**

SEE error of experiment

Table 6. Correlations of meat efficiency in nutria males at the age of eight months

Parameters (n = 18)	2	3	4	5	6	7	8	9	10	11	12	13	14
Live weight	0.8538**	0.8458**	0.6276**	0.4023	0.3257	0.8538**	0.6591**	0.5681*	0.5109*	0.3760	0.1732	0.2645	0.2641
Carcass with head		0.9786**	0.6955**	0.8174**	0.7314**	1.0000**	0.8625**	0.8362**	0.4624	0.3009	0.0696	0.2297	–0.2765
Carcass processed at slaughterhouses			0.5528*	0.7900**	0.7762**	0.9786**	0.7717**	0.7691**	0.3330	0.2370	0.1726	0.1488	–0.2517
Head				0.5299*	0.2488	0.6955**	0.6878**	0.5897*	0.7327**	0.4222	–0.3531	0.2793	–0.1301
Dressing percentage					0.9278**	0.8174**	0.7886**	0.8508**	0.2675	0.0829	–0.0938	0.0921	–0.7719**
Dressing percentage without head						0.7314**	0.5992**	0.6963**	–0.0171	–0.0133	0.1240	–0,0234	–0.7536**
Edible parts							0.8625**	0.8362**	0.4624	0.3009	0.0696	0.2297	–0.2765
Edible viscera								0.9490**	0.5601*	0.3093	–0.0408	0.4384	–0.3813
Liver									0.3840	0.0518	–0.1076	0.2404	–0.5006
Kidneys										0.5538*	–0.2691	0.2373	0.0865
Heart											0.0836	0.2560	0.1366
Spleen												0.1413	0.1909
Lungs													0.0626
Non-edible parts													

$r_{0.05}$ (16) = 0.468*

$r_{0.01}$ (16) = 0.590**

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Table 7. Correlations of meat efficiency in nutria females at the age of eight months

Parameters (n = 19)	2	3	4	5	6	7	8	9	10	11	12	13	14
Live weight	0.8204**	0.7719**	0.4843*	0.3915	0.3240	0.8163**	0.3588	0.2462	0.1352	0.3447	0.3931	0.2778	0.1944
Carcass with head		0.9446**	0.5004*	0.8456**	0.7330**	0.9996**	0.5190*	0.4673	–0.1126	0.0536	0.3129	0.3177	–0.4007
Carcass processed at slaughterhouses			0.2774	0.8009**	0.8485**	0.9438**	0.2790	0.2483	–0.2164	–0.0100	0.2699	0.3019	–0.3827
Head				0.3570	0.0428	0.4975*	0.2981	0.2249	0.3250	0.0473	0.0178	0.2345	–0.0793
Dressing percentage					0.8782**	0.8505**	0.5090*	0.5330*	–0.2933	–0.2496	0.1181	0.2460	–0.8254**
Dressing percentage without head						0.7351**	0.1211	0.1599	–0.3830	–0.2869	0.0535	0.2371	–0.7363**
Edible parts							0.5261*	0.4768*	–0.1156	0.0439	0.3087	0.3133	–0.4080
Edible viscera								0.9600**	–0.0091	0.1802	0.3505	0.0778	–0.3262
Liver									–0.1456	–0.0666	0.1859	–0.1073	–0.4205
Kidneys										0.4711*	0.0155	–0.1685	0.4100
Heart											0.6881**	0.2952	0.4702*
Spleen												0.2670	0.0971
Lungs													–0.0930
Non-edible parts													

$r_{0.05}$ (17) = 0.456*

$r_{0.01}$ (17) = 0.575**

Table 8. Correlations of meat efficiency in nutria males at the age of three years

