CZECH ACADEMY OF AGRICULTURAL SCIENCES

Czech Journal of ANIMAL SCIENCE

ŽIVOČIŠNÁ VÝROBA

INSTITUTE OF AGRICULTURAL AND FOOD INFORMATION

10

VOLUME 46
PRAGUE 2001
ISSN 1212-1819

CZECH JOURNAL OF ANIMAL SCIENCE

An international journal published under the authorization by the Ministry of Agriculture and under the direction of the Czech Academy of Agricultural Sciences

Mezinárodní vědecký časopis vydávaný z pověření Ministerstva zemědělství České republiky a pod gescí České akademie zemědělských věd

World Wide Web (URL): http://www.uzpi.cz

Aim and scope: The journal publishes scientific papers and reviews dealing with the study of genetics and breeding, physiology, reproduction, nutrition and feeds, technology, ethology and economics of cattle, pig, sheep, goat, poultry, fish and other farm animal management.
The journal is cited in the bibliographical journal Current Contents – Agriculture, Biology and Environmental Sciences and abstracted in Animal Breeding Abstracts. Abstracts from the journal are comprised in the databases: Agris, CAB Abstracts, Current Contents on Diskette – Agriculture, Biology and Environ-mental Sciences, Czech Agricultural Bibliography, Food Science and Technology Abstracts, Toxline Plus.

Periodicity: The journal is published monthly (12 issues per year). Volume 46 appearing in 2001.

Acceptance of manuscripts: Two copies of manuscript should be addressed to: Ing. Zdeňka Radošová, Institute of Agricultural and Food Information, Slezská 7, 120 56 Praha 2, Czech Republic, tel.: + 420 2 27 01 03 52, fax: + 420 2 27 01 01 16, e-mail: edit@uzpi.cz.

Subscription information: Subscription orders can be entered only by calendar year (January–December) and should be sent to: Institute of Agricultural and Food Information, Slezská 7, 120 56 Praha 2, Czech Republic. Subscription price for 2001 is 195 USD (Europe) and 214 USD (overseas).

Cíl a odborná náplň: Časopis publikuje původní vědecké práce a studie typu review z oblasti genetiky, šlechtění, fyziologie, reprodukce, výživy a krmení, technologie, etologie a ekonomiky chovu skotu, prasat, ovcí, koz, drůbeže, ryb a dalších druhů hospodářských zvířat.
Časopis je citován v bibliografickém časopise Current Contents – Agriculture, Biology and Environmental Sciences a v časopise Animal Breeding Abstracts. Abstrakty z časopisu jsou zahrnuty v těchto databázích: Agris, CAB Abstracts, Current Contents on Diskette – Agriculture, Biology and Environmental Sciences, Czech Agricultural Bibliography, Food Science and Technology Abstracts,Toxline Plus.

Periodicita: Časopis vychází měsíčně (12× ročně), ročník 46 vychází v roce 2001.

Přijímání rukopisů: Rukopisy ve dvou kopiích je třeba zaslat na adresu redakce: Ing. Zdeňka Radošová, Ústav zemědělských a potravinářských informací, Slezská 7, 120 56 Praha 2, Česká republika, tel.: + 420 2 27 01 03 52, fax: + 420 2 27 01 01 16, e-mail: edit@uzpi.cz.

Informace o předplatném: Objednávky na předplatné jsou přijímány pouze na celý rok (leden–prosinec) a měly by být zaslány na adresu: Ústav zemědělských a potravinářských informací, vydavatelské oddělení, Slezská 7, 120 56 Praha 2. Cena předplatného pro rok 2001 je 1176 Kč.

F 4886

Effect of some physical and chemical characteristics of water on the blood indices of rainbow trout, *Oncorhynchus mykiss*, fed an astaxanthin-containing diet

Vliv některých fyzikálních a chemických vlastností vody na krevní ukazatele pstruha duhového, *Oncorhynchus mykiss*, krmeného dietou s astaxanthinem

J. Řehulka[1], B. Minařík[2]

[1] *University of South Bohemia, České Budějovice, Research Institute of Fish Culture and Hydrobiology, Vodňany, Department of Aquatic Toxicology and Fish Diseases, Laboratory Opava, Czech Republic*

[2] *Mendel University of Agriculture and Forestry, Faculty of Economics, Department of Statistics, Brno, Czech Republic*

ABSTRACT: 1+ rainbow trout, *Oncorhynchus mykiss*, with starting weight of 236 ± 17 g (mean ± SD) were studied over an 81-day period for the effect of astaxanthin on growth rate, total body length, body length, body height, body width, Fulton coefficient, hepatosomatic index and some haematological and biochemical indices of the blood plasma, including: red blood cell count, haematocrit, haemoglobin, mean corpuscular volume, mean corpuscular haemoglobin, mean corpuscular haemoglobin concentration, urea, creatinine, uric acid, total protein, glucose, cholesterol, triacylglycerol, inorganic phosphate, calcium, sodium, potassium, alanine aminotransferase, aspartate aminotransferase, alkaline phosphatase, lactate dehydrogenase and α-hydroxybutyryl dehydrogenase. Using the test of regression and correlation goodness of fit, astaxanthin administered at a rate of 49.8 mg/kg of dry pellets was found to result in a significantly less pronounced trend of increase in inorganic phosphate ($r = 0.5153^{**}$ vs. $r = 0.7805^{**}$) and a significantly lower trend of decrease in mean corpuscular haemoglobin concentration ($r = -0.4722^{**}$ vs. $r = -0.8174^{**}$), depending on water temperature between 8 and 16°C. During the experiment, astaxanthin had no effect on catalytic concentration of α-hydroxybutyryl dehydrogenase, as distinct from the control fish where catalytic concentration of α-hydroxybutyryl dehydrogenase declined with the increase in dissolved oxygen in water, ranging from 8.5 to 11 mg O_2/l ($r = 0.0020$ vs. $r = -0.6538^{**}$).

Keywords: water temperature; dissolved oxygen; mean corpuscular haemoglobin concentration; inorganic phosphate; α-hydroxybutyryl dehydrogenase; test of regression and correlation goodness of fit

ABSTRAKT: U pstruha duhového, *Oncorhynchus mykiss*, o výchozí hmotnosti 236 ± 17 g (mean ± SD) byl v průběhu 81 dní sledován vliv pigmentační substance astaxanthinu na přírůstek hmotnosti (W), celkovou délku těla (TBL), délku těla (BL), výšku těla (BH), šířku těla (BW), Fultonův koeficient (FC), hepatosomatický index (HI) a některé hematologické a biochemické ukazatele krevní plazmy: počet erytrocytů, hematokrit, hemoglobin, střední objem erytrocytu, hemoglobin erytrocytu, střední barevnou koncentraci (MCHC), močovinu, kreatinin, kyselinu močovou, celkovou bílkovinu, glukózu, cholesterol, triacylglycerol (TGL), anorganický fosfát (P), celkový vápník, sodík, draslík a katalytickou koncentraci alaninaminotransferázy, aspartátaminotransferázy, alkalické fosfatázy (ALP), laktátdehydrogenázy a α-hydroxybutyrátdehydrogenázy (HBD). Pomocí testu shody regrese a korelace bylo zjištěno, že astaxanthin v dávce 49,8 mg/kg krmiva měl vliv na signifikantně nižší tendenci ke zvyšování anorganického fosfátu ($r = 0{,}5153^{**}$ vs $r = 0{,}7805^{**}$) a signifikantně menší tendenci ke snižování střední barevné koncentrace ($r = -0{,}4722^{**}$ vs $r = -0{,}8174^{**}$) v závislosti na teplotě vody v rozmezí od 8 do 16 °C. Astaxanthin neovlivňoval v průběhu pokusu katalytickou koncentraci α-hydroxybutyrátdehydrogenázy na rozdíl od kontrolních ryb, kde katalytická koncentrace α-hydroxybutyrátdehydrogenázy klesala se zvyšováním rozpuštěného kyslíku ve vodě v rozmezí od

Supported by the Grant Agency of the Czech Republic (Grant No. 525/00/0241).

8,5 do 11 mg/l (r = 0,0020 vs r = –0,6538**). Výsledky hematologických a biochemických testů motivují k prohloubení znalostí o změnách v krvi v závislosti na faktorech prostředí u ryb dostávajících astaxanthin v krmivu.

Klíčová slova: teplota vody; rozpuštěný kyslík; střední barevná koncentrace; anorganický fosfát; α-hydroxybutyrátdehydrogenáza

INTRODUCTION

The nutrition of the rainbow trout is a major ambient factor influencing the level of nutrient metabolism, performance, reproduction and resistance to diseases. A key requirement for the effective rainbow trout culture is to provide conditions for continuous anabolic and catabolic processes and to secure their control, using a suitable screening programme for timely identification of any departure from the reference limits of the methods used. Control of the physiological state of the rainbow trout, focused on haematological and biochemical examinations of the blood plasma and serum, is an integral part of the complex of methods of examining the health of the fish and, at the same time, plays a role in feeding experiments – in testing diets of different composition or testing the properties of substances having a specific effect. To follow up with the efforts, the results of which were published in our previous paper (Řehulka, 2000), we continued testing the effect of astaxanthin on growth, condition, haematological and biochemical indices, as depending on time and some physical and chemical properties of water during a defined period of time. We used days as the independent time variable, temperature as the physical parameter of water, and dissolved oxygen content as the chemical parameter of water.

MATERIAL AND METHODS

Feeding experiment

The experiments were conducted for 81 days in flow-through fibre-glass tanks 5 × 0.8 × 0.8 m in size, located at an altitude of 651 m above sea level. The parameters of water temperature, dissolved oxygen and oxygen saturation of water during the experiment and at the time of fish sampling for examination are indicated in Figure 1. The fish tested in the experiments was juvenile rainbow trout (*Oncorhynchus mykiss*) with starting weight of 236 ± 17 g, all of the same origin and all in good condition and health. One test group in two replications and one control group in two replications were formed, each containing 300 fishes. Pellets 5 mm in size were used as

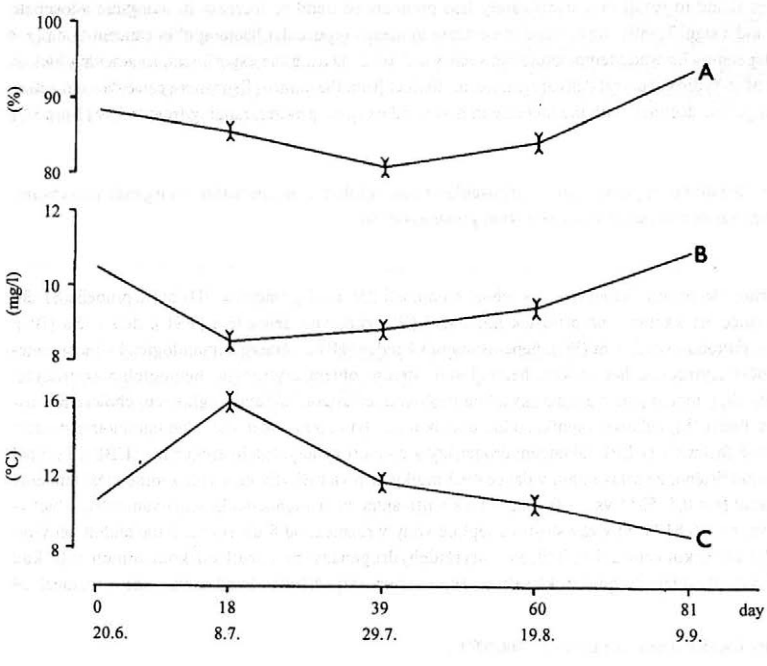

Figure 1. O_2 saturation of water (A), dissolved O_2 content (B) and water temperature (C) at the moment of rainbow trout sampling

Table 1. Formulation and chemical composition of the control diet (per kg)

Ingredients	(g)
Fish meal[a]	150
Meat and bone meal[b]	370
Soybean meal (free of fat)	230
Wheat flour	140
Hay meal	50
Milk powder	30
Vitamin and micromineral premix*	30
Chemical analysis	(g)
Dry matter	900
Crude protein (N × 6.25)	400
Crude fat	70
Ash	160
Crude fibre	30
Nitrogen free extract	230

[a] "Köster" Fishmehl – 64% crude protein, Germany
[b] "Viandor" – 60% protein, France
*Supplied per kg of diet: Vitamin A 27 000 I.U.; vitamin D_3 2 250 I.U.; α-tocopherol 108 mg; vitamin K_3 8.1 mg; thiamin 12.75 mg; riboflavin 8.25 mg; niacin 30 mg; Ca-pantothenate 42 mg; pyridoxine 10.8 mg; vitamin B_{12} 0.018 mg; ascorbic acid 64.5 mg; folic acid 1.08 mg; biotin 0.24 mg; Fe 48 mg; Cu 4.5 mg; Co 0.99 mg; Se 0.18 mg; Zn 27 mg; Mn 30 mg; I 1.20 mg; choline chloride 840 mg; antioxidant Endox

an experimental diet; their formulation and chemical composition are shown in Table 1. The fish were fed an astaxanthin-free diet (control group) and a diet containing 49.8 mg astaxanthin/kg (test group): astaxanthin was added to the vitamin and micromineral premix of the same composition. The vitamin and mineral premix was supplied by Vitamex (Belgium) and the quantity of astaxanthin corresponded to a 0.166% concentration, recommended by Vitamex to achieve an attractive flesh colour within 10 weeks. The daily feed intake, split into two rations, corresponded to 2 to 4% of the fish weight. During the two-week acclimation period the fish were fed commercial dry pelleted feed free of astaxanthin.

The growth and condition parameters

In an interval of 21 days 30 fish out of the total stock of 300 fish were caught in each test group and control group and were individually weighed and measured to the nearest 1 g and 1 mm.

The following parameters were examined: weight (W, g), body weight without viscera (BWWV, g), total body length (TBL, mm), body length (BL, mm), body height (BH, mm), body width (BW, mm), Fulton coefficient (FC), absolute weight of liver (AWL, g) to the nearest 0.01 g, hepatosomatic index (HI: liver weight as % of the body weight), and hepatosomatic index HI/II (liver weight as % of the body weight without viscera). Days, water temperature (WT, °C) and dissolved oxygen content in water (O_2, mg/l) were used as independent variables.

Preparation of blood samples

Blood was sampled from ten fish caught at random between the 9.00 h and 10.00 h. The samples were taken by puncturing the caudal veins immediately after catching and stunning. Aqueous solution of heparin (through which the syringe was drawn before each sampling) was used as anticoagulant.

Haematology and clinical chemistry

The Bürker cell was used for determining the erythrocyte count and the blood cells were counted in 2 × 20 rectangles. Haematocrit was determined in microhaematocrit heparinised capillaries in duplicate within 30 minutes after blood sampling, using a microhaematocrit centrifuge (13 000 r.p.m. for 3 min). Haemoglobin was determined by the cyanohaemoglobin method. The derived blood indices of mean corpuscular volume, mean corpuscular haemoglobin, and mean corpuscular haemoglobin concentration (MCHC) were calculated from the haematological values.

The biochemical indices of the blood plasma were determined within 24 h of storage at 4°C; a Hitachi 704C instrument was used for the determinations. They included urea, creatinine, uric acid, total protein, glucose, cholesterol, triacylglycerol (TGL, mmol/l), catalytic concentration of alanine aminotransferase, aspartate aminotransferase, alkaline phosphatase (ALP, μkat/l), lactate dehydrogenase and α-hydroxybutyryl dehydrogenase (HBD, μkat/l). Inorganic phosphate (P, mmol/l) was determined spectrophotometrically and the contents of total calcium, sodium (Na, mmol/l) and potassium were determined by flame emission photometry.

Statistical analysis

Statistically, it is a regression model with replications that makes it possible to test the null hypothesis "Population regression is linear" against an alternative hypothesis "Population regression is not linear" using the test statistic

$$F = \frac{\text{regression error MS}}{\text{within groups MS}}$$

which has Fisher-Snedecor distribution with $k - 1$ and $n - k$ degrees of freedom (Zar, 1984).

The hypothesis of linearity of all regressions was accepted for this test. Therefore we could estimate parameters of the regression lines for all computed regressions defined as

$$y' = B_0 + B_1 x$$

where: $B_1 = \frac{\text{Cov}\, xy}{\text{Var}\, x}$, $B_0 = \frac{\sum y - B_1 \sum x}{n}$

correlation coefficients $R = \frac{\text{Cov}\, xy}{\sqrt{\text{Var}\, y\ \text{Var}\, x}}$ and determination coefficients 100 R^2 (%).

The significance of calculated correlation coefficients was tested using the test statistic

$$t = |R| \sqrt{\frac{n-2}{1-R^2}}$$

which has Student's t-distribution with $n - 2$ degrees of freedom.

The goodness of fit in parameters of regression lines between test group and control group was tested using the heterogeneity of regression test after calculation with pooled (p), common (c) and total (t) regression (Armitage and Berry, 1994).

Three null hypotheses were tested. The null hypothesis "All slopes are identical" has the test statistic

$$F = \frac{\frac{SS_c - SS_p}{k-1}}{\frac{SS_p}{DF_p}}$$

with degrees of freedom $k - 1$ and DF_p.

The second null hypothesis "All intercepts are identical' has the test statistic

$$F = \frac{\frac{SS_t - SS_c}{k-1}}{\frac{SS_c}{DF_c}}$$

with degrees of freedom $k - 1$ and DF_c.

And finally the third null hypothesis "All regressions are identical" has the test statistic

$$F = \frac{\frac{SS_t - SS_p}{2k-2}}{\frac{SS_p}{DF_p}}$$

with $2k - 2$ and DF_p degrees of freedom.

The null hypothesis "Correlation coefficients are identical" was tested using the test statistic

$$u = \frac{z_1 - z_2}{\sqrt{\frac{1}{n_1 - 3} + \frac{1}{n_2 - 3}}}$$

where z is Fisher's transformation of correlation coefficients

$$z = \frac{1}{2} \ln \frac{1+R}{1-R}$$

The statistic u has Gauss distribution N[0,1].

All the calculations were made using the statistical package Unistat® for MS Windows™. All the used procedures are described in user's guide (1995).