Parameters (n=5)	2	3	4	5	6	7	8	9	10	11	12	13	14
Live weight	0.9935**	0.9987**	0.6675	0.7918	0.8407	0.9935**	0.9526*	0.9109*	0.2281	0.9858**	0.0734	0.6334	0.9216*
Carcass with head		0.9874**	0.7207	0.8563	0.7840	1.0000**	0.9649**	0.9297*	0.1615	0.9740**	–0.0334	0.6572	0.8712
Carcass processed at slaughterhouses			0.6428	0.7650	0.8669	0.9874**	0.9465*	0.9036*	0.2369	0.9839**	0.1037	0.6275	0.9366*
Head				0.8477	0.2986	0.7207	0.5766	0.5260	0.2373	0.5710	–0.4982	0.9122*	0.4195
Dressing percentage					0.3888	0.8563	0.8475	0.8459	–0.1509	0.7500	–0.5116	0.6632	0.4927
Dressing percentage without head						0.7840	0.7505	0.7031	0.2832	0.8241	0.3918	0.4684	0.9488*
Edible parts							0.9649**	0.9297*	0.1615	0.9740**	–0.0334	0.6572	0.8712
Edible viscera								0.9932**	–0.0562	0.9593**	–0.0497	0.4765	0.8151
Liver									–0.1680	0.9239*	–0.0977	0.4084	0.7554
Kidneys										0.2184	0.5828	0.3365	0.4317
Heart											0.1694	0.5014	0.9267*
Spleen												–0.3759	0.4293
Lungs													0.4886
Non-edible parts													

$r_{0.05}$ (3) = 0.878*
$r_{0.01}$ (3) = 0.959**

Table 9. Correlations of meat efficiency in nutria females at the age of three years

Parameters (n = 14)	2	3	4	5	6	7	8	9	10	11	12	13	14
Live weight	0.9523**	0.9163**	0.6553*	0.5460*	0.5574*	0.9523**	0.3703	0.2079	0.4618	0.6197*	0.3712	0.3657	0.5514*
Carcass with head		0.9931**	0.5555*	0.7741**	0.7793**	1.0000**	0.1918	0.0631	0.4054	0.4605	0.2391	0.2893	0.2705
Carcass processed at slaughterhouses			0.4929	0.8294**	0.8413**	0.9931**	0.1011	–0.0174	0.3427	0.4093	0.1998	0.2978	0.1761
Head				0.1572	0.1322	0.5555*	0.0759	–0.0970	0.8224**	0.4307	0.0552	0.2649	0.5488**
Dressing percentage					0.9913**	0.7741**	–0.2309	–0.2509	0.1323	–0.0043	–0.0731	0.0694	–0.3935
Dressing percentage without head						0.7793**	–0.2743	–0.3037	0.0743	0.0242	–0.0457	0.1477	–0.3719
Edible parts							0.1918	0.0631	0.4054	0.4605	0.2391	0.2893	0.2705
Edible viscera								0.9699**	0.1499	0.4414	0.4853	–0.1781	0.6439*
Liver									0.0441	0.2542	0.3945	–0.3431	0.4833
Kidneys										0.0208	0.0469	–0.1009	0.3486
Heart											0.2927	0.5098	0.6961**
Spleen												0.3657	0.5173
Lungs													0.3627
Non-edible parts													

$r_{0.05}$ (12) = 0.532*
$r_{0.01}$ (12) = 0.661**

who performed the experiments in similar breeding conditions. The dressing percentage is somewhat higher compared with the results of Kovalski (1987) and lower compared with the results of Hermann and Müller (1991). Although the presented results differ only little, we suppose that this fact is caused by different live weight as the cited authors used animals of various weight categories in their experiments. Skřivan *et al.* (1976) confirms our statement, he mentioned that dressing percentage depends on fattiness of animals, and on age and sex to a certain extent.

The edible viscera represent from 4.58% to 6.02% out of the live weight and the given values are in line with the results of Skřivan *et al.* (1976), who gave 4–7%. Liver has the highest weight out of the edible viscera, on average 153.76 ± 7.79 g in young animals and 198.68 ± 10.54 g in the old ones. Its proportion in the edible viscera is 62.22% in males and 69.85% in females. We found highly significant differences in liver weight between the sexes in dependence on age – males in total: 146.65 ± 8.90 g, females in total: 184.58 ± 8.95 g. Our results correspond with the results reported by Kovalski (1987). Barta *et al.* (1984) gave lower weight of liver in females in the same age category as well as differences in liver weight in dependence on age in favour of males. According to our results the differences in liver weight between the sexes in the same age category were not statistically significant although higher values were recorded in females, which was obvious mainly in young animals. The differences in dependence on age correspond with the results of the cited work. Expressed absolutely, the weight of kidneys, heart, spleen and lungs is approximately on the same level as in the cited sources of literature.

In the next part of our work we examined the correlations of the studied parameters of meat efficiency in nutrias in relation to age and sex (Tables 5–8). Some of the analysed parameters correlated significantly with a number of them, this was manifested more markedly in young animals (Tables 6–9), others only with some parameters. Because of a higher number of correlations we concentrated on those parameters that are significant from the practical aspect. In eight months old animals (Tables 6–7) correlations of live weight with carcass with head, dressed carcass, head, edible parts were significant, and in males also with edible viscera, liver and kidneys. Dressing percentage significantly correlated with carcass with head, dressed carcass, dressing percentage without head, edible parts, edible viscera, liver and non-edible parts, and also with head in males. We found highly significant correlations with all parameters except for viscera and liver in edible parts. Highly significant correlations of liver with all parameters except for viscera existed in males, and in females with dressing percentage, edible parts and edible viscera. During the analysis of other viscera we found in males significant correlations of kidneys only with live weight, head, edible viscera and heart, and in females those of heart with kidneys and spleen.

The correlations in three years old animals (Tables 8–9) were not so marked, however, there was a certain analogy of correlations like in eight months old animals, they presented themselves more markedly in old females.

CONCLUSIONS

The results of our study demonstrate that there are statistically significant and highly significant differences in the studied parameters of meat efficiency in nutrias kept on farms in dependence on sex and age. The average live weight of animals was 4 788.39 g, dressing percentage 64.22%, weight of edible parts 3 084.32 g, edible viscera 252.21 g, liver 169.00 g, and non-edible parts 1 704.07 g. We found significant and highly significant correlations in most of the studied parameters that manifested themselves more markedly in young animals.

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ABSTRAKT

Hodnotenie mäsovej úžitkovosti nutrie riečnej (*Myocastor coypus*)

Cieľom práce bolo objektívne charakterizovať mäsovú úžitkovosť nutrie riečnej v experimentálnom chove VÚŽV a vyhodnotiť jatočnú výťažnosť a skladbu jatočného tela v závislosti od pohlavia a veku. V pokuse boli zvieratá v období kožušinovej zrelosti, a to skupina mladých zvierat vo veku osem mesiacov a skupina starých zvierat vo veku troch rokov. Po usmrtení zvierat mechanickým prerušením krčnej chrbtice a kožkovaní v rámci jednotlivých vekových kategórií a pohlavia sme hodnotili tieto ukazovatele mäsovej úžitkovosti: živá hmotnosť (g), jatočné telo s hlavou (g), jatočne opracované telo (g), hlava (g), jatočná výťažnosť s hlavou (%), jatočná výťažnosť bez hlavy (%), požívateľné časti (g), požívateľné vnútornosti (g), pečeň (g), obličky (g), srdce (g), slezina (g), pľúca (g) a nepožívateľné časti (g). Výsledky sme matematicko-štatisticky spracovali dvojfaktorovou analýzou rozptylu interakciou pohlavia a veku. Priemerná živá hmotnosť zvierat bola 4 788,39 g, jatočná výťažnosť 64,22 %, hmotnosť požívateľných častí 3 084,32 g, požívateľných vnútorností 252,21 g, pečene 169,00 g a nepožívateľných častí 1 704,07 g. Zistili sme preukazné a vysokopreukazné korelácie u väčšiny sledovaných ukazovateľov, ktoré sa výraznejšie manifestovali u mladých zvierat.