RESULTS AND DISCUSSION

The effect of astaxanthin on the growth, condition, haematological and biochemical parameters of the fish in the test group, as depending on time, water temperature and dissolved oxygen content, is documented in Table 2, and for the control group in Table 3. There exist strong positive and negative correlations in both groups of fish expressed by highly significant correlation coefficients ($P \leq 0.01$). In both tables the correlations can be divided into two categories: those expressed by a correlation coefficient above 0.7 (a change in the independent variable contributes more than 50% to the change in the dependent variable) and those expressed by a correlation coefficient above 0.5 (a change in the independent variable contributes more than 25% to the change in the dependent variable). The correlations in the test group that can be included in the first category ($r \geq 0.7$) are total body length, body length, body height, body width, weight and body weight without viscera, as depending on days, and those in the second category ($r \geq 0.5$) are absolute weight of the liver, Fulton coefficient, triacylglycerol, sodium and catalytic concentration of alkaline phosphatase, as depending on days, and also both hepatosomatic indexes and inorganic phosphate depending on water temperature, and mean corpuscular haemoglobin concentration, both hepatosomatic index and triacylglycerol depending on O_2. In the control group the first category includes total body length, body length, body height, body width, weight, body weight without viscera, triacylglycerol and catalytic concentration of alkaline phosphatase which depend on days, and both hepatosomatic indexes, inorganic phosphate and mean corpuscular haemoglobin concentration which depend on water temperature; the second category includes absolute weight of the liver and Fulton coefficient depending on days, and mean corpuscular haemoglobin concentration, both hepatosomatic indexes, triacylglycerol and catalytic concentration of α-hydroxybutyryl dehydrogenase depending on O_2.

As to the correlation and regression parameters, what we consider to be the most important is the results of the test of goodness of fit in regression line slopes and correlation coefficients. A hypothesis of the fit of regression line slopes and hypothesis of the fit of correlation coefficients were rejected in the case of the dependence of inorganic phosphate and mean corpuscular haemoglobin concentration on water temperature and in the case of

Table 2. Parameters of regression and correlation between the indicators assessed in a test group fed an astaxanthin-containing diet

Dependent variable	Independent variable	Parameters of regression line type $y' = B_0 + B_1x$		Coefficient of		Statistical significance of R	
		B_0	B_1	correlation R	determination $100\ R^2$	t-value	prob.
TBL (mm)	days	283.0825	0.3653	0.7739	53.87	5.068**	0.000
BL (mm)	days	255.7217	0.3649	0.7351	54.03	5.085**	0.000
BH (mm)	days	60.5408	0.1716	0.8497	72.20	7.558**	0.000
BW (mm)	days	31.1993	0.0860	0.7970	63.51	6.189**	0.000
W (g)	days	238.6000	1.7641	0.8837	78.09	8.856**	0.000
BWWV (g)	days	204.5371	1.4116	0.8576	73.56	7.823**	0.000
AWL (g)	days	3.5361	0.0337	0.6704	44.94	4.237**	0.000
FC	days	1.4396	0.0028	0.5781	33.42	3.323**	0.002
TGL (mmol/l)	days	2.5799	0.0232	0.5271	27.78	2.557*	0.011
Na (mmol/l)	days	160.3828	–0.0904	–0.5327	28.38	–2.595**	0.009
ALP (µkat/l)	days	4.1219	0.0358	0.5528	30.56	3.040**	0.003
HI (%)	WT (°C)	0.8050	0.0700	0.5724	32.77	3.274**	0.002
HI/II (%)	WT (°C)	0.9111	0.0870	0.5752	33.08	3.298**	0.002
P (mmol/l)	WT (°C)	2.6326	0.1957	0.5153	26.56	2.820**	0.005
MCHC	WT (°C)	0.2107	–0.0024	–0.4722	22.30	–2.513**	0.010
MCHC	O_2 (mg/l)	0.0938	0.0094	0.5854	34.27	3.387**	0.001
HI (%)	O_2 (mg/l)	3.6929	–0.2209	–0.5738	32.93	–3.286**	0.002
HI/II (%)	O_2 (mg/l)	4.3887	–0.2629	–0.5516	30.43	–3.102**	0.003
TGL (mmol/l)	O_2 (mg/l)	–1.9084	0.5940	0.5194	26.98	2.506*	0.011
HBD (µkat/l)	O_2 (mg/l)	4.0926	0.0034	0.0020	00.00	0.009	0.496

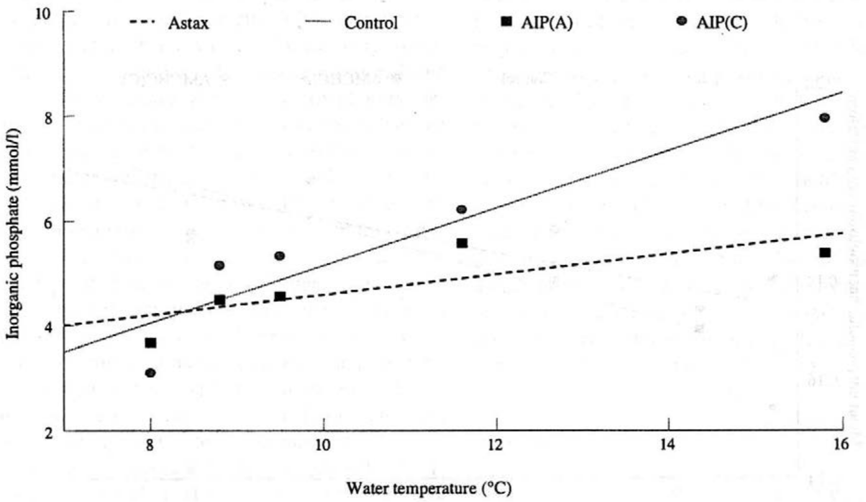

Figure 2. Dependence of inorganic phosphate on water temperature, represented by regression lines

Table 3. Parameters of regression and correlation between the indicators assessed in the control group

Dependent variable	Independent variable	Parameters of regression line type $y' = B_o + B_1x$		Coefficient of		Statistical significance of R	
		B_0	B_1	correlation R	determination $100\ R^2$	t-value	prob.
TBL (mm)	days	280.4730	0.4210	0.8102	65.65	6.484**	0.000
BL (mm)	days	254.1985	0.3974	0.8320	69.21	7.033**	0.000
BH (mm)	days	60.8392	0.1946	0.8823	77.84	8.791**	0.000
BW (mm)	days	31.1409	0.0898	0.8376	69.16	7.024**	0.000
W (g)	days	242.4854	1.8574	0.8738	76.35	8.427**	0.000
BWWV (g)	days	206.4621	1.4179	0.8724	76.11	8.372**	0.000
AWL (g)	days	4.0429	0.0378	0.6819	46.49	4.372**	0.000
FC	days	1.4892	0.0025	0.5617	31.55	3.184**	0.002
TGL (mmol/l)	days	3.2755	0.0264	0.7047	49.67	3.717**	0.001
Na (mmol/l)	days	159.6836	−0.0556	−0.4276	18.29	−1.832*	0.043
ALP (µkat/l)	days	3.1789	0.0501	0.7798	60.82	5.709**	0.000
HI (%)	WT (°C)	0.6191	0.1029	0.7772	60.40	5.793**	0.000
HI/II (%)	WT (°C)	0.6389	0.1341	0.7666	58.77	5.600**	0.000
P (mmol/l)	WT (°C)	−0.3519	0.5499	0.7805	60.92	5.584**	0.000
MCHC	WT (°C)	0.2397	−0.0055	−0.8174	66.81	−6.502**	0.000
MCHC	O_2 (mg/l)	0.0445	0.0141	0.6651	44.23	4.081**	0.000
HI (%)	O_2 (mg/l)	4.4057	−0.2771	−0.6646	44.17	−4.172**	0.000
HI/II (%)	O_2 (mg/l)	5.4540	−0.3488	−0.6333	40.10	−3.838**	0.000
TGL (mmol/l)	O_2 (mg/l)	−1.9194	0.6897	0.6598	43.53	3.285**	0.002
HBD (µkat/l)	O_2 (mg/l)	15.2812	−1.1367	−0.6538	42.74	−3.864**	0.001

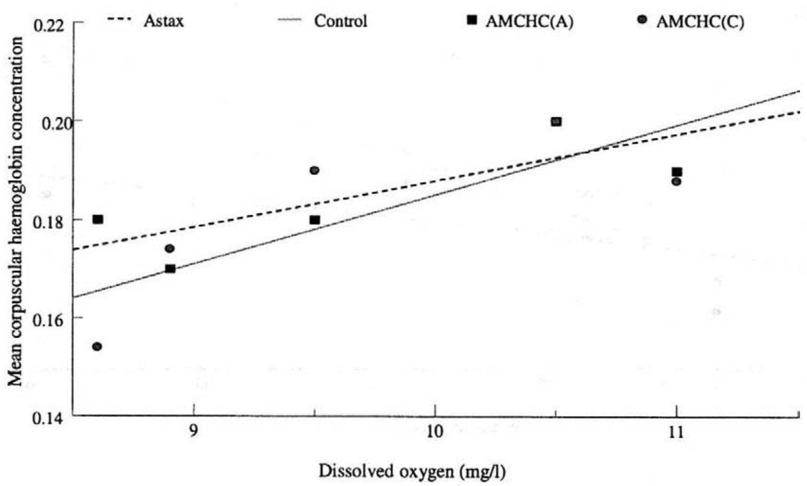

Figure 3. Dependence of the mean corpuscular haemoglobin concentration on water temperature, represented by regression lines

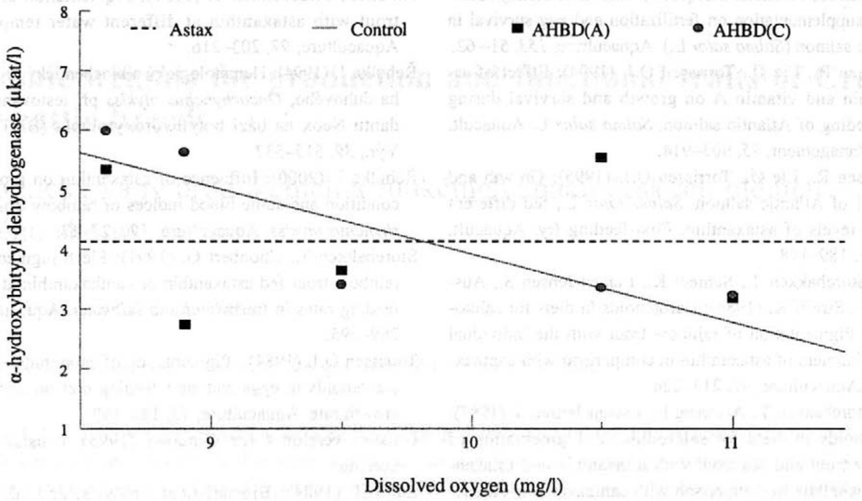

Figure 4. Dependence of catalytic concentration of α-hydroxybutyryl dehydrogenase on dissolved oxygen, represented by regression lines

of the dependence of α-hydroxybutyryl dehydrogenase catalytic activity on O_2. These results indicate that the dependence of inorganic phosphate and mean corpuscular haemoglobin concentration on water temperature and the dependence of α-hydroxybutyryl dehydrogenase catalytic activity on O_2 are less intensive in the test group fed an astaxanthin diet. This is best illustrated in Figure 2, showing a distinctly smaller increase in inorganic phosphate with water temperature in the test group, compared with the control group. Figure 3 indicates a markedly lower decline in the values of mean corpuscular haemoglobin concentration with water temperature in the test group. As shown in Figure 4, α-hydroxybutyryl dehydrogenase catalytic concentration was not influenced by higher O_2 levels in the fish fed astaxanthin-enriched diet, as distinct from the control fish in which catalytic concentration of α-hydroxybutyryl dehydrogenase fell steeply with increasing O_2 concentrations. In this α-hydroxybutyryl dehydrogenase catalytic activity identical with the H_4 and H_3M lactate dehydrogenase (LD) subunits, this insignificant dependence in the test group is expressed by a correlation coefficient of $r = 0.0020$; on the other hand, this relation in the control fish is the very contrary of the results in the test group in terms of both its closeness and its trend ($r = -0.6538$). A significant drop in α-hydroxybutyryl dehydrogenase catalytic concentration was also recorded when we tested the Neox forte antioxidant with a lecithin supplement (Řehulka, 1994). In the fish given a diet with 100 mg Neox and 5 g lecithin per kg of pellets, the α-hydroxybutyryl dehydrogenase catalytic concentration decreased to 0.99 ± 0.267, as compared with the control fish in which the α-hydroxybutyryl dehydrogenase catalytic concentration was 1.52 ± 0.449, the temperature, oxygen content, fish culture method and site being the same.

In our trials we confirmed the finding (Řehulka, 2000) that astaxanthin had no effect on growth. This was proved by the tests of goodness of fit of regressions and correlations, documented by the data in Table 4. The hypothesis of the fit of regression line slopes and hypothesis of the fit of correlation coefficients were not rejected in all conformation traits (total body length, body length, body height, body width) and weight, as depending on days. These results expanded the knowledge acquired from the studies conducted by Foss *et al.* (1984, 1987), Storebakken and Choubert (1991), No and Storebakken (1991), and for the Atlantic salmon by Torrissen (1984), Christiansen and Torrissen (1996, 1997) and Christiansen *et al.* (1994, 1995). The results of the haematological and biochemical tests encourage the efforts to expand the knowledge of the changes in the blood of the fish on an astaxanthin-containing diet, as depending on ambient factors. Current results in blood serum enzymology in relation to the administration of feeds containing astaxanthin were provided by Nakano *et al.* (1995).

REFERENCES

Armitage P., Berry G. (1994): Statistical Methods in Medical Research. (3rd ed.) Blackwell Scientific Publications, Oxford.

Christiansen R., Torrissen O.J. (1996): Growth and survival of Atlantic salmon, *Salmo salar* L., fed different dietary levels of astaxanthin. Juveniles. Aquacult. Nutr., *2*, 5–62.

Christiansen R., Torrissen O.J. (1997): Effects of dietary astaxanthin supplementation on fertilization and egg survival in Atlantic salmon (*Salmo salar* L.). Aquaculture, *153*, 51–62.

Christiansen R., Lie Ø., Torrissen O.J. (1994): Effect of astaxanthin and vitamin A on growth and survival during first feeding of Atlantic salmon, *Salmo salar* L. Aquacult. Fish. Management, *25*, 903–914.

Christiansen R., Lie Ø., Torrissen O.J. (1995): Growth and survival of Atlantic salmon, *Salmo salar* L., fed different dietary levels of astaxanthin. First-feeding fry. Aquacult. Nutr., *1*, 189–198.

Foss P., Storebakken T., Schiedt K., Liaaen-Jensen S., Austreng E., Streiff K. (1984): Carotenoids in diets for salmonids. I. Pigmentation of rainbow trout with the individual optical isomers of astaxanthin in comparison with canthaxanthin. Aquaculture, *41*, 213–226.

Foss P., Storebakken T., Austreng E., Liaaen-Jensen S. (1987): Carotenoids in diets for salmonids. V. Pigmentation of rainbow trout and sea trout with astaxanthin and astaxanthin dipalmitate in comparison with canthaxanthin. Aquaculture, *65*, 93–305.

Nakano T., Tosa M., Takeuchi M. (1995): Improvement of biochemical features in fish health by red yeast and synthetic astaxanthin. J. Agric. Food Chem., *43*, 1570–1573.

No H.K., Storebakken T. (1991): Pigmentation of rainbow trout with astaxanthin at different water temperatures. Aquaculture, *97*, 203–216.

Řehulka J. (1994): Hematologický a biochemický profil pstruha duhového, *Oncorhynchus mykiss* při testování antioxidantu Neox na bázi butylhydroxytoluolu (BHT). Živoč. Výr., *39*, 515–537.

Řehulka J. (2000): Influence of astaxanthin on growth rate, condition and some blood indices of rainbow trout, *Oncorhynchus mykiss*. Aquaculture, *190*, 27–47.

Storebakken T., Choubert G. (1991): Flesh pigmentation of rainbow trout fed astaxanthin or canthaxanthin at different feeding rates in freshwater and saltwater. Aquaculture, *95*, 289–295.

Torrissen O.J. (1984):. Pigmentation of salmonids – effect of carotenoids in eggs and start-feeding diet on survival and growth rate. Aquaculture, *43*, 185–193.

Unistat. Version 4 for Windows (1995). Unistat Limited, London.

Zar J.H. (1984): Biostatistical Analysis. 2nd ed. Prentice Hall.

Received: 01–01–17

Accepted after corrections: 01–10–04

Corresponding Author:

Ing. Jiří Řehulka, CSc., Jihočeská univerzita České Budějovice, Výzkumný ústav rybářský a hydrobiologický Vodňany, pracoviště Opava, Nádražní okruh 33, 746 01 Opava, Česká republika
Tel. +420 653 62 86 60, fax +420 653 62 47 60, e-mail: vurhjuop@pvtnet.cz

Economic weights for production and functional traits of Czech dairy cattle breeds

Ekonomické váhy produkčních a funkčních znaků českých plemen dojeného skotu

M. WOLFOVÁ, J. PŘIBYL, J. WOLF

Research Institute of Animal Production, Prague-Uhříněves, Czech Republic

ABSTRACT: Economic weights of traits were calculated as partial derivatives of the profit function using a closed herd model for the whole population of Holstein or dual-purpose Czech Pied cattle in the Czech Republic. All revenues and costs connected with one generation of progeny of selected parents were discounted at a discounting rate of 10% or 0% to the birth date of the progeny. The calculations were carried out with and without quota for milk and milk fat. The following economic weights (10% discounting rate, with quota) were calculated for Holstein or Czech Pied (in parentheses) cattle: milk yield with constant fat and protein contents 3.20 (3.71) CZK/kg, fat content 879 (1 186) CZK/%, protein content 6 272 (5 017) CZK/%, net daily gain 9.76 (10.51) CZK per g/day, dressing percentage 160 (185) CZK/%, feed conversion –163 (–184) CZK/MJ NE/kg, cow weight –5.4 (–4.9) CZK per kg, interval between first and last successful breeding of heifers –17.9 (–15.6) CZK/day, calving interval –23.1 (–17.0) CZK per day, cow longevity 397 (559) CZK/lactation. A sensitivity analysis of the influence of changes in input parameters on the economic weights was performed. The relations between the economic weights of milk, beef and reproduction traits were quite insensitive to changes in input and output prices. The economic weight of cow longevity considerably depended on the input parameters. Discounting was the most important factor influencing the relative economic importance of traits.

Keywords: dairy cattle; dual-purpose cattle; economic weights; bioeconomic model; profit function

ABSTRAKT: Ekonomické váhy znaků byly stanoveny parciální derivací ziskové funkce pro uzavřený obrat stáda zahrnující celou populaci holštýnského nebo českého strakatého plemene. Tržby i náklady spojené s jednou generací potomků selektovaných rodičů byly odúrokovány k době narození potomků diskontní úrokovou mírou 10 % a 0 %. Výpočet byl proveden pro situaci bez kvóty a s kvótou pro množství mléka a tuku. Pro holštýnský (v závorkách český strakatý) skot byly stanoveny tyto ekonomické váhy (při 10% diskontaci, s kvótou): množství mléka s konstantním obsahem tuku a bílkovin 3,20 (3,71) Kč/kg, obsah tuku 879 (1 186) Kč/%, obsah bílkovin 6 272 (5 017) Kč/%, netto přírůstek 9,76 (10,51) Kč/g/den, jatečná výtěžnost 160 (185) Kč/%, konverze krmiva –163 (–184) Kč/MJ NE/kg, hmotnost krav –5,4 (–4,9) Kč/kg, interval mezi první a poslední úspěšnou inseminací u jalovic –17,9 (–15,6) Kč/den, mezidobí –23,1 (–17,0) Kč/den, dlouhověkost krav 397 (559) Kč/laktaci. Byla provedena analýza citlivosti relativních ekonomických vah znaků na změny vstupních parametrů. Relace mezi ekonomickými vahami znaků mléčné užitkovosti, masné užitkovosti a reprodukce byly poměrně málo citlivé na změny cen produktů a nákladů. Ekonomická váha dlouhověkosti krav byla značně závislá na úrovni vstupních parametrů. Největší vliv na relativní ekonomický význam znaků mělo použití odúrokování v ziskové funkci.

Klíčová slova: dojený skot; ekonomické váhy; bioekonomický model; zisková funkce

INTRODUCTION

The aim of selection in animal breeding is the choice of parents whose progeny will retrieve the highest economic profit under the given economic circumstances. Therefore, the breeding objective should be described by a profit function that takes genetic values as input and produces profit as outcome (Goddard, 1998). The first step in the design of a breeding programme is to define the traits that influence all sources of income and costs

Supported by the Ministry of Agriculture of the Czech Republic (Project MZE-M02-99-02).

and to calculate their economic values. In the second step the selection criteria are determined. The traits used in the selection criteria may not be the same as in the breeding objective.

For Czech cattle populations, economic weights of traits were calculated first in 1994 (Wolfová *et al.*, 1994). Since 1994 the production circumstances have changed fundamentally. Firstly, the level of some traits has changed substantially. The milk performance has risen quickly, but the fertility parameters and further functional traits have deteriorated. The population size has decreased considerably. Secondly, the prices of inputs for agricultural enterprises have risen sharply without being balanced out by increasing output prices. And thirdly, preparing for the accession to the EU, milk and fat quotas were introduced on 1 April 2001.

It was shown in many papers especially for functional traits that the relative economic weights of traits depend on the trait levels (Mack, 1996; Miesenberger, 1997; Essl, 1998; Steinwidder and Greimel, 1999) as well as on the relations between milk, meat and feed prices (Groen, 1989a; Wolfová and Wolf, 1997; Hirooka and Sasaki, 1998; Koenen *et al.*, 2000). Considerable changes in the relative economic importance of milk and meat production traits with different quota scenarios were reported by Gibson (1989), Mack (1996) and Henze (2000).

Therefore, being in a situation with substantial changes in production circumstances in the Czech Republic, the economic weights should be recalculated. The aim of the present study was to calculate a new set of economic weights for the breeding objective of the Czech dairy cattle populations under expected future economic circumstances. These weights should be used for the construction of economic selection indices and for the evaluation of breeding programmes.

MATERIAL AND METHODS

For the derivation of the economic weights, a bioeconomic model of a closed herd was used which included the whole integrated production system of a dairy or dual-purpose breed. The total discounted profit for this herd was calculated as the difference between all revenues and costs that occurred during the whole life of animals born in the herd in one year and that was discounted to the birth year of these animals:

$$Z_T^0 = Z^0 S_{StFU}$$

$$Z^0 = \sum_{k \in \Omega} N_k \left(R_k q_{R_k} - C_k q_{C_k}\right) \quad (1)$$

with $\Omega = \{BCa, CCa, FBu, BHei, CHei, CCo1, CCo2+\}$

where: Z_T^0 = total discounted profit in the population of the given breed (closed herd)

S_{StFU} = number of standard female units (StFU = one cow place occupied during the whole year)

Z^0 = discounted profit per StFU

N_k = average number of animals in category k per StFU

R_k, C_k = average revenues and costs, respectively, per animal of category k

q_{Rk}, q_{Ck} = discounting coefficient for revenues and costs, respectively, in category k

The discounting coefficients for the revenues were calculated by the following equation:

$$q_{R_k} = (1+u)^{-\Delta t_{R_k}} \quad (2)$$

where: Δt_{Rk} = average time interval between the birth of animals of category k and the time of collecting revenues

u = discounting rate (expressed as a fraction)

The discounting coefficients for the costs were calculated in the same way and at the same discounting rate.

The categories (k) of animals were as follows:

BCa = breeding calves with rearing period from birth to 6 months of age (male and female calves together)

CCa = calves culled within 6 months of age (only calves not suitable for breeding)

FBu = fattened bulls, from 6 months of age to slaughter

BHei = breeding heifers (used for replacement of the cow herd) from the age of 6 months to first calving

CHei = heifers culled before calving (not suitable for breeding or not pregnant)

*CCo*1 = cows culled in the first lactation

*CCo*2+ = cows culled in the second and later lactations

The not discounted profit (that means the average profit per year in the whole balanced system) was calculated by setting $u = 0$ so that all q's took the value 1.

The discounted economic weight of a given trait i was defined as the partial derivative of the total profit function for the closed herd with respect to the given trait whereby all traits were assumed to take their mean values:

$$a_i = \left\{\partial Z_T^0 / \partial x_i \,|_{\mathbf{x}=\boldsymbol{\mu}}\right\} / S_{StFU} \quad (3)$$

where: x_i = value of the trait i under consideration

$\mathbf{x}$ = vector of the values of all traits (dimension of $\mathbf{x}$ = number of traits)

$\boldsymbol{\mu}$ = vector of the means of all traits

Detailed definitions of all evaluated traits and a complete description of the method and the individual models used for the calculation of economic weights can be found in Wolfová and Wolf (1996). The computer programme EW (Wolfová and Wolf, 1996) was used for all calculations after some minor actualisation of the programme.

For milk production traits, the programme offers two ways for their definition. They can be expressed either as amount of milk carrier, fat yield and protein yield (all three traits in kg) or as milk yield (kg) with given fat and protein contents (both in %). The situation with milk quota with reference to fat content and the situation without milk quota were calculated. A decrease in the number of the standard female units was assumed as a response to exceeding the limit for the quota.

As a response to an increased productive lifetime of cows, the following three scenarios were taken into account to calculate the economic weight of cow longevity:

Table 1. Biological and technical parameters for the Czech Pied and Holstein cattle

Parameter (unit)	Czech Pied	Holstein
305-day milk production in 1st lactation (kg)	5 300	6 700
Milk protein content (%)	3.45	3.35
Milk fat content (%)	4.25	4.10
Average number of lactations per StFU	3.53	3.17
Maximum number of lactations per cow	10	10
Calving interval (days)	395	405
Interval from 1st to last successful breeding of heifers (days)	15	15
Number of inseminations per conception in heifers	1.6	1.6
Number of inseminations per conception in cows	2.0	2.1
Interval from calving to 1st breeding in cows (days)	70	80
Genetic standard deviation for milk production (kg)	350	480
Birth weight of calf (average from male and female) (kg)	40	38
Daily gain of calves to 6th month of age (kg/day)	0.85	0.85
Daily gain of heifers from 6th month of age to 1st breeding (kg/day)	0.75	0.75
Daily gain of heifers (without foetus) from 1st breeding to calving (kg/day)	0.4	0.4
Daily gain of bulls from 6th month of age to slaughter (kg/day)	1.0	1.0
Mature weight of cows (kg)	640	620
Live weight of bulls at slaughter (kg)	650	580
Dressing percentage of bulls (%)	59	57
Dressing percentage of heifers (%)	53	51
Dressing percentage of cows (%)	52	50
Age of heifers at 1st breeding (days)	540	480
Regression of milk production on age at 1st breeding		
– linear coefficient (kg/day)	0.876	0.876
– quadratic coefficient $(kg/day)^2$	–0.00036	–0.00036
Coefficient of repeatability for milk production	0.5	0.5
Discounting rate (% per year)	10	10
Milk production in lactation 2nd : 1st	1.14	1.13
3rd : 1st	1.21	1.19
4th : 1st	1.25	1.2
5th : 1st	1.28	1.2
6th : 1st	1.26	1.18
7th : 1st	1.24	1.18
8th : 1st	1.24	1.16
9th : 1st	1.23	1.16
10th : 1st	1.11	1.15

StFU = standard female unit

Scenario 1

All heifers suitable for breeding are mated; the heifers needed for replacement are selected during the first lactation for their milk production. The increase in selection gain is taken into account in the calculations.

Scenario 2

Heifers are selected for their pedigree breeding values before the first breeding and the excessive heifers are fattened and slaughtered at a weight of 460 kg (Czech Pied cattle) or 440 kg (Holstein).

Scenario 3

Heifers are selected as in the foregoing scenario but excessive heifers are mated to beef bulls and sold to the cow-calf production system for 25 000 Czech crowns (CZK) per animal.

The main input parameters for the Czech Pied and Holstein breeds used for the calculations are summarized in Tables 1 and 2. The prices of inputs and products are roughly the prices in the Czech Republic in the year 2000 with some minor deviations taking into account expected developments. The prices for energy units in feed were estimated on the basis of the average feed rations for each category of animals.

A sensitivity analysis was performed to investigate the influence of the price relations of feed, milk, meat and other costs on the relative economic weights of the traits. The influence of the milk production level, the genetic standard deviation of milk yield and of the strategy of mating heifers on the economic weights of cow longevity under different scenarios was also investigated.

RESULTS

The economic weights for Holstein cattle are given in Table 3. The economic weight for cow longevity was calculated according to scenario 3 (excessive heifers were assumed to be sold for cow-calf production systems). The results are presented for a discounting rate 0.10 and for the situation without discounting (zero discounting rate). Using the discounting procedure, the traits which influenced revenues earlier and costs later in the lifetime of the improved animals were preferred in comparison with

Table 2. Economic parameters for the basic situation for the Czech Pied and Holstein cattle

Parameter (unit)	Czech Pied	Holstein
Basic price of milk (CZK/kg)	0.5	0.5
Price for milk protein (CZK/10g)	1.3	1.3
Price for milk fat (CZK/10g)	0.65	0.65
Average price of bulls (CZK/kg slaughter weight)	65	64
Average price of heifers (CZK/kg slaughter weight)	63	62
Average price of cows (CZK/kg slaughter weight)	54	53
Price of energy in average feed ration for bulls (CZK/MJ NE)	0.27	0.27
Price of energy in average feed ration for heifers (CZK/MJ NE)	0.32	0.32
Price of energy in average feed ration for calves (CZK/MJ NE)	0.78	0.78
Price of energy in average feed ration for cows (CZK/MJ NE)	0.46	0.48
Price of energy in concentrate for bulls (CZK/MJ NE)	0.63	0.63
Price of energy in concentrate for heifers (CZK/MJ NE)	0.55	0.55
Price of energy in concentrate for cows (CZK/MJ NE)	0.72	0.72
Price of energy in roughage for bulls (CZK/MJ NE)	0.19	0.19
Price of energy in roughage for heifers (CZK/MJ NE)	.27	0.27
Price of energy in roughage for cows (CZK/MJ NE)	0.32	0.32
Price of one insemination (CZK/insemination)	250	350
Variable labour cost for milk (CZK/kg)	0.5	0.5
Other cost per one stable place for bulls (CZK/day)	9	9
Other cost per one stable place for heifers (CZK/day)	11	1
Other cost per one stable place for calves (CZK/day)	12	12
Other cost per one stable place for cows (CZK/day)	70	70

1 EUR is about 35 CZK

the traits which influenced revenues later and costs earlier. Therefore the ratio of economic values for milk and meat production traits (e.g. milk yield and dressing percentage) was much higher without discounting (1 to 42) than with discounting (1 to 32).

Discounted economic weights of traits, the changes of which did not influence the discounting coefficient (i.e. which did not influence the time when revenues and costs occurred), were always lower than economic weights calculated without discounting. The differences were the higher the longer was the time interval between the birth of improved animals and the time when the improved trait influenced revenues or costs (compare e.g. the differences between discounted and not discounted economic values for milk yield and feed conversion in Table 3). But the discounted economic weights can be higher than the economic weights calculated without discounting if changes in the performance of the given trait (e.g. net daily gain or cow weight) influence not only revenues or costs but also the discounting coefficient through changing the time intervals Δt in equation (2). The differences between the discounted and not discounted economic values can be very high in this case (see the values for cow longevity).

Introducing quotas for milk production with reference to fat content, the economic weights for milk yield and fat content decreased. There were no changes in the economic weights for fattening traits and small changes in the economic weights for the interval between the first and the last successful breeding in heifers, calving interval and cow longevity. With a higher productive lifetime of the cows, the number of cows in later lactations rose followed by an increase in the average milk production per StFU. As a result, the number of cows had to be decreased not to exceed the milk quota.

The economic weights for the Czech Pied breed are summarized in Table 4. The results were similar to those for the Holstein breed. The slightly higher weights for milk, fat and protein in comparison with the Holstein breed were caused by the lower average milk production (cheaper feed ration) of the Czech Pied cattle. Differences in the economic weights of fattening and functional traits between the two breeds were due to dissimilarities in the slaughter weight and in the reproduction parameters (Table 1). As expected, the relative economic importance of meat compared with milk production traits was slightly higher in Czech Pied than in Holstein cattle.

The sensitivity of the relative economic weights of traits to changes in economic parameters is shown in Tables 5 (with discounting) and 6 (without discounting). All results are for the Holstein breed assuming no quota. The economic weights are expressed per genetic standard deviation (only for the basic situation) or as a proportion of the economic value per standard deviation of milk yield. As economic weights may be negative, the unsigned values will be considered for comparisons of the significance of individual traits in the following text. The economic value was always highest for milk yield. The second economically most important trait was protein content.

Table 3. Economic weights of traits for Holstein cattle (in CZK per unit of the given trait and per standard female unit)

Trait (unit)	Variant			
	without quota		with quota[2]	
	u = 0.10	u = 0	u = 0.10	u = 0
Milk yield (kg)	3.79	5.79	3.20	4.01
Fat content (%)	1 942	2 962	879.2	824.3
Protein content (%)	6 272	9 569	6 272	9 569
Carrier yield (kg)	–0.53	–0.81	–1.13	–2.58
Fat yield (kg)	28.98	44.21	13.12	12.30
Protein yield (kg)	93.62	142.8	93.62	142.82
Net daily gain (g/day)	9.76	7.20	9.76	7.20
Dressing percentage (%)	160.1	185.7	160.1	185.7
Feed conversion (MJ NE/kg gain)	–163.4	–176.8	–163.4	–176.8
Cow weight (kg)	–5.44	–1.94	–5.44	–1.94
Interval between 1st and last successful breeding in heifers (days)	–17.68	–16.59	–17.86	–17.14
Calving interval (days)	–21.61	–31.11	–23.13	–35.64
Cow longevity[1] (lactations)	450.0	1 660	396.6	1504

u = discounting rate

[1]scenario when the excessive heifers are mated to beef bulls and sold for a cow-calf production system

[2]quota for milk yield with reference to fat content

Table 4. Economic weights of traits for Czech Pied cattle (in CZK per unit of the given trait and per standard female unit)

Trait (unit)	Variant			
	without quota		with quota[2]	
	u = 0.10	u = 0	u = 0.10	u = 0
Milk yield (kg)	3.97	6.17	3.71	5.01
Fat content (%)	1 553	2 413	1 186	1 254
Protein content (%)	5 017	7 796	5 017	7 796
Carrier yield (kg)	–0.54	–0.83	–0.80	–2.05
Fat yield (kg)	29.30	45.54	22.37	23.66
Protein yield (kg)	94.65	147.1	94.65	147.1
Net daily gain (g/day)	10.51	8.51	10.51	8.51
Dressing percentage (%)	185.3	218.9	185.3	218.9
Feed conversion (MJ NE/kg gain)	–183.9	–200.6	–183.9	–200.6
Cow weight (kg)	–4.90	–2.23	–4.90	–2.23
Interval between 1st and last successful breeding in heifers (days)	–15.58	–15.42	–15.64	–15.74
Calving interval (days)	–16.50	–27.42	–16.98	–29.82
Cow longevity[1] (lactations)	623.3	1 494	559.0	1 387

u = discounting rate.

[1]scenario when the excessive heifers are mated to beef bulls and sold for a cow-calf production system

[2]quota for milk yield with reference to fat content

If the time delay for the influence of a trait on the revenues and costs was taken into account (discounted values in Table 5), the relative economic importance of net daily gain, feed conversion, calving interval and cow longevity was nearly the same in the basic situation; the relative economic weights of these traits ranged from 12 to 17% of the economic weight for milk yield. The lowest value was found for cow weight (9% of the value of milk yield).