Kľúčové slová: nutria; parciálne jatočné ukazovatele

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Use of an ethological test to calculate a distance covered by selected categories of Thoroughbred horses

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ABSTRACT: Background data to evaluate locomotor activities of Thoroughbred horses on the open range were provided by an ethological test of breeding mares, foals until weaning and one-year-old horses conducted on stud-farms Šamorín (SR) and Erlenhof (Germany). The results show that average duration of locomotions is longer on Erlenhof stud-farm for each type of gait. An increase in the difference in total values for all types of locomotions is expressed by index 195.3% in breeding mares, 124.7% in foals until weaning and 292.1% in the category of one-year-old horses in favor of German horses. The following findings were provided by a metric expression of locomotions of Thoroughbred horses investigated on the open range in the daytime. If the stocking of the range area (1 animal per ha) is optimum, breeding mares from Erlenhof stud-farm cover a distance of 14 716 m at average speed of 10.52 km/h. In case the mare concentration is ten times higher (Šamorín stud-farm), the mares cover a distance of 7 537 m at a speed of 8.72 km/h. Foals until weaning in optimum conditions of the German stud-farm (i.e. one animal per ha) cover a distance of 22 247 m at average speed 7.98 km/h. A distance of 17 842 m at average speed of 8.24 km/h was covered by foals on Šamorín stud-farm with the concentration of 10 individuals per 1 ha of range area. In the case of one-year-old horses on Erlenhof farm (2 animals/ha) the defined distance 14 879 m was covered at average speed 9.91 km/h. A distance of 5 094 m at average speed of 10.21 km/h was covered by horses of the same category on Šamorín stud-farm with the concentration of five individuals per 1-ha area. The stay on the open range lasted ten hours in all cases (from 8 to 18 hours). The locomotions in form of fragmentary walk, short trot and canter were compared in both statistical sets of Thoroughbred horses by means of *F*-test; the results of this comparison confirmed the existence of significant and highly significant differences in the studied traits. This finding should be taken as a recommendation to adjust the possible inadequate load of the range unit area when such breeding conditions have long-term and considerable negative impacts on the assertion of innate locomotor abilities. Dynamic forms of locomotions (trot and gallop) as well as the disposition of horses of this breed to endurance in speed influencing the performance on a racing track are affected most substantially.

Keywords: Thoroughbred horse; ethological characteristic; metric expression of locomotions

Most papers analyzing the locomotion of Thoroughbred horses are based on the methods of evaluation of quantitative parameters (gait length, speed, frequency) and/or qualitative characteristics (impulsion, locomotion equilibrium, rhythm, action, etc.). It is obvious that the manifestations of locomotions are influenced by other factors of physical, biological and psychological type. This is the reason why the horse locomotion cannot be evaluated from one-sided physical aspects only, but they should be analyzed in a broad context of all related disciplines. The present study provides input information and should initiate further discussion.

There has been no attempt to describe the locomotor behavior of Thoroughbred horses in metric terms on the basis of ethological test in professional literature until now. Such an attempt should be based on the previous knowledge of horse speeds in the particular types of gaits on the one hand and on average proportions of duration of the analyzed forms of locomotions on the open range on the other hand.

To solve the problem, ethological characteristics of Thoroughbred horses defined by Duruttya (1990, 1993) were used laying an emphasis on average proportions of duration of the particular types of locomotions on the open range in an ethogram of some horse categories of this breed. The interpretation of the findings was presented in the Result section of the cited study. Therefore they are not mentioned in this paper.

The influence of management on commercial traits of Thoroughbred horses is a complicated problem related to physiological functions of the growing organism, specifically to the central nervous system. Dušek (1973) supposed that the method of horse management was manifested through performance, among other things by the "formation of horse's psyche". Experimental studies of these problems require to carry out repeated investigations in the particular years and analytical testing of CNS during training. Taking into account the individual variability of equine CNS, it would be necessary to create a large set but the exactness of analytical investigation could decrease in this way.

Klement (1973) included among the factors influencing the performance of Thoroughbred horses first of all a hereditary transfer of dispositions to basic biological functions, that means dispositions to active locomotion as well as coordination of the nervous system and physiological and biochemical functions, and last but not least the effects of external environment, i.e. nutrition, housing, management methods, horse tending, horse training and rider.