Table 5. Relative economic weights of traits in Holstein cattle in dependence on milk, meat and feed prices and other costs. No quota, discounting rate 10%

Trait (unit)	Genetic standard deviation[2]	Economic weights (EW)					
		for the basic situation[1]		for 20% increase in			
		in CZK per standard deviation	proportion of EW for milk yield	prices milk	prices meat	prices feed	all costs
				proportion of EW for milk yield			
Milk yield[3] (kg)	450	1 705.5	1.00	1.00	1.00	1.00	1.00
Fat content (%)	0.207	402.0	0.24	0.23	0.24	0.22	0.22
Protein content (%)	0.095	595.8	0.35	0.32	0.35	0.38	0.39
Net daily gain (g/day)	30	292.8	0.17	0.15	0.18	0.17	0.18
Dressing percentage (%)	1.14	182.5	0.11	0.08	0.13	0.12	0.12
Feed conversion (MJ NE/kg)	1.5	–245.1	–0.14	–0.11	–0.14	–0.19	–0.20
Cow weight (kg)	30	–163.2	–0.09	–0.10	–0.07	–0.12	–0.12
Interval between the 1st and the last successful breeding in heifers (days)	10	–176.8	–0.10	–0.09	–0.10	–0.12	–0.13
Calving interval (days)	10	–216.1	–0.13	–0.13	–0.16	–0.11	–0.09
Cow longevity[4] (days)	180	200.0	0.12	0.01	0.08	0.18	0.27

[1]see Tables 1 and 2

[2]literature values (Heckenberger 1991; Reinsch, 1993; Sölkner *et al*., 2000; Dědková and Wolf, 2001; Wünsch and Bergfeld, 2001)

[3]with constant fat and protein contents

[4]scenario when the excessive heifers are mated to beef bulls and sold for a cow-calf production system

Table 6. Relative economic weights of traits in Holstein cattle in dependence on milk, meat and feed prices and other costs. No quota, discounting rate 0%

Trait (unit)	Economic weights (EW) for the basic situation[1] in CZK per standard deviation	proportion of EW for milk yield	for 20% increase in prices: milk	meat	feed	all costs
			proportion of EW for milk yield			
Milk yield[3] (kg)	2 605.5	1.0	1.0	1.0	1.0	1.0
Fat contents (%)	613.1	0.24	0.23	0.24	0.22	0.22
Protein contents (%)	909.1	0.35	0.32	0.35	0.38	0.39
Net daily gain (g/day)	216.0	0.08	0.06	0.08	0.09	0.11
Dressing percentage (%)	211.7	0.08	0.06	0.10	0.09	0.09
Feed conversion (MJ NE/kg)	–265.2	–0.10	–0.08	–0.10	–0.14	–0.14
Cow weight (kg)	–58.2	–0.02	–0.02	0.00	–0.05	–0.06
Interval between 1st and last successful breeding in heifers (days)	–165.9	–0.06	–0.05	–0.06	–0.08	–0.09
Calving interval (days)	–311.1	–0.12	–0.10	–0.15	–0.11	–0.10
Cow longevity[4] (days)	737.8	0.28	0.24	0.25	0.31	0.32

see Table 5 for the footnotes

If the time delay was not taken into account (not discounted values in Table 6), the highest relative economic importance after milk and protein yields was achieved by cow longevity (28% of the milk value) followed by fat content (24%). Feed conversion and calving interval reached about 10% of the level of the economic weight for milk yield. The cow weight showed the lowest value. Discounting did not influence the relations between the economic values of milk production traits because the discounting coefficient was equal for all these traits.

A 20% increase in the milk price did not influence the economic weights for fattening traits so that the relative economic importance of these traits was diminished in comparison with the economic weights of the milk performance traits (Table 6). Similarly, the relative importance of functional traits decreased slightly as a result of higher milk price. Including the discounting procedure in the calculation of economic weights, the relative economic importance of cow longevity decreased sharply with increasing milk prices (Table 5).

Calculating the economic weight of cow weight, a correlated increase in age at the first breeding was assumed, that is why the discounted economic weight of cow weight declines as a result of increasing milk price. A higher meat price lowered the losses due to higher maintenance costs of heavier cows; therefore the economic weight of cow weight grew (Table 5). The changes in economic weights of functional traits by increasing milk or meat prices depended on the proportion in which the increase in these traits influenced the revenues from milk in comparison with the revenues from slaughtered animals. The direction of these changes was partially different for discounted and not discounted economic weights. An increase in feed or in all costs resulted in a higher importance of fattening traits (except daily gain) and cow longevity relatively to milk production traits.

Summarizing the results from Tables 5 and 6 it can be concluded that under the assumptions used for the calculations, the relative economic weights (discounted as well as not discounted) of the traits mostly used to characterise milk and meat production (milk yield and net daily gain) are quite insensitive to changes in the economic input parameters.

In Table 7, the three different scenarios described in Material and Methods for the calculation of economic weight for cow longevity were examined for the Holstein breed in a situation without quota. The discounted economic weight of cow longevity was highest in scenario 1 for all proportions of heifers calving from the reared female calves. In scenario 3, the economic weight of cow longevity was higher than in scenario 2. The lower the number of replacement heifers, the higher the discounted economic weight of longevity in scenario 2. In scenario 3 the discounted economic value was lowest for the smallest proportion (0.70) of calving heifers. The increase in the discounted profit per StFU connected with a longer productive lifetime of cows in scenario 3 was considerably lower than in scenario 1 (especially at higher milk and meat prices), but it was higher at low milk production level, higher costs or higher price for breeding heifers.

If not taking into account the time delay between the revenues from milk and sold heifers (profit function without discounting), the economic weight of longevity in

Table 7. Discounted (at a rate of 10% – 1st row) and not discounted (2nd row) economic weights of cow longevity (in CZK/lactation and StFU) for alternative levels of input parameters and for alternative scenarios after increasing the productive lifetime of cows (Holstein cattle, no quota)

Changed input parameter(s)	Economic weights for scenarios after increasing cow longevity: higher voluntary culling in 1st lactation (scenario 1)	higher number of fattened heifers (scenario 2)	sale of breeding heifers (scenario 3)
No changes (basic situation[1])	726.8	183.7	450.0
	1 250	1 154.8	1 660.0
Proportion of heifers calving from reared female calves (0.76[2])	888.6	186.5	452.8
	1 483.5	1 129.3	1 634.5
Proportion of heifers calving from reared female calves (0.70[3])	1 014.0	199.6	413.2
	1 661.5	1 127.2	1 632.4
305-day milk production in 1st lactation (5 000 kg)	737.7	585.8	852.0
	668.3	1 010.6	1 515.8
305-day milk production in 1st lactation (5 700 kg)	733.2	420.2	686.5
	908.2	1 070.0	1 575.1
Genetic standard deviation for milk production (400 kg)	688.7	169.7	436.0
	1 181.6	1 123.6	1 628.8
Price for breeding heifers (35 000 CZK)	726.8	183.7	827.4
	1 250.8	1 154.8	2 318.3
20% increase in milk price	732.5	–227.9	38.4
	1 994.0	1 361.7	1 866.9
20% increase in meat prices	798.5	134.6	291.6
	1 447.3	1 122.6	1 444.6
20% increase in all costs	794.8	681.0	921.1
	561.2	1 210.7	1 671.0

[1]proportion of heifers calving from reared female calves 0.88, culling rate in 1st lactation 44.7% (55.2% out of this percentage is voluntary culling for low milk production)

[2]culling rate in 1st lactation 0.30, out of this voluntary culling 33%

[3]culling rate in 1st lactation 0.21, out of this voluntary culling 4%

[1, 2, 3]the average production life of cows surviving to 2nd lactation was assumed to be equal for all proportions of heifers calving from reared female calves

scenario 3 was higher than in scenario 1 for all changes in input parameters except for the proportion of heifers calving being 0.70 and the 20% increase in milk price. The lower the proportion of calving heifers, the lower the not discounted economic weight of longevity in scenarios 2 and 3 and the higher this weight in scenario 1. In scenario 2, the not discounted economic weight of cow longevity was higher than in scenario 1 only for the lower milk production levels (5 000 or 5 700 kg) and for increasing all costs.

The effect of higher selection intensity in the 1st lactation depended on the genetic standard deviation and repeatability of milk production. A repeatability of 0.5 was used. The decrease in the genetic standard deviation from 480 kg (basic situation) to 400 kg lowered the economic weight of cow longevity, but the differences between the scenarios were nearly the same.

DISCUSSION

Method and trait definition

In most papers, the economic value of a trait is calculated as the difference in profit caused by a genetic change in this trait. Commonly the economic value is expressed per year and refers to a given herd. This approach answers the question: "How much would the profit change if the current herd could be replaced by a new herd with a higher genetic value for a trait?" But if a breeding animal (e.g. a bull) were selected from the given pool of animals, the question "What profit in an integrated production system will be obtained from the progeny of a parent whose genetic value for the trait of interest exceeds those of other possible parents?" would be more appropriate.

Table 8. Comparison of not discounted economic weights (in EUR per unit of trait, cow and year) for milk production traits in different countries

Country (Author(s))	Milk production traits			Notes
	milk carrier (kg)	fat (kg)	protein (kg)	
Australia (Beard, 1992)	–0.05	1.50	1.93	without quota
The Netherlands (Steverink *et al.*, 1994)	–0.08	0.29–2.77	6.20–7.99	quota[2], normative for production of P_2O_5 and N losses
Germany (Mack, 1996)	0.08[1]	0.72	2.78	quota, with possibility to buy quota
	0.09[1]	1.09	2.79	situation when quota is not fulfilled
Austria (Miesenberger, 1997)	–0.05	1.19	3.34	quota
	–0.002	2.47	3.34	without quota
The Netherlands (Van der Beek, 1999)	–0.07	0.91	5.44	quota
United Kingdom (Pryce *et al.*, 1999)	–0.03	0.47	4.09	
Finland (Juga *et al.*, 1999)	0.06	1.09	6.05	
Germany, Saxony (Wünsch and Bergfeld, 2001)	0.03	0.77	2.68	quota
	0.03	2.07	2.68	without quota
Czech Republic (present paper)	–0.07	0.35	4.08	quota
	–0.02	1.26	4.08	without quota

[1]milk yield in kg, [2]quota for milk yield with reference to fat content
1 EUR = 2.2037 NGL = 1.9558 DEM = 13.7603 ATS = 0.6412 GBP =5.9457 FIM = 1.6957 AUD = 35 CZK

The purchase of a breeding animal (or its semen) is always an investment and not only the size of returns and costs connected with the trait level is of interest, but also the time when these returns and costs occur after using this animal in the herd. Therefore, discounted values of the changes in a trait level should be used when calculating economic weights for selection decisions. This was proposed by McClintock and Cunningham (1974), but this method was rarely applied to the calculation of economic weights (Ponzoni and Newman, 1989, or Hirooka and Groen, 1999, in beef cattle; Dekkers, 1994 in dairy cattle for calving ease). The discounting procedure is especially important in cattle where the differences in the time when milk or functional traits and fattening traits influence revenues and costs are much greater than in pigs, chickens or sheep; the lifetime of cows can involve a long time period (10 to 15 years). As shown in this paper, discounting is the most important factor that influences the relative economic importance of traits (compare the results in Tables 5 and 6). The value itself of the discounting rate is not so important (Wolfová *et al.*, 1993).

Economic weights may also serve for a comparison of different breeding programmes. In calculating the economic return for certain breeding programmes by the gene-flow method, the ageing of animals and the time delay in the expression of different traits are already taken into account in the transmission matrix. Therefore, economic values without discounting should be used for this purpose.

Defining the breeding objective, all traits that determine profit should be included regardless of the fact if they are recorded in practice and used as selection criteria. Great attention should be paid to the exact definition of the traits. Miesenberger (1997) or Wünsch and Bergfeld (2001) calculated the economic weights of milk production traits for two alternatives – (i) including milk carrier, fat and protein yields in the breeding objective or (ii) including only fat and protein yields. In the first case, an increase in fat (protein) yield is caused by an increase in fat (protein) content. In the second case, an increase in fat (protein) yield is caused by an increase in milk yield at constant fat (protein) content and is accompanied by a decrease in protein (fat) content.

This approach seems to be controversial. If only fat and protein yields describe the milk production of a herd, it is impossible to calculate the true economic weights for these traits. The increase in fat (protein) yield by 1 kg per cow can be due to a higher milk yield or a higher fat content, but the economic weight of fat yield is different in both cases.

For illustration, an example will be given. The following parameter values were assumed: basic price of milk with 4% fat and 3.5% protein: 0.28 EUR/kg; premium for each additional per cent of fat and protein: 0.031 EUR or 0.041 EUR, respectively; average milk yield: 5 000 kg per cow and year; price of concentrate: 0.024 EUR per MJ NE; other variable costs except feed costs: 0.01 EUR per kg. The variable costs per 1 kg milk with given fat and protein contents were then 0.0865 EUR [0.024**(0.2136*3.5 + 0.41*4.0 + 0.8) + 0.01].

For calculating the economic weight, it was assumed in the first case that the fat content increased by 0.02%

at constant milk yield. The equivalent assumption for the second case was a 25 kg increase in milk yield with constant content of milk component contents. The economic value of fat yield (per cow and year) was then 2.12 EUR/kg fat [(0.02*0.031*5000) – (0.41*0.024)*100 = 2.12] for case (i) and 4.84 EUR/kg fat [25*(0.28 – 0.0865) = 4.84] for case (ii).

It can be seen that to describe the influence of milk production traits on the profit both milk yield and content of milk components have to be included in the breeding objective. Therefore the economic weights should always be calculated for three traits – either milk yield, fat and protein contents or milk carrier, fat and protein yields. As Goddard (1998) pointed out, it is important to distinguish between traits in the breeding objective and traits used as selection criteria. Only one or two out of the three traits can be included in the selection criterion for milk production.

Economic weights of traits

A direct comparison of economic weights calculated in different countries is very difficult. In the calculations, different production models and estimation methods are used. The assumptions about the impact of changes in a trait on revenues and costs vary. Furthermore, distinct assumptions about future conditions (milk payment system, relations of input and output prices, possibility to buy milk quota, etc.) are made. Estimates of economic weights for milk production traits in different countries which were published in the recent decade are summarized in Table 8. The economic weight for milk carrier is mostly very low and negative. The relative weighting of fat and protein yields (contents) varies between countries in dependence on the payment system for milk components and on the quota scenarios. Under quota this weighting ranged from 1 : 3 (Miesenberger, 1997) to 1 : 20 (Steverink, 1994); in the present study this ratio was 1 : 12. Without quota the relative weighting of fat becomes more important, the ratio of economic weights for fat and protein taking values from 1 : 1.3 (Beard, 1992) to 1 : 3.2 (present study).

The economic weight of average daily gain from the present study (0.12 EUR/g/day, recalculated from the net daily gain) is much smaller than in other studies. In Germany, this weight was about 1.0 EUR/g/day (Heckenberger, 1991; Hoffmann and Kaltenecker, 1994), in Austria 0.24 EUR/g/day (Miesenberger, 1997). The same holds for feed conversion and dressing percentage. Our values (5.05 EUR/MJ NE/kg and 5.3 EUR/%) are lower than literature values (8.8 EUR/MJ NE/kg – Heckenberger, 1991; 9.9 EUR/% – Miesenberger, 1997). This can be caused by higher prices of slaughter animals in these countries in comparison with the Czech Republic.

Low and mostly negative values were cited in the literature for the economic weight of cow weight. Koenen *et al.* (2000) reviewing 12 papers reported economic values of cow weight in the range from –1.28 to +0.02 EUR/kg/cow and year. The value calculated in the present study (–0.055 EUR/kg/cow and year) fits in this interval. The cow weight is the trait most comparable between countries and breeding organizations because the economic value is mostly calculated only as the difference between the increase in revenues for slaughtered cows and the increase in feed costs for growth and maintenance.

Concerning the functional traits, the economic weights are mostly calculated for cow longevity and calving interval. In Germany, the economic value of cow longevity varied from 0.09 to 0.16 EUR/day (Heckenberger, 1991; Reinsch, 1993; Mack, 1996; Weidele, 1996; Wünsch and Bergfeld, 2001), in Austria a value of 0.12 EUR/day (Miesenberger, 1997; Steinwidder and Greimel, 1999) was calculated and in Switzerland the estimate was 0.28 EUR/day (Böbner, 1994). The estimates in Italy (0.46 to 0.56 EUR/day – Brandts *et al.*, 1996), United Kingdom (about 1 EUR/day – Pryce *et al.*, 1999) and Australia (0.96 EUR/day – Beard, 1992) were much higher. Essl (1998) pointed out in his review that the economic weight of cow longevity depended very strongly on the starting values of the population parameters (e.g. age structure, culling strategy, milk production level, calving interval), and changed nonlinearly with the average length of productive life. As shown in Tables 5 to 7, the economic weight of cow longevity is also very sensitive to price changes in all inputs and outputs. The economic value of cow longevity depends also on the assumption about the utilisation of excessive heifers after increasing the productive life of cows. Under the economic circumstances assumed in this paper, the highest economic weight of cow longevity was obtained if all heifers entered the herd and were selected for their milk production in the first lactation (scenario 1 in Table 7).

The value obtained in the present study for calving interval (–0.62 EUR/day) is in good agreement with that of Weidele (1996) (–0.61 EUR/day). In other studies lower (Reinsch, 1995) as well as higher values (Mack, 1996) were calculated. Pryce *et al.* (1999) reported a very high value (–6.24 EUR/day). Whereas in the present paper a similar value (–0.51 EUR/day) was calculated for a closely related trait (interval between the 1st and the last successful breeding in heifers), Heckenberger (1991) obtained a higher value (–1.5 EUR/day).

In the present investigation no economic weight for the carcass class according to the SEUROP system was calculated as no sufficient input information was available. Nevertheless, it can be supposed that in future the carcass conformation will have an important effect on the price paid for fattened bulls and culled cows. Several Western European indices have already included a conformation score for live animals as well as information about carcass classification in the SEUROP system. No such a system is at present available on the Czech beef market, but data should be collected for the Czech Pied breed in order to include those traits at a later stage.

Comparing the economic weights calculated in this study and in a foregoing paper (Wolfová *et al.*, 1994), important changes in the relations between economic weights can be observed. The prediction made in 1994 for the price relations between milk, meat and feed was not realized. The relations used in the present study (8.6 : 1 for prices of 1 kg milk to 1 kg slaughter weight in bulls, 20 : 1 for prices of 1 kg milk to 1 MJ NE in barley) are close to the situation in 1998. After accession to the EU, important changes in economic parameters as well as in other production circumstances might occur in the Czech Republic. Therefore, only a short planning horizon of 5 years was taken into account for the present calculations. The economic weights should be recalculated if changes in economic circumstances are greater than about 20% or if new output limitations (e.g. for sustainable agricultural production) are introduced (Groen, 1989a, b).

Acknowledgement

Thanks are due to Ludmila Dědková, Pavlína Mlázovská, Elena Kudrnová, Eliška Machačová, Hubert Herrmann, Petr Šafus, Petr Kopeček and Zdeněk Poděbradský for their help to obtain the input parameters. Furthermore, the authors would like to thank Jindřich Kvapilík, Josef Bouška, Mojmír Vacek, Luděk Šereda, František Urban and Václav Teslík for valuable discussions and Gottfried Averdunk (Kirchheim-Heimstetten) for the critical reading of the manuscript.

REFERENCES

Beard K. T. (1992): Studies on breeding objectives and selection indices applicable to the Australian dairy cattle industry. [PhD. Thesis.] University of New South Wales.

Böbner C. (1994): Schätzung wirtschaftlicher Gewichte für sekundäre Leistungsmerkmale bei schweizerischen Zweinutzungsrindern unter Anwendung der dynamischen Optimierung. [Dissertation.] ETH Zürich.

Brandts A., Canavesi F., Cassandro M. (1996): Economic weights for longevity in the Italian Holstein breed. Interbull Bulletin, No. 14, 76–80.

Dědková L., Wolf J. (2001): Estimation of genetic parameters for milk production traits in Czech dairy cattle populations. Czech J. Anim. Sci., *46*, 292–301.

Dekkers J.C.M. (1994): Optimal breeding strategies for calving ease. J. Dairy Sci., *77*, 3441–3453.

Essl A. (1998): Longevity in dairy cattle breeding: a review. Livest. Prod. Sci., *57*, 79–89.

Gibson J.P. (1989): Economic weights and index selection of milk production traits when multiple production quotas apply. Anim. Prod., *49*, 171–181.

Goddard M.E. (1998): Consensus and debate in the definition of breeding objectives. J. Dairy Sci., *81*, 6–18.

Groen A.F. (1989a): Economic values in cattle breeding. I. Influences of production circumstances in situations without output limitations. Livest. Prod. Sci., *22*, 1–16.

Groen A.F. (1989b): Economic values in cattle breeding. II. Influences of production circumstances in situations with output limitations. Livest. Prod. Sci., *22*, 17–30.

Heckenberger G.J. (1991): Planungsrechnungen über den Einfluß von Grenznutzenwerten der Leistungsmerkmale, Parametern der Populationsstruktur und von Züchtungssystemen auf den Züchtungserfolg beim Zweinutzungsrind. [Dissertation.] Universität Hohenheim.

Henze C. (2000): Merkmalsbewertung bei Milchrindrassen mit und ohne Milchquote. In: Vortragstagung der DGfZ und GfT „Aus der Arbeit der Forschungsstätten für Tierproduktion". Kiel, September 20–21, 2000. Kiel: Christian-Albrechts-Universität. C27.

Hirooka H., Groen A.F. (1999): Effects of production circumstances on expected responses for growth and carcass traits to selection of bulls in Japan. J. Anim. Sci., *77*, 1135–1143.

Hirooka H., Sasaki Y. (1998): Derivation of economic weights for carcass traits in Japanese Black cattle from field records. J. Anim. Breed. Genet., *115*, 27–37.

Hoffmann H., Kaltenecker T. (1994): Zuchtziele aus der Sicht der Agrarpolitik und Betriebswirtschaft. Züchtungskunde, *66*, 447–459.

Juga J., Mäntysaari E.A., Pösö J. (1999): Economic response to total merit selection in Finnish Ayrshire breeding. Interbull Bulletin, No. 23, 79–87.

Koenen E.P.C., Berentsen P.B.M., Groen A.F. (2000): Economic values of live weight and feed-intake capacity of dairy cattle under Dutch production circumstances. Livest. Prod. Sci., *66*, 235–250.

Mack G. (1996): Wirtschaftlichkeit des züchterischen Fortschritts in Milchviehherden – Gesamtbetriebliche Analyse mit Hilfe eines simultan-dynamischen Linearen Planungsansatzes. [Dissertation.] Universität Hohenheim.

McClintock A.E., Cunningham E.P. (1974): Selection in dual purpose cattle populations: defining the breeding objective. J. Anim. Prod., *18*, 237–247.

Miesenberger J. (1997): Zuchtzieldefinition und Indexselektion für die österreichische Rinderzucht. [Dissertation.] Wien, Universität für Bodenkultur.

Ponzoni R.W., Newman S. (1989): Developing breeding objectives for Australian beef cattle production. Anim. Prod., *49*, 35–47.

Pryce J., Simm G., Amer P., Coffey M., Stott A. (1999): Returns from genetic improvement on indices that include production, longevity, mastitis and fertility in UK circumstances. Interbull Bulletin, No. 23, 55–61.

Reinsch N. (1993): Berechnung wirtschaftlicher Gewichtungsfaktoren für sekundäre Leistungsmerkmale beim Fleckvieh. [Dissertation.] München-Weihenstephan, Technische Universität.

Sölkner J., Miesenberger J., Willam A., Fuerst C., Baumung R. (2000): Total merit indices in dual purpose cattle. Arch. Tierz., *43*, 597–608.

Steinwidder A., Greimel M. (1999): Ökonomische Bewertung der Nutzungsdauer bei Milchkühen. Bodenkultur, *50*, 235–249.

Steverink M.H.A., Groen A.F., Berentsen, P.B.M. (1994): The influence of environmental policies for dairy farms on dairy cattle breeding goals. Livest. Prod. Sci., *40*, 251–261.

Van der Beek S. (1999): Breeding for profit in the Netherlands. Interbull Bulletin, No. 23, 75–78.

Weidele A. (1996): Die Auswirkungen von Leistungssteigerungen primärer und sekundärer Merkmale beim Rind auf die Wirtschaftlichkeitskoeffizienten und Struktur der Milchviehhaltung in der Bundesrepublik Deutschland – Sektoraler Ansatz. [Dissertation.] Universität Hohenheim.

Wolfová M., Wolf J. (1996): PC-programs for estimating economic weights in cattle. Živoč. Výr., *41*, 97–101.

Wolfová M., Wolf J. (1997): Citlivost ekonomických vah na změny podmínek v chovu skotu. Živoč. Výr., *42*, 97–105.

Wolfová M., Přibyl J., Wolf J. (1993): Vliv úrokové míry na výpočet ekonomických vah vlastností skotu. Živoč. Výr., *38*, 193–201.

Wolfová M., Přibyl J., Wolf J. (1994): Stanovení ekonomických vah vybraných vlastností pro domácí populaci skotu. Živoč. Výr., *39*, 109–120.

Wünsch U., Bergfeld U. (2001): Berechnung wirtschaftlicher Gewichte für ökonomisch wichtige Leistungsmerkmale in der Milchrinderzucht. Züchtungskunde, *73*, 3–11.

Received: 01–06–11
Accepted after corrections: 01–09–24

Corresponding Author:

Ing. Marie Wolfová, Výzkumný ústav živočišné výroby, P.O. Box 1, 104 01 Praha-Uhříněves, Česká republika
Tel. +420 2 67 00 95 71 , fax +420 2 67 71 07 79, e-mail: wolfova@vuzv.cz

Allele frequency at *PRL* (prolactin) and *LGB* (lactoglobulin beta) genes in Red cattle breeds from Central Europe and in other breeds

Frekvence alel v genech *PRL* (prolaktin) a *LGB* (laktoglobulin beta) u středoevropských plemen červeného skotu a dalších plemen

J. Čítek, V. Řehout, V. Neubauerová

University of South Bohemia, Agricultural Faculty, Department of Genetics, Animal Breeding and Nutrition, České Budějovice, Czech Republic

ABSTRACT: Allele frequencies were determined at prolactin (*PRL*) and lactoglobulin beta (*LGB*) genes by PCR/RFLP technique in the following cattle breeds: Czech Pied ($n = 46$), Black and White ($n = 42$), German Black and White ($n = 39$), Czech Red ($n = 59$), Polish Red ($n = 65$), and German Red ($n = 29$). At *PRL* the following frequencies of allele *A* were found in breeds under investigation: Czech Pied – 0.83, Black and White – 0.90, German Black and White – 0.81, Czech Red – 0.56, Polish Red – 0.87, and German Red – 0.86. At *LGB* allele *B* predominated and its estimated gene frequencies in the same order were 0.53, 0.59, 0.70, 0.56, 0.81, and 0.68, respectively. At *PRL* significant differences were found between Czech Red and other breeds. At *LGB* significant differences were detected between Polish Red and other breeds, with the exception of German Red, and between Czech Pied and German Black and White breeds.

Keywords: cattle; allele frequencies; PCR/RFLP; prolactin; lactoglobulin beta

ABSTRAKT: Metodou polymerázové řetězové reakce a polymorfismu délky restrikčních fragmentů PCR/RFLP byly u českého strakatého skotu ($n = 46$), černostrakatého skotu ($n = 42$), německého černostrakatého skotu ($n = 39$), českých červinek ($n = 59$), polských červinek ($n = 65$) a německých červinek ($n = 29$) stanoveny frekvence alel v *PRL* (prolaktin) genu a *LGB* (laktoglobulin beta) genu. V lokusu *PRL* převládala alela *A* s těmito frekvencemi: český strakatý skot – 0,83; černostrakatý skot – 0,90; německý černostrakatý skot – 0,81; české červinky – 0,56; polské červinky 0,87; německé červinky 0,86. V lokusu *LGB* byla u všech plemen vyšší četnost alely *B* s frekvencemi 0,53; 0,59; 0,70; 0,56; 0,81; 0,68. V *PRL* lokusu byly rozdíly v četnostech alel mezi českými červinkami a ostatními plemeny statisticky významné, v lokusu *LGB* byly významné rozdíly mezi četnostmi alel polských červinek a ostatních plemen s výjimkou německých červinek a mezi českým strakatým skotem a německým černostrakatým skotem.

Klíčová slova: skot; frekvence alel; PCR/RFLP; prolaktin; laktoglobulin beta

INTRODUCTION

The study of genetic polymorphisms contributes to the genetic characterization of populations. In cattle, genetic polymorphisms of milk proteins and some proteohormones have been intensively studied by many authors during the last 30 years. Extensive studies were carried out to determine the occurrence and frequency of milk protein genotypes in bovine species and in different breeds within those species (Eigel *et al.*, 1984; Coulon *et al.*, 1998; Grosclaude and Grosclaude, 1993; Sabour *et al.*, 1997).

The prolactin gene (*PRL*) belongs to a family of evolutionarily related genes together with the pituitary growth hormone and the placental lactogen (chorionic somatomammotropin) (Niall *et al.*, 1971). *PRL* is known

Supported by the Ministry of Education, Youth and Sports of the Czech Republic (Grant CEZ J 06/98 1222 0004).

to be involved in a wide range of biological functions including lactation (Nicol and Bern, 1972; Bazan, 1998). The gene is approximately 10 kilobase in length (Camper *et al.*, 1984). A silent A-G transition mutation at the codon for amino acid 103 in exon 3 of bovine *PRL* gives rise to a polymorphic restriction site revealed by *Rsa*I (Lewin *et al.*, 1992). The associations between the prolactin gene and production traits in Holstein Friesian cattle breed were investigated by Chung *et al.* (1996).

Proteins are the most appreciated milk components. In cattle, six milk protein genes are often studied: casein alpha-S1 (*CASA*), casein alpha-S2 (*CASA2*), casein beta (*CASB*), casein kappa (*CSN10*), lactalbumin alpha (*LALBA*), and lactoglobulin beta (*LGB*) (Erhardt *et al.*, 1998). Although lactoglobulin beta, encoded by *LGB* gene, is the most abundant protein in the whey protein fraction, its function and physiological role are unclear. It may be involved in the transport of retinol and fatty acids in the gut. It is not found in the milk of all mammals, e.g. lactoglobulin beta is absent in human milk (Perez *et al.*, 1992). Genetic polymorphism at *LGB* was first described by Aschaffenburg and Drewry in 1957. Numerous alleles at *LGB* locus have been identified (*A, B, C, D, E, F, G, H, I, W, X, Y, Z, Dr*), but in our cattle breeds the *A* and *B* are predominant. The variants differ in single amino acid substitutions at positions 64 and 118 (Eigel *et al.*, 1984). At position 64 Asp is changed to Gly and at position 118 Val is changed to Ala, for A and B variants, respectively (Jamieson *et al.*, 1987). These changes arise from two single base substitutions, A-G and T-C, respectively, the change at position 118 creates a *Hae*III site at allele *LGB B*, which is not present in the *A* allele (Lien *et al.*, 1990). There is an evidence for association of bovine *LGB* genetic variants to protein content, lactation performance and processing properties of milk (Geldermann, 1993; Bovenhuis, 1992; Hanuš, 1995).

PRL maps to chromosome 23 (Fries *et al.*, 1993), and *LGB* is localized on chromosome 11 (Eggen and Fries, 1995).

MATERIAL AND METHODS

Czech Pied ($n = 46$), Black and White ($n = 42$), German Black and White ($n = 39$), Czech Red ($n = 59$), Polish Red ($n = 65$), and German Red ($n = 29$) breeds were genotyped. The Czech Pied cattle (Simmental) was represented by purebred animals. Black and White cattle in the Czech Republic originates from the crossing of Czech Pied breed with Black and White bulls of both European and American origin. The German Black and White group originated in the Eastern Federal lands (Meklenburg-Vorpommern). Czech Red, German Red and Polish Red cattle alike are endangered gene reserves. The total number of purebred Czech Red females is about 60, the number of sires is 6. Especially the German Red cattle is very low-numbered. This group consisted of partially related individuals, offspring of twelve mothers and nine fathers, the fathers of nine animals were unknown. Also Polish Red breed is endangered, even though not in the same order. There are about 100 000 purebred and crossbred cows in Poland, but only 900 cows are under milk recording (Filistowicz and Zwolińska-Bartczak, 1995), less than 100 cows are included in a preservation programme. Many herds have been crossed with Danish Red and Angler cattle, which are related to the above-mentioned breeds, therefore the number of original Polish genotypes is decreasing. In gene reserves, we tried to analyze as high number of animals as possible, that is why the number of Polish and Czech Red cattle is higher. In German Red cattle, we were not able to get more probes, therefore its number is lower.

Genomic DNA was isolated from the whole blood using the method of Gemmel and Akiyama (1996), or the quick method of Kawasaki (1990). For genotyping, PCR/RFLP methods were used, following the previously reported procedure of Mitra *et al.* (1995) for *PRL* locus and Medrano and Aguilar-Cordove (1990) for *LGB* locus. The primers synthetized 156 bp fragment for *PRL* and 274 bp fragment for *LGB*. The *PRL* and *LGB* amplimers were digested with restriction endonucleases *Rsa*I and *Hae*III, respectively, at 37°C for 2 h. The fragments were electrophoresed in 3% agarose gel stained with ethidium bromide.

Allele and genotype frequencies were determined. Comparison of the genotype frequencies found and those theoretically estimated was performed by the chi-square test (χ^2). The test of difference in relative values was used to test the allele differences between the breeds examined.

RESULTS AND DISCUSSION

The digestion of the *PRL* amplimer with *Rsa*I resulted in genotypes *AA* (156 bp), *AB* (156, 82, 74 bp) and *BB* (82, 74 bp). The digestion of the *LGB* PCR product with *Hae*III resulted in fragments 148 and 99 bp (*AA*), 148, 99, 74 and 74 bp (*AB*), 99, 74 and 74 bp (*BB*). The frequencies for the breeds examined are given in Table 1 for *PRL* gene and in Table 2 for *LGB* gene.

At the *PRL* gene, there is an obvious tendency of the allele *A* to predominate in all the populations under study. The frequencies ranged from 0.81 to 0.90 except for Czech Red cattle with frequency 0.56. The frequency of the allele *B* was low and it occurred mainly in heterozygous individuals. The frequency of the *BB* homozygotes was low, it ranged from 0 to 0.05, a higher frequency was found in the population of Czech Red cattle only. In Black and White cattle and German Red cattle, *PRL B* allele was present only in heterozygotes.

In the literature there are only a few data concerning the allele frequencies at *PRL* gene. Chrenek *et al.* (1997)

Table 1. The genotype and allele frequencies at *PRL* (prolactin) gene

Breed	Frequency	Genotypes/Alleles				χ^2-test
		AA	AB	BB		
Czech Pied $n = 46$	absolute	32	12	2		0.85[ns]
	relative	69.56	26.09	4.35		
			A		B	
	relative		0.83		0.17	
	frequency	AA	AB	BB		χ^2-test
Black and White $n = 42$	absolute	34	8	0		1.11[ns]
	relative	80.95	19.05	0.00		
			A		B	
	relative		0.90		0.10	
	frequency	AA	AB	BB		χ^2-test
German Black and White $n = 39$	absolute	26	11	2		0.85[ns]
	relative	66.67	28.20	5.13		
			A		B	
	relative		0.81		0.19	
	frequency	AA	AB	BB		χ^2-test
Czech Red $n = 59$	absolute	17	32	10		1.00[ns]
	relative	28.81	54.24	16.95		
			A		B	
	relative		0.56		0.44	
	frequency	AA	AB	BB		χ^2-test
Polish Red $n = 65$	absolute	49	15	1		0.03[ns]
	relative	75.38	23.08	1.54		
			A		B	
	relative		0.87		0.13	
	frequency	AA	AB	BB		χ^2-test
German Red $n = 29$	absolute	21	8	0		2.56[ns]
	relative	72.41	27.59	0.00		
			A		B	
	relative		0.86		0.14	

ns = non significant

found the frequency of the allele *A* of 0.95 in Holstein cattle, 0.85 in Piemontese, 0.72 in Montbeliard, 0.70 in Fleckvieh and 0.68 in Austrian Pinzgau. Chung *et al.* (1996) published the frequency of the allele *A* in Holstein dairy cattle 0.73. Mitra *et al.* (1995) found a predominating tendency of the *A* allele too, they genotyped German Black and White cattle (0.80) and Braunvieh (0.61). Our data are in accordance with the above mentioned references.