An optimum stocking of the range area was studied e.g. by Dušek (1999). The concentration in a current horse-breeding practice was found to be 6 weanlings and/or three young horses older than one-year per 1 ha of the range, i.e. 0.17 ha per weanling and 0.33 ha per one-year-old animal.

Ihle (1984) reported the proportion of the total time of locomotions in the total time of stay on the open range to be 55.2% in breeding mares and 69.6% in weaned foals. The latter author also studied the duration of locomotions on the open range in adult populations of Thoroughbred horse. These values were reported: fragmentary locomotion in walk 110.0 min on average, in trot 10.1 min and in canter 33.9 min. We used this data for calculations that gave the following results: total distance covered by the reported category of horses was 18 739.5 m (7 920 m walk, 1 666.5 trot and 9 153 m canter).

Similar research was conducted in the Thoroughbred population by Görözdi (1986). He found a 15.7% proportion of locomotions in one-year-old horses during a 10-hour stay on the open range. Our calculations show that it accounted for 94.32 minutes of all locomotions.

MATERIAL AND METHOD

Background data to calculate distances covered by horses on the open range were provided by research on ethological characteristics of Thoroughbred horses conducted on two stud-farms: Šamorín (SR) and Erlenhof (Germany). Repeated observations were carried out in a herd of breeding mares, foals until weaning and one-year-old horses in the course of 10-year stays on the open range (from 8 to 18 hours).

The method of acquisition of information on locomotor activities in selected categories of Thoroughbred horses is based on the average frequency of locomotions in a defined time interval. The locomotions of the horses are recorded in five-minute intervals. Twelve records are made within an hour, that means 120 records within 10 hours. The values $\bar{x}$ indicate percent proportions of average duration of observed locomotions in the course of stay on the open range. These values are converted to time units. A distance covered by the animal was calculated from the following speed standards for fragmentary walk, short trot and canter: 1.20 m/s, 2.75 m/s and 4.50 m/s in breeding mares; 1.10 m/s, 2.40 m/s and 3.80 m/s in foals until weaning; 1.50 m/s, 3.75 m/s and 6.25 m/s in one-year-old horses, in accordance with the findings published by Michal (1958), Dušek (1972, 1998) or Komárek and Majzlík (1993).

Data processing was carried out by current mathematical and statistical methods. Student's t-test was used for the testing of differences in sample means of locomotions. Equality of variances was verified by F-test for the respective degrees of freedom and compared at 5% and 1% significance level.

RESULTS AND DISCUSSION

Evaluation of locomotions of breeding mares on the open range

Table 1a shows basic mathematical and statistical characteristics of Thoroughbred mares. The index of difference in total distance covered by breeding mares is higher for the mares from Erlenhof stud-farm (195.3%), that means German mares

Table 1. Analysis of locomotor activities in Thoroughbred horses on two stud-farms (Šamorín and Erlenhof)

a) Breeding mares

Stud-farm	Type of gait	$\bar{x}$	s	$s_{\bar{x}}$	v	x_{min}	x_{max}	r	t	F
Šamorín n = 24	walk	5.44	4.08	1.36	75.08	2.30	8.58	–	0.890	2.440
	trot	1.31	1.70	0.57	129.90	0.00	2.62	0.030	0.000	4.450
	canter	1.86	2.45	0.82	85.64	0.98	4.74	0.167	0.190	2.450
Erlenhof n = 15	walk	6.79	2.36	0.79	34.80	4.97	8.60	–	0.850	4.140
	trot	1.42	1.03	0.34	72.78	0.63	2.21	0.607	0.680	1.320
	canter	7.34	5.12	1.71	69.75	3.41	11.28	0.045	0.500	2.040

b) Foals until weaning

Stud-farm	Type of gait	$\bar{x}$	s	$s_{\bar{x}}$	v	x_{min}	x_{max}	r	t	F
Šamorín n = 24	walk	11.23	8.83	4.44	78.67	4.44	18.02	–	1.270	2.280
	trot	1.76	1.49	0.50	84.87	0.61	2.90	0.810	0.660	1.150
	canter	10.13	7.31	2.44	72.21	4.51	15.75	0.747	1.080	1.320
Erlenhof n = 15	walk	17.32	2.50	0.83	14.46	15.39	19.24	–	0.940	1.850
	trot	1.61	0.27	0.09	16.75	1.40	1.81	–0.062	1.280	1.410
	canter	12.04	3.90	1.30	32.44	9.04	15.04	–0.201	0.910	1.970

c) One-year-old horses

Stud-farm	Type of gait	$\bar{x}$	s	$s_{\bar{x}}$	v	x_{min}	x_{max}	r	t	F
Šamorín n = 24	walk	3.18	2.38	0.75	74.76	1.48	4.88	–	0.480	1.580
	trot	0.77	0.64	0.20	83.36	0.31	1.22	0.964	0.260	1.280
	canter	1.04	1.08	0.34	104.11	0.27	1.82	0.585	0.160	3.220
Erlenhof n = 15	walk	10.28	1.87	0.59	18.17	8.94	11.62	–	2.700	2.710
	trot	1.46	0.73	0.23	49.96	0.94	1.98	–0.376	1.480	1.220
	canter	3.27	5.29	1.67	161.83	0.00	7.05	–0.560	0.100	9.250

cover twice a longer distance than the animals of corresponding category on Šamorín stud-farm. In metric expression, Šamorín mares cover a distance of 7 537 m at average speed of 8.72 km/h while their German counterparts cover 14 716 m at 10.52 km/h.

The following results were provided by testing the hypothesis about the equality of variances of the means for the particular forms of locomotions performed by breeding mares on the open range. The values are at a significance level ($\alpha_{0.05}$ = 2.21; $\alpha_{0.01}$= 3.10) for walk (F_{wa} = 2.990) and trot (F_{tr} = 2.720), they are highly significant for canter (F_{ca} = 4.390 > $\alpha_{0.01}$ = 3.10 and corresponding number of degrees of freedom v_1 = 22 and v_2 = 13). The results clearly demonstrate a statistically highly significant difference in all types of gaits between the locomotor activities of breeding mares from both stud-farms.

Evaluation of locomotions of foals until weaning

Dispositions to voluntary locomotions in foals at 5–6 months of age are better in horses of the German breeder (index 124.7%). The foals from Šamorín stud-farm cover a distance of 17 842 m at average speed of 8.24 km/h.

A distance covered by foals from Erlenhof stud-farm is 22 247 m, average speed 7.98 km/h (Table 1b).

F-test of locomotor activities in the set of Thoroughbred foals indicated a high statistical significance of recorded values (F_{wa} = 12.450; F_{tr} = 30.720 > $\alpha_{0.05}$ = 2.21 > $\alpha_{0.01}$ = 3.10; v_1 = 22; v_2 = 13). Only the *F* test value for canter (3.510) is close to a critical level of significance.

Evaluation of locomotions of one-year-old horses

All forms of locomotions in one-year-old horses account for 5.0% (Šamorín) and 15.0% (Erlenhof) out of the total time of stay on the open range (Table 1c). Šamorín one-year-old horses cover a distance of 5 094 m at average speed of 10.21 km/h; Erlenhof one-year-old horses cover a distance of 14 879 m at 9.91 km/h (index 292.1%).

The analysis of equality of variances of the locomotion activities conducted among animals from the two stud-farms indicated a high significance for canter (F_{ca} = 23.740 > $\alpha_{0.05}$ =2.19; $\alpha_{0.01}$ = 3.03 for the corresponding number of degrees of freedom v_1 = 28; v_2 = 10); the values were close to a critical level of significance for fragmentary walk and short trot (F_{wa} = 1.620 and F_{tr} = 1.310 < $\alpha_{0.05}$ = 2.19.

The first crucial finding derived from the results of investigations into locomotor activities of some categories of Thoroughbred horses coming from two different stud-farms is an analogical speed of locomotion from 8 to 10 km/h measured in the horses of both populations during the stay on the open range.