At the *LGB* gene, the predominance of the allele *B* was found, even though only slightly expressed in most breeds. The frequencies ranged from 0.53 to 0.81, the most outstanding frequency was found in Polish Red cattle.

In literature, the prevalence of the allele *B* in the *LGB* gene is evident, it corresponds well with our results. Sowiński (1993) established the frequency 0.65 in Black and White cattle. Chrenek *et al.* (1997) published the frequencies of allele *B* in some cattle breeds: Montbeliard 0.59,

Table 2. The genotype and allele frequencies at *LGB* (lactoglobulin beta) gene

Breed	Frequency	Genotypes/Alleles					χ^2-test
		AA		AB	BB		
	absolute	8		18	10		$9.58.10^{-4\text{ns}}$
Czech Pied	relative	22.22		50.00	27.78		
$n = 36$			A			B	
	relative		0.47			0.53	
	frequency	genotypes/alleles					χ^2-test
		AA		AB	BB		
Black and White	absolute	5		20	12		1.47^{ns}
$n = 37$	relative	13.52		54.05	32.43		
			A			B	
	relative		0.41			0.59	
	frequency	genotypes/alleles					χ^2-test
		AA		AB	BB		
German Black and White	absolute	4		15	19		0.42^{ns}
$n = 38$	relative	10.53		39.47	50.00		
			A			B	
	relative		0.30			0.70	
	frequency	genotypes/alleles					χ^2-test
		AA		AB	BB		
Czech Red	absolute	10		32	17		1.00^{ns}
$n = 59$	relative	16.95		54.24	28.81		
			A			B	
	relative		0.44			0.56	
	frequency	genotypes/alleles					χ^2-test
		AA		AB	BB		
Polish Red	absolute	2		21	42		0.16^{ns}
$n = 65$	relative	3.08		32.31	64.61		
			A			B	
	relative		0.19			0.81	
	frequency	genotypes/alleles					χ^2-test
		AA		AB	BB		
German Red	absolute	1		14	10		8.22*
$n = 25$	relative	4.00	5	6.00	40.00		
			A			B	
	relative		0.32			0.68	

ns = non significant
*$P < 0.05$

Fleckvieh 0.60, Holstein 0.63, Piemontese 0.64 and Austrian Pinzgau 0.78. Similar values were detected by Uhrín *et al.* (1995). Bech and Kristiansen (1990) found the frequency of 0.89 in Danish Red cattle, which exceeds even our highest frequency, and Feleńczak (1983) established 0.66 in Polish Red cattle, it is a bit lower compared to our findings in this breed. Erhardt *et al.* (1998) give the frequency of 0.74 in Polish Red cattle, and 0.78 in German Red cattle. Comparing the frequencies in Czech Pied cattle to the results of Mácha and Müllerová (1968), no considerable change has occurred in the last 30 years.

The observed and theoretically expected genotype frequencies at both *PRL* and *LGB* genes were in agreement with Hardy-Weinberg equilibrium in all populations under study with the exception of German Red breed at *LGB* gene ($P < 0.05$).

Using the test of difference in relative values, the significance of differences in allelic frequencies between the

Table 3. Allele frequencies: the test of differences in relative values for *PRL* (prolactin) gene (below diagonal) and *LGB* (lactoglobulin beta) gene (above diagonal)

	LGB					
Breed	1	2	3	4	5	6
Czech Pied	×	0.813^{ns}	2.119^{*}	0.424^{ns}	4.268^{**}	1.681^{ns}
Black and White	1.543^{ns}	×	1.317^{ns}	0.481^{ns}	3.245^{**}	1.083^{ns}
German Black and White	0.309^{ns}	1.784^{ns}	×	1.927^{ns}	4.134^{**}	0.206^{ns}
Czech Red	4.253^{**}	5.775^{**}	3.728^{**}	×	4.278^{**}	1.457^{ns}
Polish Red	0.883^{ns}	0.804^{ns}	1.172^{ns}	5.599^{**}	×	1.770^{ns}
German Red	0.592^{ns}	0.782^{ns}	0.847^{ns}	4.308^{**}	0.133^{ns}	×
	PRL					

ns = non significant
* $P < 0.05$
** $P < 0.01$

breeds was tested (Table 3). Significant differences ($P < 0.01$) at the *PRL* gene were found between Czech Red cattle and other breeds. At the *LGB* gene, significant differences ($P < 0.01$) were found between Polish Red cattle and other breeds with the exception of German Red cattle, and between Czech Pied cattle and German Black and White cattle ($P < 0.05$).

In conclusion, some differences in frequencies between the breeds were found, namely within the Red cattle group, even though the similarity in phylogenetically related breeds has been expected. In our opinion, the different frequencies may be explained namely by the influence of genetic drift and inbreeding in small populations of endangered Red breeds under study.

REFERENCES

Aschaffenburg R., Drewry J. (1957): Genetics of the β-lactoglobulins of cow's milk. Nature, *180*, 376–378.

Bazan J.F. (1998): Structural design and molecular evolution of a cytokine receptor super family. Proc. Natl. Acad. Sci. USA, *87*, 6934–6938.

Bech A.M., Kristiansen K.R. (1990): Milk protein polymorphism in Danish dairy cattle and the influence of genetic variants on milk yield. J. Dairy Res., *57*, 53–62.

Bovenhuis I. (1992): The Relevance of Milk Protein Polymorphisms for dairy cattle breeding. [Doctoral Thesis.] Agricultural University, Wageningen.

Camper S.A., Luck D.N., Yao Y., Woychick R.P., Goodwin, R.G., Lyons R.H. Jr., Rottmann F.M. (1984): Characterization of the bovine prolactin gene. DNA, *3*, 237–249.

Chrenek P., Vašíček D., Haladová D., Bauerová M., Oberfranc M. (1997): Detekcia genetických markerov plemien hovädzieho dobytka importovaných na Slovensko. J. Farm. Anim. Sci., *30*, 138–143.

Chung E.R., Rhim T.J., Han S.K. (1996): Associations between PCR-RFLP markers of growth hormone and prolactin genes and production traits in dairy cattle. Korean J. Anim. Sci., *38*, 321–336.

Coulon J.B., Hurtaud C., Remond B., Verite R. (1998): Factors contributing to variation in the protportion of casein in cow's milk true protein: a review of recent INRA experiments. J. Dairy Res., *65*, 375–387.

Eggen A., Fries R. (1995): An integrated cytogenetic and meiotic map of the bovine genome. Anim. Genet., *26*, 255–269.

Eigel W.N., Butler J.E., Ernstrom C.A., Farrel H.M. jr., Harwalkar R.J., Whitney R. (1984): Nomenclature of proteins of cow's milk. 5th revision. J. Dairy Sci., *67*, 1599.

Erhardt G., Juszczak J., Panicke L., Krick-Saleck H. (1998): Genetic polymorphism of milk proteins in Polish Red cattle: a new genetic variant of β-lactoglobulin. J. Anim. Breed. Genet., *115*, 63–71.

Felenczak A. (1983): Genetyczny polimorfizm i zawartość niektórych frakcji bialek mleka u ras bydla hodowanego w poludniowej Polsce. Zesz. Nauk. Krakow, *22*, 175–191.

Filistowicz A., Zwolińska-Bartczak I. (1995): Genetic potential of breeding animals in Poland. In: Proc. Inter. Symp. Conservation Measures for Rare Farm Animal Breeds. Balice, May 17–19, 1994. National Research Institute of Animal Productin Balice near Kraków, Poland. 102–115.

Fries R., Eggen A., Womack J. (1993): The bovine genome map. Mamm. Genome, *4*, 405–428.

Geldermann H. (1993): New aspects of genome analysis in farm animal populations. In: XVI. Days of Genetics of Farm Animals. Nitra, Slovakia. 1–12.

Gemmel N.J., Akiyama S. (1996): An efficient method for the extraction of DNA from vertebrate tissues. Trends Genet., *12*, 338–339.

Grosclaude P., Grosclaude F. (1993): Improvement of milk protein quality by gene technology. Livest. Prod. Sci., *35*, 95–115.

Hanuš O. (1995): Složení a vlastnosti mléka využitelné v plemenářské práci a prvovýrobě. [Autoreferát disertační práce.] Výzkumný ústav pro chov skotu, Rapotín.

Jamieson A.C., Vandeyar M.A., Kang Y.C., Kinsella J.E., Batt C.A. (1987): Cloning and nucleotide sequence of the bovine b-lactoglobulin gene. Gene, *61*, 85.

Kawasaki E.S. (1990): Sample preparation from blood, cells and other fluids. In: PCR Protocols: A Guide to Methods and Applications. New York, Academic Press. 146–152.

Lewin H.A., Schmitt K., Hubert R., van Eijk, M.J.T., Arnheim N. (1992): Close linkage between bovine prolactin and BoLA-DRB3 genes: genetic mapping in cattle by single sperm typing. Genomics, *13*, 44–48.

Lien S., Alestrom P., Steine T., Langsrud T., Vegarud G., Rogne S. (1990): A method for β-lactoglobulin genotyping of cattle. Livest. Prod. Sci., *25*, 173.

Mácha J., Müllerová Ž. (1968): Milk protein polymorphism in different cattle breeds. Acta Univ. Agric. Brno, *16*, 409.

Medrano J.F., Aguilar-Cordove E. (1990): Polymerase chain reaction amplification of bovine β-lactoglobulin genomic sequences and identification of genetic variats by RFLP analysis. Anim. Biotechnol., *1*, 73.

Mitra A., Schlee P., Balakrishnan C.R., Pirchner F. (1995): Polymorphisms at growth-hormone and prolactin loci in Indian cattle and buffalo. J. Anim. Breed. Genet., *112*, 71–74.

Niall H.D., Hogan M.L., Sayer R., Rosenblum I.Y., Greenwood F.C. (1971): Sequences of pituitary and placental lactogenic and growth hormones: Evolution from a primordial peptide by gene reduplication. Proc. Natl. Acad. Sci. USA, *68*, 866–869.

Nicoll C.S., Bern A.(1972): On the actions of PRL among the vertebrates: Is there common denominator? In: Wolstenholme G. E. W., Knight J. (eds.): Lactogenic Hormones. Churchill–Livingstone, London. 99–327.

Perez M.D., Sanchez L., Aranda P., Ena J. M., Oria R., Calvo M. (1992): Effect of β-lactoglobulin on the activity of pregastric lipase. A possible role for this protein in ruminant milk. Biochim. Biophys. Acta, *1123*, 151–155.

Sabour M.P., Lin C.Y., Smith C. (1997): Association of genetic variants of bovine growth hormone with milk production traits in Holstein cattle. J. Anim. Breed. Genet., *114*, 435–442.

Sowiński G. (1993): Zwiazek genetycznych wariantów β-laktoglobuliny, α_{S1}-, β- oraz κ-kazein z wydajnoscia, skladem chemicznym i wskaznikami technologicznej przydatności mleka krów rasy nizinnej czarno-bialej. Acta Acad. Agricult. Tech. Olst. Zootechnica, *38*, Suppl. B, 3–38.

Uhrín P., Chrenek P., Vašíček D., Bauerová M., Bulla J. (1995): Genotyping of β-lactoglobulin gene in different breeds of cattle in Slovakia. Živoč. Výr., *40*, 49–52.

Received: 00–06–06
Accepted after corrections: 01–09–26

Corresponding Author:

Ing. Jindřich Čítek, CSc., Jihočeská univerzita, Zemědělská fakulta, Studentská 13, 370 05 České Budějovice, Česká republika
Tel. +420 38 77 725 91, fax +420 38 77 725 93, e-mail: citek@zf.jcu.cz

Growth ability, carcass and meat quality of lambs of the German Long-wooled sheep and their crosses

Růstová schopnost, jatečná hodnota a kvalita masa jehňat plemene německá dlouhovlnná ovce

J. KUCHTÍK, F. HORÁK

Mendel University of Agriculture and Forestry, Brno, Czech Republic

ABSTRACT: Ram and ewe lambs of the genotypes of German Long-wooled (GL, n = 15/14), F_1 crosses of the German Long-wooled × Oxford Down (GL × OD, n = 15/15) and the F_{12} (Merino × German Long-wooled) × Oxford Down (M × GL) × OD, (n = 12/12), were fattened in a semi-intensive fattening system involving grazing on an alfalfa-grass mixed sward. In terms of growth evaluation the investigations showed the effect of fathers of the Oxford Down meat breed. The highest growth ability of ram lambs in the period from birth to weaning, and/or from birth to 100 days of age, was determined for (M × GL) × OD (0.231 and 0.250 kg, respectively) when the difference from the ram lambs with genotype GL was statistically highly significant ($P \leq 0.01$) in the period from birth to weaning and it was statistically significant ($P \leq 0.05$) in the period from birth to 100 days of age. Evaluation of the basic parameters of carcass analyses of ram lambs showed that the effect of the respective genotypes on these parameters was not significant. Evaluation of the valuable parts of the dressed carcass showed that the proportions of leg, rib and rack were the highest in GL. The proportions of the individual tissues were evaluated in the right leg and right rack, and the highest proportion of muscle (67.60 and 66.65%), or the lowest proportion of fat (5.13 and 5.80%), was found in GL × OD while the values of these parameters in genotypes GL and (M × GL) × OD were basically the same. Based on the analyses of quality parameters, the lowest proportion of intramuscular fat (2.54%), and the highest proportion of protein (19.39%) and ash (1.05%) were found in the GL genotype.

Keywords: growth; carcass value; meat quality; lambs

ABSTRAKT: Výkrm jehňat beránků genotypů německá dlouhovlnná ovce (ND), kříženců F_1 německá dlouhovlnná ovce × × Oxford Down (ND × OD) a F_{12} (Merino × německá dlouhovlnná ovce) × Oxford Down (M × ND) × OD byl realizován aplikací polointenzivního výkrmu s využitím pastvy na vojtěškotravním porostu. Ze zhodnocení růstu vyplývá, že v rámci našeho sledování se projevil vliv masného plemene Oxford Down v otcovské pozici. Nejintenzivnější růst u beránků byl zaznamenán u (M × ND) × OD u kterých průměrný přírůstek v intervalu od narození do odstavu byl 0,231 kg, v intervalu od 70 do 100 dnů věku 0,296 kg a v intervalu od narození do 100 dnů věku 0,250 kg. Ve stejných intervalech byly u jehniček zaznamenány v podstatě totožné hodnoty u ND × OD a (M × ND) × OD, a to 0,191 kg vs. 0,189 kg, 0,261 kg vs. 0,251 kg a 0,213 kg vs 0,208 kg. Z vyhodnocení základních ukazatelů jatečných analýz vyplývá, že ani v jednom případě nebyl zaznamenán průkazný vliv na tyto ukazatele z pohledu jednotlivých genotypů, když průměrná výtěžnost jatečně opracovaných těl se pohybovala v rozmezí od 42,88 do 43,81 % a podíly kůže v rozmezí od 10,26 do 11,16 % v závislosti na jednotlivých genotypech. V případě posuzování podílů jednotlivých partií JOT, zde byly v případě kýty (32,88 %), kotlety (7,80 %), ledviny (9,20 %) a plece (19,05 %) stanoveny nejvyšší podíly u ND, když u ND x OD a (M x ND) x OD tyto podíly činily 32,77 vs. 32,23 %, 7,48 vs. 6,72 %, 8,74 vs. 8,25 % a 18,44 vs 17,66 %. Na základě posouzení podílů jednotlivých tkání jak v pravé kýtě, tak v pravé pleci nejvyšší podíly svaloviny (67,60 a 66,65 %), respektive nejnižší podíly tuku (5,13 a 5,80 %) byly stanoveny u ND × OD, když u genotypů ND a (M × ND) × OD byly v těchto ukazatelích stanoveny v podstatě totožné hodnoty (64,66 vs. 64,68 %, 64,44 vs. 64,54 % a 7,37 vs. 7,75 %, 7,28 vs. 7,35 %). Ze základních analýz ukazatelů jakosti na základě rozborů *m. triceps brachii* vyplývá, že u ND byl stanoven nejnižší podíl intramuskulárního tuku (2,54 %) a nejvyšší podíly bílkovin (19,39 %) a popelovin (1,05 %). Průměrný podíl sušiny u všech tří genotypů byl v podstatě totožný, hodnoty se pohybovaly v rozmezí od 23,52 do 23,60 %. U průměrných energetických hodnot v původní hmotě nebyly stanoveny statisticky průkazné

Supported by the Ministry of Education, Youth and Sports of the Czech Republic (Grant No. MSM 4321 00001).

rozdílů mezi sledovanými genotypy, hodnoty se pohybovaly v rozmezí od 515,05 do 549,47 kJ/100 g. Nejvyšší obsah myoglobinu byl stanoven u ND × OD (1,59 mg v 1 g svaloviny). Průměrné obsahy hydroxyprolinu, jež jsou ukazatelem míry obsahu vazivové tkáně v kosterní svalovině, byly stanoveny v podstatě totožné u ND × OD a (M × ND) × OD (0,24 a 0,25 mg ve 100 g svaloviny), nejnižší obsah byl stanoven u ND (0,22 mg ve 100 g svaloviny).

Klíčová slova: růst; jatečná hodnota; kvalita masa; jehňata

INTRODUCTION

The German Long-wooled (GL) breed was selected by combination crossing of Würtemberg ewes with rams of the North-Caucasian, Corriedale and Lincoln breeds (Horák *et al*., 1999). Although this breed is suitable both for lowland and submontane regions, at present it is kept in the Czech Republic only on a few farms in the region of the Bohemian-Moravian Highlands. It is a dual-purpose breed (wool and meat production). The GL breed is raised mainly in its pure form at present. After 1995 some individuals of the GL population were crossed with Oxford Down in order to improve the growth ability and carcass quality of lambs. The GL breed was also used for the grading up of Merino sheep. Horák and Pinďák (1997) published the results of performance testing aimed at the growth of purebred GL lambs in the Czech Republic, Fantová and Čislíkovská (1991) studied the growth and carcass value of lambs – crosses with this breed. Their investigations also included an evaluation of the growth and carcass value of crosses with Merino (M) ewes. Mátlová (1999) studied the growth of lambs-crosses with Oxford Down (OD) in conditions of the Czech Republic. Puntila and Fredlund (1992) investigated the growth and carcass value of lambs – crosses with OD rams. Kališ *et al*. (1994) and Scales *et al*. (2000), among others, studied the growth ability in lambs – crosses with Merino. The aim of our study was to determine the influence of the genotype of lambs of both sexes – single-born ones, namely of the genotypes German Long-wooled, F_1 crosses of the German Long-wooled × Oxford Down and F_{12} crosses (Merino × German Long-wooled) × Oxford Down, on growth ability and the influence of the genotype of randomly selected ram lambs on carcass and meat quality when all the investigated lambs were kept in identical conditions.

MATERIAL AND METHODS

Investigations into the growth ability of lambs of both sexes – single-born ones of the genotypes German Long-wooled (GL, 15 ram lambs and 14 ewe lambs), F_1 crosses of the German Long-wooled × Oxford Down (GL × OD, 15 ram lambs and 15 ewe lambs) and F_{12} crosses (Merino × German Long-wooled) × Oxford Down ((M × GL) × OD, 12 ram lambs and 12 ewe lambs) were carried out on the sheep farm of the AZ Holding Rovečne in 1997, applying the semi-intensive system of fattening. All evaluated lambs of all three genotypes were born during the last decade of April and during the first decade of May, namely in the period from April 22 to May 6 in 1997. All evaluated lambs of all three genotypes were single-born ones and came only from ewes of the same age (from the second lambing). From mid-May the lambs with their mothers were driven to the pasture. All investigated lambs were weaned at average age of 70 days. The feed ration before weaning consisted of the mother's milk (*ad libitum*), alfalfa hay (*ad libitum*) and grazing on a mixed alfalfa-grass sward (*ad libitum*). Concentrates were added to the feed ration of the lambs at the age of ca. 30 days. The average consumption of concentrates per lamb/day in the period from birth to weaning (70 days of age) was 0.075 kg. In the period from weaning to the end of our investigations the daily feed ration of the lambs consisted of alfalfa-grass sward grazing (*ad libitum*) and concentrates (0.200 kg/lamb). During the grazing season the lambs were housed in a free barn with deep litter where the feed could be supplemented and with free access to the pasture. The composition of the concentrate was as follows: triticale – ground (41%), barley – crushed (31%), thermally treated soya groats (23%), rape cake (2%), vitamin mineral additive – Mikros M 12 (2.5%) and ground limestone (1.5%). The lambs had free access to drinking water.

During the experiment all the lambs were weighed after their birth, before weaning and at average age of 100 days. Control slaughter of randomly selected ram lambs of all three investigated genotypes ($n = 6$) was carried out after the end of the fattening period at the average age of 100 days. After slaughter the dressed carcass was evaluated for meatiness and fat content using the SEUROP system (Pour *et al*., 1998). The carcass dissection was made according to Figure 1. Selected parts of the dressed carcass (right leg and right rack) were analysed to determine the weight or the proportions of the individual tissues. Evaluation of the basic and other selected parameters of meat quality of the lambs of all three studied genotypes was based on analyses of the meat of right rack, i.e. from the *musculus triceps brachii*. Analyses of the meat quality were carried out by common chemical methods according to Vrchlabský and Veselá (1985). For the mathematical and statistical evaluation, on the basis of the facts described above, the one-factor analysis of variance with subsequent testing according to Scheffe's method was applied. The Statgraphics programme ver-

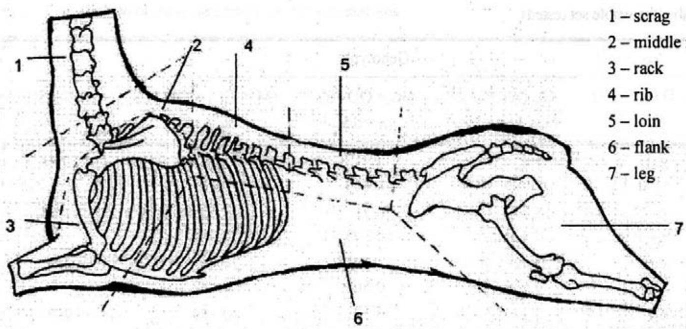

Figure 1. Dissection of the lamb carcass

sion 7.0 was used. The dressed carcass was not statistically evaluated according to the SEUROP system and this is briefly mentioned in the Results and Discussion section.

RESULTS AND DISCUSSION

In the category of ram lambs (Table 1) the GL lambs had the highest average live weight at birth (4.12 kg), GL × OD had the lowest (3.69 kg), but all average weights at birth in our experiment were lower than those reported by Stopka *et al.* (1996). The highest average live weight of ram lambs at weaning (70 days of age) was determined in the genotype (M × GL) × OD (19.99 kg), and the lowest in GL (18.98 kg), the difference between these two groups was statistically significant ($P \leq 0.05$). According to Kališ *et al.* (1994) the live weight of purebred lambs of the Improved Wallachian and Tsigai breeds at 70 days of age was higher than the weight determined in the present study (i.e. 21.68 kg and 21.36 kg, respectively), but lower than the live weight of Merino × Ile de France crosses at this age (i.e. 18.64 kg).

The highest and the lowest average live weight at 100 days of age was found in the ram lambs (M × GL) × OD (i.e. 28.88 kg) and GL (27.12 kg), respectively. The difference between these two groups was statistically significant as it was in the case of average live weights at weaning, (i.e. $P \leq 0.05$). The average weight of the GL × OD ram lambs at 100 days of age was 27.79 kg.

The highest growth ability in the period from birth to weaning (0.231 kg) was observed in the (M × GL) × OD group and this value was lower than the average daily weight gains (AWG) reported by Speedy (1989) for lambs

Table 1. Some growth characteristics – ram lambs (the whole set tested)

Characteristic		Genotype			*F*- test
		GL (A) (n = 15)	GL × OD (B) (n = 15)	(M × GL) × OD (C) (n = 12)	
Live weight at birth (kg)	$\bar{x}$	4.12	3.69	3.85	3.19
	$s_{\bar{x}}$	0.091	0.151	0.138	
Live weight at weaning (kg)	$\bar{x}$	18.98^{c}	19.16	19.99^{a}	4.53*
	$s_{\bar{x}}$	0.252	0.261	0.191	
Live weight at 100 days of age (kg)	$\bar{x}$	27.12^{c}	27.79	28.88^{a}	3.61*
	$s_{\bar{x}}$	0.399	0.512	0.427	
AWG from birth to weaning (kg)	$\bar{x}$	0.212^{C}	0.221	0.231^{A}	5.41**
	$s_{\bar{x}}$	0.004	0.005	0.002	
AWG from weaning to 100 days of age (kg)	$\bar{x}$	0.271	0.287	0.296	1.39
	$s_{\bar{x}}$	0.007	0.001	0.001	
AWG from birth to 100 days of age (kg)	$\bar{x}$	0.230^{c}	0.241	0.250^{a}	5.02*
	$s_{\bar{x}}$	0.004	0.006	0.004	

AWG = average daily weight gain
*a, b = $P \leq 0.05$
**A, B, C = $P \leq 0.01$

Table 2. Some growth characteristics – ewe lambs (the whole set tested)

Characteristic		GL (A) (n = 14)	GL × OD (B) (n = 15)	(M × GL) × OD (C) (n = 12)	F- test
		Genotype			
Live weight at birth (kg)	$\bar{x}$	3.42	3.33	3.27	0.54
	$s_{\bar{x}}$	0.099	0.104	0.115	
Live weight at weaning (kg)	$\bar{x}$	15.77	16.71	16.52	1.57
	$s_{\bar{x}}$	0.424	0.393	0.381	
Live weight at 100 days of age (kg)	$\bar{x}$	22.32^{b}	24.56^{a}	24.06	4.00*
	$s_{\bar{x}}$	0.639	0.566	0.582	
AWG from birth to weaning (kg)	$\bar{x}$	0.176	0.191	0.189	2.79
	$s_{\bar{x}}$	0.005	0.005	0.005	
AWG from weaning to 100 days of age (kg)	$\bar{x}$	0.218^{b}	0.261^{a}	0.251	1.39
	$s_{\bar{x}}$	0.012	0.010	0.008	
AWG from birth to 100 days of age (kg)	$\bar{x}$	0.189^{B}	0.213^{A}	0.208	5.58**
	$s_{\bar{x}}$	0.006	0.005	0.005	

AWG = average daily weight gain
*a, b, c = $P \leq 0.05$
**A, B, C = $P \leq 0.01$

of meat breeds. The GL group showed the lowest growth ability in the period from birth to weaning (0.212 kg), the difference from (M × GL) × OD was statistically highly significant ($P \leq$ 0.01). In the period from birth to 100 days of age the AWG was highest in the (M × GL) × OD ram lambs (0.250 kg), the difference from GL (0.230 kg) in this period being statistically significant ($P \leq$ 0.05), but higher than AWG reported by Mátlová (1999) in lambs of the Šumavská × Texel and Šumavská × Oxford Down crosses kept in an intensive grazing system, supplemented with hay and concentrates. The AWG of the GL × OD crosses in the period from birth to weaning and from birth to 100 days of age were 0.221 kg and 0.241 kg, respectively. As for the AWG from weaning to the age of 100 days, they were relatively high in all three investigated groups, ranging between 0.271 kg in GL and 0.296 kg in (M × GL) × OD.

Table 2 shows gives selected growth parameters of ewe lambs of the same genotypes and shows that GL had the highest live weight at birth (3.42 kg), the weight at birth of the GL × OD and (M × GL) × OD groups was 3.33 kg and 3.27 kg, respectively. Subsequently in comparison with the category of ram lambs, the average live weight at weaning and at the age of 100 days was highest in ewe lambs of GL × OD (i.e. 16.71 kg and 24.56 kg, respectively), the average live weights of ewe lambs of the genotype (M × GL) × OD at weaning and at the age of 100 days were the same (i.e. 16.52 kg and 24.06 kg, respectively). The lowest average live weight at weaning and at 100 days of age was found in GL (15.77 kg and 22.32 kg, respectively), the difference in average weights of ewe lambs of this genotype at 100 days of age compared to GL × OD was statistically significant ($P \leq 0.05$).

The highest AWG in the period from birth to weaning were found to be the same for GL × OD (0.191 kg) and (M × GL) × OD (0.189 kg). These data are considerably higher than those reported by Ploumi *et al.* (1997) for ewe lambs of the Florina breed, but lower than those reported by Perret *et al.* (1986) for ewe lambs of the Lacaune and Suffolk breeds. The average daily weight gains of both these groups in the period from birth to 100 days of age were higher than 0.200 kg, i.e. 0.213 kg and 0.208 kg, respectively. The lowest AWG in this period was found in GL (0.189 kg). The difference between the GL and GL × OD groups was statistically highly significant ($P \leq 0.01$). As for AWG in the period from weaning to 100 days of age it was found that the AWG of the GL × OD (0.261 kg) and (M × GL) × OD (0.251 kg) ewe lambs were the same as those of ram lambs, that means relatively high. The lowest AWG in this period was observed in the GL group (0.218 kg), the difference from the AWG of GL × OD being statistically significant ($P \leq$ 0.05).

Table 3 shows the evaluation of the basic parameters of carcass analyses of selected ram lambs of all three investigated groups. The average live weight of selected ram lambs at the time of slaughter was 27.91 kg for GL (n = 6), 27.77 kg for GL × OD (n = 6) and 28.35 kg for (M × GL) × OD (n = 6). The average weight of dressed carcass was 11.97 kg for GL, 12.17 kg for GL × OD and 12.42 kg for (M × GL) × OD, no statistical difference being found in the average live weights prior to slaughter nor in the average weights of dressed carcass between the respective genotypes.

The dressed carcass was experimentally evaluated within 24 hours from slaughter according to the SEUROP sys-

Table 3. Evaluation of basic parameters of carcass analyses

Characteristic		Genotype			*F*- test
		GL (A) ($n = 6$)	GL × OD (B) ($n = 6$)	(M × GL) × OD (C) ($n = 6$)	
Live weight at slaughter (kg)	$\bar{x}$	27.91	27.77	28.35	0.10
	$s_{\bar{x}}$	0.982	1.129	0.737	
Dressed carcass weight (kg)	$\bar{x}$	11.97	12.17	12.42	0.20
	$s_{\bar{x}}$	0.424	0.612	0.457	
Dressing percentage (%)	$\bar{x}$	42.88	43.78	43.81	0.43
	$s_{\bar{x}}$	0.181	1.029	0.937	
Skin weight (kg)	$\bar{x}$	2.88	3.09	3.01	0.39
	$s_{\bar{x}}$	0.184	0.175	0.152	
Skin percentage (%)	$\bar{x}$	10.26	11.16	10.59	1.02
	$s_{\bar{x}}$	0.326	0.594	0.377	
Kidney weight (kg)	$\bar{x}$	0.066	0.067	0.075	1.05
	$s_{\bar{x}}$	0.003	0.005	0.006	
Kidney fat weight (kg)	$\bar{x}$	0.073	0.080	0.118	3.38
	$s_{\bar{x}}$	0.012	0.008	0.017	
Heart weight (kg)	$\bar{x}$	0.157	0.193	0.182	0.83
	$s_{\bar{x}}$	0.013	0.024	0.022	
Lungs weight (kg)	$\bar{x}$	0.382	0.475	0.440	3.44
	$s_{\bar{x}}$	0.026	0.029	0.020	
Liver weight (kg)	$\bar{x}$	0.462	0.438	0.407	1.82
	$s_{\bar{x}}$	0.031	0.017	0.004	
Spleen weight (kg)	$\bar{x}$	0.063	0.050	0.059	1.33
	$s_{\bar{x}}$	0.003	0.008	0.006	
Testicle weight (kg)	$\bar{x}$	0.078	0.094	0.114	1.33
	$s_{\bar{x}}$	0.012	0.014	0.020	

tem. In genotype GL, 5 carcasses were classified in category C (the carcass weight at take-over ranged between 10.1 and 13.0 kg), according to the meat colour in class 1 (light pink or pink); one carcass was included in class 2 for fattiness, 1 carcass in class 3 and 3 carcasses in class 4. The 6th carcass, which weighed more than 13.0 kg, was included in class R 4. Five carcasses of the genotype GL × OD were also classified in category C and in class 1; in terms of fattiness 2 carcasses were included in class 2, two carcasses in class 3 and one in class 4. The 6th carcass, which weighed more than 13.0 kg, was classified as class R 2. The (M × GL) × OD genotype was classified as follows: 4 carcasses in category C and quality 1; in terms of fattiness one carcass was included in class 2, one in class 3 and two in class 4. Two carcasses of this genotype weighed more than 13.0 kg and were classified as class R 4. The above-mentioned facts imply that the meat colour of basically all carcasses of all genotypes weighing less than 13.0 kg was light pink to pink, however, in terms of the fattiness the genotype GL × OD showed the most satisfactory parameters.

No statistical differences were discovered between the average dressing percentages of dressed carcasses; the same dressing percentage was found in (M × GL) × OD and in GL × OD (i.e. 43.81% and 43.78%, respectively), in GL it was 42.88%. The dressing percentages of all three investigated genotypes found in our experiment were higher than those reported by Kleczek and Skrzyzala (1997) and Puntila and Fredlund (1992), but lower than those determined by Perret *et al.* (1986) for different genotypes. The proportion of skin depended on the genotype and ranged between 10.26% and 11.16%. These values are considerably higher than those determined by Kuchtík *et al.* (1997) in Charollais lambs and Booroolo × Charollais crosses. The highest average weight of kidney and kidney fat was found in (M × GL) × OD (i.e. 0.075 kg and 0.118 kg, respectively) and lowest in GL (i.e. 0.066 kg and 0.073 kg, respectively). No statistically significant difference was observed between the groups although a comparison of the average weight of kidney fat in these groups is on the margin of statistical significance. It is similar with the lungs, where the difference between the highest average weight determined in (M × GL) × OD (0.44 kg) and the lowest average weight determined in GL (0.382 kg) was also on the margin of statistical significance. The average weight of the other edible internal parts, i.e. heart, liver and spleen, was also

Table 4. Evaluation of the separate cuts of dressed carcass

Dressed carcass cuts		Genotype			F- test
		GL (A) (n = 6)	GL × OD (B) (n = 6)	(M × GL) × OD (C) (n = 6)	
Leg (kg)	$\bar{x}$	3.92	3.98	4.00	0.06
	$s_{\bar{x}}$	0.116	0.187	0.130	
Leg (%)	$\bar{x}$	32.88	32.77	32.23	0.80
	$s_{\bar{x}}$	0.524	0.199	0.377	
Rib (kg)	$\bar{x}$	0.94	0.92	0.83	1.17
	$s_{\bar{x}}$	0.049	0.066	0.024	
Rib (%)	$\bar{x}$	7.80 ^{c}	7.48	6.72 ^{a}	6.44**
	$s_{\bar{x}}$	0.282	0.227	0.114	
Loin (kg)	$\bar{x}$	1.10	1.07	1.03	0.42
	$s_{\bar{x}}$	0.064	0.074	0.042	
Loin (%)	$\bar{x}$	9.20 ^{c}	8.74	8.25 ^{a}	4.52*
	$s_{\bar{x}}$	0.273	0.212	0.173	
Rack (kg)	$\bar{x}$	2.28	2.24	2.20	0.19
	$s_{\bar{x}}$	0.088	0.106	0.095	
Rack (%)	$\bar{x}$	19.05 ^{C}	18.44^{c}	17.66 ^{Ab}	11.81**
	$s_{\bar{x}}$	0.292	0.125	0.150	
Middle neck (kg)	$\bar{x}$	0.96	1.00	1.02	0.35
	$s_{\bar{x}}$	0.044	0.056	0.053	
Middle neck (%)	$\bar{x}$	8.03	8.22	8.20	0.42
	$s_{\bar{x}}$	0.196	0.121	0.166	
Flank (kg)	$\bar{x}$	2.00 ^{C}	2.24	2.56 ^{A}	7.79**
	$s_{\bar{x}}$	0.096	0.116	0.086	
Flank (%)	$\bar{x}$	16.72 ^{BC}	18.40 ^{AC}	20.62 ^{AB}	51.59**
	$s_{\bar{x}}$	0.339	0.245	0.339	
Scrag (kg)	$\bar{x}$	0.76	0.72	0.79	0.79
	$s_{\bar{x}}$	0.026	0.029	0.055	
Scrag (%)	$\bar{x}$	6.31	5.94	6.32	1.01
	$s_{\bar{x}}$	0.152	0.242	0.242	

*a, b, c = $P \leq 0.05$
**A, B, C = $P \leq 0.01$

determined and the differences between the genotypes were not statistically significant. The average weight of the heart was highest in the GL × OD genotype (0.193 kg) while the highest average weight of the liver and spleen was found in the genotype GL (0.462 kg and 0.063 kg, respectively). The highest average weight of the testicles was found in the (M × GL) × OD ram lambs (0.114 kg) while the average testicle weight of the other two genotypes was insignificantly lower (0.094 kg and 0.078 kg for GL × OD and GL, respectively).