The second finding is the existence of diametrically different proportions of locomotion duration in both herds, and the ensuing differences in distances covered by the animals. The differences are ascribed to the limited conditions of range areas available for free locomotion in the long run. This assumption is confirmed by the measured values of locomotions of foals until weaning. The foals before weaning on Šamorín stud-farm, where the concentration of animals per unit area of the range is ten times higher than on Erlenhof stud-farm, cover a distance shorter by 4.4 km than their western counterparts.

This finding is still more evident in one-year horses in spite of the fact that the limiting factors influencing the locomotor activities are not so manifest as in foals until weaning.

The locomotion deficit cannot be compensated by high-quality training of horses for racing career. We are convinced that one of the causes why the Thoroughbred horses of local provenance are little successful is the method of management of these horses, especially in the early stage of their ontogenesis. Desirable performance of Thoroughbred horses is conditioned by an acquirement of endurance in speed.

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ABSTRAKT

Vyjádření délky absolvované distance vybranými kategoriemi anglických plnokrevníků na základě etologického testu

Podklad k hodnocení lokomoce anglických plnokrevníků prezentované ve volnosti (na pastvě) poskytl výsledek etologického testu chovných klisen, hříbat do odstavu a ročků realizovaný v hřebčíně Šamorín (SR) a Erlenhot (SRN). Ze závěrů je patrné, že průměrná doba trvání lokomocí je v každém druhu chovů větší v hřebčíně Erlenhof. U chovných klisen tvoří nárůst diference souhrnných hodnot všech druhů lokomocí index 195,3 %, u hříbat do odstavu 124,7 % a u kategorie ročků 292,1 % ve prospěch koní. Z metrického vyjádření lokomočních projevů anglických plnokrevníků zkoumaných na pastvě v denním období vyplývají tyto poznatky: Chovné klisny hřebčína Erlenhof absolvují v podmínkách optimálního zatížení plochy pastvy (jedna klisna na 1 ha) 14 716 m průměrnou rychlostí 10,52 km/h. Při desetinásobně vyšší koncentraci klisen (hřebčín Šamorín) byla délka trasy 7 537 m absolvovaná rychlostí 8,72 km/h. Hříbata do odstavu v optimálních podmínkách německého chovu (tj. jedno hříbě na 1 ha) absolvují trasu 22 247 m průměrnou rychlostí 7,98 km/h. Při koncentraci 10 hříbat na 1 ha plochy pastvy v hřebčíně Šamorín bylo zaznamenáno absolvování trasy 17 842 m průměrnou rychlostí 8,24 km/h. V případě ročků hřebčína Erlenhof (dvě hříbata na 1 ha) byla definovaná trasa 14 879 m absolvovaná průměrnou rychlostí 9,91 km/h. Analogická kategorie koní šamorinského chovu při koncentraci pěti hříbat na ploše 1 ha absolvovala trasu 5 094 m průměrnou rychlostí 10,21 km/h. Ve všech případech byla doba pobytu na pastvě desetihodinová (od 08 do 18 h). Výsledkem provnání obou statistických souborů anglických plnokrevníků z hlediska prezentovaných lokomocí v podobě fragmentárního kroku, krátkého klusu a středního cvalu pomocí *F*-testu je potvrzení existence průkazných až vysoce průkazných rozdílů ve sledovaných znacích. Tento poznatek je současně doporučením ke korekci neadekvátního zatížení jednotky plochy pastvy v těch případech, kdy tyto okolnosti odchovných podmínek dlouhodobě a ve výrazné míře negativně ovlivňují uplatnění vrozených vloh plnokrevníků k pohybu. Nejvýrazněji se tato skutečnost projevuje v případě dynamických forem lokomocí (klus a cval) právě tak, jako v dispozici příslušníků koní tohoto plemene k vytrvalosti v rychlosti s dopadem na výkonnost prezentovanou na dostihové dráze.

Klíčová slova: anglický plnokrevník; etologická charakteristika; metrické vyjádření lokomocí

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