Table 4 shows the average weights, or the average proportions, of the cuts of the dressed carcass of all three genotypes. Depending on the genotype, the average weight of the leg ranged between 3.92 kg and 4.00 kg. The average proportion of the leg was highest in the GL genotype (32.88%), in GL × OD and (M × GL) × OD it was 32.77% and 32.23%, respectively, i.e. the values lower than those reported by Craplet and Thibier (1980) and Kuchtík *et al.* (1997) but the same as in Gut (1991). The GL genotype was found to have the highest average weight and/or proportion of the rib (0.94 kg and 7.80%, respectively) and (M × GL) × OD the lowest (0.83 kg and 6.72%, respectively); the difference in the average proportions between these two groups was statistically significant ($P \leq 0.05$). In the GL × OD ram lambs the average proportion of the rib was 7.48%. The highest average weight or average proportion of the loin, like those of the rib, was found in the GL genotype (1.10 kg and 9.20%, respectively) and the lowest in the group (M × GL) × OD (1.03 kg and 8.25%, respectively). The difference in the average proportions of the loin between these two genotypes was statistically significant ($P \leq 0.05$). The respective values for the GL × OD ram lambs were 1.07 kg and 8.74%.

Although the average weight of the rack of all three genotypes was the same (i.e. 2.28 kg, 2.24 kg and 2.20 kg for GL, GL × OD and (M × GL) × OD, respectively), the difference in the average proportion between GL

Table 5. Evaluation of the tissues in the right leg

Tissue		Average (n = 18)	Genotype GL (A) (n = 6)	GL × OD (B) (n = 6)	(M × GL) × OD (C) (n = 6)	F- test
Muscle (kg)	$\bar{x}$	1.30	1.27	1.34	1.29	0.64
	$s_{\bar{x}}$	0.028	0.034	0.064	0.048	
Muscle (%)	$\bar{x}$	65.65	64.66 ^{B}	67.60 ^{AC}	64.68 ^{B}	13.27**
	$s_{\bar{x}}$	0.419	0.526	0.337	0.508	
Bones (kg)	$\bar{x}$	0.55	0.55	0.54	0.55	0.03
	$s_{\bar{x}}$	0.011	0.022	0.026	0.009	
Bones (%)	$\bar{x}$	27.60	27.97	27.27	27.57	0.44
	$s_{\bar{x}}$	0.296	0.363	0.326	0.780	
Fat (kg)	$\bar{x}$	0.13	0.15 ^{b}	0.10 ^{ac}	0.16 ^{b}	7.10**
	$s_{\bar{x}}$	0.081	0.010	0.011	0.011	
Fat (%)	$\bar{x}$	6.75	7.37 ^{B}	5.13 ^{AC}	7.75 ^{B}	11.95**
	$s_{\bar{x}}$	0.358	0.288	0.554	0.338	

*a, b, c = $P \leq 0.05$
**A, B, C = $P \leq 0.01$

Table 6. Evaluation of the tissues in the right rack

Tissue		Average (n = 18)	Genotype GL (A) (n = 6)	GL × OD (B) (n = 6)	(M × GL) × OD (C) (n = 6)	F- test
Muscle (kg)	$\bar{x}$	0.73	0.73	0.75	0.71	0.33
	$s_{\bar{x}}$	0.018	0.026	0.034	0.036	
Muscle (%)	$\bar{x}$	65.21	64.44 ^{b}	66.65 ^{a}	64.54	4.85*
	$s_{\bar{x}}$	0.395	0.575	0.566	0.562	
Bones (kg)	$\bar{x}$	0.31	0.32	0.31	0.31	0.31
	$s_{\bar{x}}$	0.008	0.016	0.018	0.009	
Bones (%)	$\bar{x}$	27.98	28.27	27.54	28.11	0.44
	$s_{\bar{x}}$	0.323	0.423	0.588	0.697	
Fat (kg)	$\bar{x}$	0.08	0.08	0.07	0.08	2.33
	$s_{\bar{x}}$	0.004	0.006	0.006	0.007	
Fat (%)	$\bar{x}$	6.81	7.28	5.80	7.35	3.41
	$s_{\bar{x}}$	0.310	0.432	0.552	0.427	

*a, b, c = $P \leq 0.05$

(19.05%) and (M × GL) × OD (17.66%) was statistically highly significant ($P \leq 0.01$) and between GL × OD (18.44%) and (M × GL) × OD (17.66%) statistically significant ($P \leq 0.05$). The average proportions of the rack found in the present study are lower than those reported by Perret *et al.* (1986), but comparable with data reported by Fantová and Čislíkovská (1991) and Ochodnická *et al.* (1992) in their genotypes.

The differences in the average weight and average proportion of the middle neck and scrag between the genotypes were not statistically significant. The average proportion of the middle neck was highest in the GL × OD genotype and lowest in GL (i.e. 8.22% and 8.03%, respectively). The proportion of the scrag in the GL, GL × OD and (M × GL) × OD genotypes was 6.31%, 5.94% and 6.32%, respectively. The highest average weight and proportion of the flank were found in (M × GL) × OD (2.56 kg and 20.62%, respectively); the differences from the average weight in the genotype GL (2.00 kg), and from the average proportions of the flank in GL and in GL × OD (16.72% and 18.40%) were statistically highly significant ($P \leq 0.01$). The difference in the average proportion of the flank between the GL and GL × OD groups was also statistically highly significant ($P \leq 0.01$).

We can conclude from the evaluation of tissue proportions in the right leg (Table 5) and tissue proportions in the right rack (Table 6) that in both cases the highest proportions of the muscle were reported in the GL × OD group (67.60% and 66.65%, respectively); the differences in the muscle proportion in the leg between GL (64.66%) and (M × GL) × OD (64.68%) were statistically highly significant ($P \leq 0.01$). The difference in the average proportions of rack muscle between GL × OD and GL (64.44%) was statistically significant ($P \leq 0.05$). The proportions of leg muscle found in the present study ranged between 64.66% and 67.60%, depending on the respective genotype, and are higher than those reported by Sanz *et al.* (1995), but lower than the data of Tafta and Murat (1997). As for the average weights and average proportions of the bone tissue in these two cuts, no statistically significant differences between the groups were found. The average bone proportions of both the right leg and the right rack were lowest in the GL × OD group (27.27% and 27.54%, respectively), in both cases the highest average proportion of the bones was observed in the GL group (27.97% and 28.27%).

Investigations of the average proportion of fat showed that the GL × OD group had the lowest, that means the most favourable proportions of fat in the right leg and right rack, (i.e. 5.13% and 5.80%, respectively), and the group (M × GL) × OD the highest, i.e. 7.75% and 7.35%, respectively. The values for the genotype GL were the same as for (M × GL) × OD in both cases, i.e. 7.37% and 7.28%. Statistically highly significant differences ($P \leq 0.01$) in the average proportions of fat in the right leg were found between GL × OD and (M × GL) × OD and between GL × OD and GL. As for the right rack, no statistically significant difference was determined between the genotypes although the differences between GL × OD and (M × GL) × OD and between GL × OD and GL were on the margin of significance. The average proportions of fat in the leg and rack in all three genotypes were lower than those reported by Sanz *et al.* (1995) and Ochodnická *et al.* (1992); on the other hand, the data reported by Gajdošík and Moravčík (1993) on the average proportions of fat both in the rack and in the leg in their genotypes were lower than our data.

Table 7 shows the evaluation of the basic quality parameters by the analysis of the *musculus triceps brachii*. The average proportions of dry matter were the same in all three genotypes, ranging between 23.52% and 23.60%. The average contents of dry matter in all three genotypes were the same as the values reported by Lawrie (1979), but lower than the data of Fantová and Čislíkovská (1991). The content of intramuscular fat ranged between 2.54% and 3.56%, it was lowest in GL and highest in (M × GL) × OD, the difference between these groups being statistically significant ($P \leq 0.05$). The average content of intramuscular fat in GL (2.54%) corresponds with the value given by Heylen *et al.* (1997). The average protein content was highest in GL (19.39%), the values in GL × OD and (M × GL) × OD were insignificantly lower (18.96% and 18.79%, respectively). The average protein content in all three genotypes found by the authors of this paper is lower than the data reported by Swartvagherová *et al.* (1996) and Slaná *et al.* (1980).

The (M × GL) × OD group had the lowest ash content (0.97%), and GL the highest (1.05%), the difference between these two groups was statistically significant ($P \leq 0.05$). The average ash content in GL × OD was 1.00%, and is higher than the value reported by Lawrie (1979) for the rack. Based on the evaluation of the average energy

Table 7. Evaluation of the basic quality parameters of the *m. triceps brachii*

Characteristic		Average (n = 18)	Genotype GL (A) (n = 6)	GL × OD (B) (n = 6)	(M × GL) × OD (C) (n = 6)	F-test
Dry matter (%)	$\bar{x}$	23.55	23.52	23.52	23.60	0.02
	$s_{\bar{x}}$	0.201	0.313	0.442	0.346	
Intramuscular fat (%)	$\bar{x}$	3.11	2.54 ^{c}	3.24	3.56 ^{a}	5.97*
	$s_{\bar{x}}$	0.156	0.233	0.209	0.200	
Protein (%)	$\bar{x}$	19.05	19.39	18.96	18.79	0.44
	$s_{\bar{x}}$	0.258	0.233	0.706	0.298	
N-content (%)	$\bar{x}$	3.04	3.10	3.03	3.01	0.44
	$s_{\bar{x}}$	0.041	0.037	0.112	0.047	
Ash (%)	$\bar{x}$	1.00	1.05 ^{c}	1.00	0.97 ^{a}	6.42**
	$s_{\bar{x}}$	0.012	0.020	0.006	0.020	
Energy value in the original matter (kJ/100 g)	$\bar{x}$	529.96	522.85	515.05	549.47	2.16
	$s_{\bar{x}}$	7.588	9.714	15.709	11.833	

*a, b, c = $P \leq 0.05$

**A, B, C = $P \leq 0.01$

Table 8. Evaluation of the other quality parameters of the *m. triceps brachii*

Characteristic		Average (n = 18)	GL (A) (n = 6)	GL × OD (B) (n = 6)	(M × GL) × OD (C) (n = 6)	F- test
Myoglobin (mg in 1 g of muscle)	$\bar{x}$	1.48	1.33	1.59	1.50	0.89
	$s_{\bar{x}}$	0.082	0.135	0.162	0.129	
Water holding capacity (%)	$\bar{x}$	4.45	4.38 ^{b}	5.42 ^{aC}	3.55 ^{B}	14.20**
	$s_{\bar{x}}$	0.229	0.332	0.237	0.138	
Reflectance	$\bar{x}$	7.17	7.68	6.92	6.90	3.32
	$s_{\bar{x}}$	0.161	0.224	0.241	0.269	
Hydroxyproline (mg in 100 g of muscle)	$\bar{x}$	0.24	0.22	0.24	0.25	0.75
	$s_{\bar{x}}$	0.012	0.021	0.023	0.017	
Collagen (mg in 100 g muscle)	$\bar{x}$	1.78	1.63	1.84	1.88	0.75
	$s_{\bar{x}}$	0.088	0.157	0.175	0.129	
Elastin (mg in 100 g of muscle)	$\bar{x}$	0.33	0.31	0.35	0.35	0.75
	$s_{\bar{x}}$	0.016	0.029	0.033	0.024	
Connective tissue (mg in 100 g of muscle)	$\bar{x}$	2.12	1.94	2.19	2.23	0.75
	$s_{\bar{x}}$	0.104	0.186	0.207	0.153	

*a, b, c = $P \leq 0.05$
**A, B, C = $P \leq 0.01$

value in the original matter, ranging between 515.05 and 549.47 kJ/100 g, no statistical differences between the genotypes were found. The values found in the GL and GL × OD groups were basically the same (522.85 and 515.05 kJ/100 g, respectively), in (M × GL) × OD it was 549.47 kJ/100 g.

Table 8 gives the results of evaluation of the other quality parameters showing that the highest level of myoglobin was found in the GL × OD group (1.59 mg in 1 g of muscle) and the lowest in GL (1.33 mg in 1 g of muscle). The differences between the groups were not statistically significant. On the other hand, a statistically highly significant difference ($P \leq 0.01$) was found in the average water-holding capacity between the groups GL × OD and (M × GL) × OD (i.e. 5.42% and 3.55%), and a statistically significant difference ($P \leq 0.05$) between GL and GL × OD (4.38% and 5.42%). The highest value of reflectance, i.e. the lightest muscle, was found in the group GL (7.68); GL × OD and (M × GL) × OD showed the same values (i.e. 6.92 and 6.90, respectively). The average levels of hydroxyproline, a parameter of the content of connective tissue in the muscle, were the same in GL × OD and (M × GL) × OD (0.24 and 0.25 mg in 100 g of muscle, respectively). This content was lowest in the GL group (0.22 mg in 100 g of muscle), but no significant effect of the genotype on this parameter was observed. Table 8 shows that the level of hydroxyproline found in the present paper was subsequently reflected in the weight of collagen, elastin and connective tissue; no statistically significant effect of the genotypes on the level of these substances was found.

CONCLUSION

Based on the estimations of growth ability, the effect of the fathers of the Oxford Down meat breed was proved. The growth of the (M × GL) × OD ram lambs was the most intensive, the growth of the GL × OD and (M × GL) × OD ewe lambs was found to be the same. As indicated by the basic parameters of carcass analyses, no significant effect of the respective genotypes on these parameters was observed. However, the estimation of the proportions of valuable parts of dressed carcass indicated that the GL genotype had the highest proportions of leg, rib, loin and rack. Estimations of the proportions of the respective tissue in the right leg and right rack showed the highest proportion of muscle and the lowest proportion of fat in the GL × OD genotype while the values in the genotypes GL and (M × GL) × OD were the same. Analyses of the basic quality parameters showed the lowest proportion of intramuscular fat and the highest proportion of protein and ash in the GL genotype.

REFERENCES

Craplet C., Thibier M. (1980): Le Mouton. Édition Vigot, Paris. 428 pp.
Fantová M., Čislíkovská H. (1991): Vliv plemenné příslušnosti na kvalitu masa jehňat odchovaných na společné pastvě s matkami. Živoč. Výr., 36, 633–640.
Gajdošík M., Moravčík F. (1993): Hodnotenia mäsovej užitkovosti jemnovlnných plemen v časovom horizonte 15 ro-

kov. In: Sbor. Ref. Produkcia, kvalita, zpracovanie a odbyt ovčího mäsa na Slovensku. Výskumný ústav ov-čiarský, Trenčín. 38–42.

Gut A. (1991): Wartosc rzezna tryczkow krajowych ras i cterech syntetycznych linii owiec. Práce Kom. Nauk Rolnicz., *71*, 27–44.

Heylen K., Suess R., Freudenreich P., Wicke M., Lengerken G. (1997): Influence of intramuscular fat on meat quality. In: Book of Abstracts of the 48th Annual Meeting of the EAAP, Wien. 291.

Horák F. a kol. (1999): Chov ovcí. Nakl. Brázda, s. r. o. , Praha. 36 s.

Horák F., Pinďák A. (1997): Chov ovcí a koz historie – současnost – perspektiva. SCHOK v ČR, Brno. 15 s.

Kališ M., Čapistrák A., Margetín M. (1994): Doterajšie poznatky s kontrolou masné užitkovosti oviec. In: Sbor. Ref. Predpoklady efektivního chovu oviec v súčastnosti. Výskumný ústav ovčiarský, Trenčín. 60–64.

Kleczek C., Skrzyzala I. (1997): Efektywnosz odchowu i tuczu jagniat przy róznych sposobach żywenia. In: Sbor. Mezinár. Konf. Organizacja hodowli oraz ekonomiczne uwarunkowania chowu owiec w gospodarce rynkowej w Polsce, Czechach i Slowacji. 25. 9. 1997, Bielsko-Biala, Polska. 91– 94.

Kuchtík J., Žižlavská S., Horák F., Kučera J. (1997): Růstová schopnost a jatečná hodnota jehňat odchovaných na společné pastvě skotu a ovcí. Živoč. Výr., *42*, 293–298.

Lawrie R.A. (1979): Meat Science. Pergamon International Librare. U.S.A. 420 pp.

Mátlová V. (1999): Sheep raising in wet mountain areas of Czech Republic: a three – level system. In: Book of Abstracts of the 50th Annual Meeting of the EAAP, Zurich. 223.

Ochodnická K., Kačincová A., Palanská O. (1992): Vplyv senáže na jatočnú hodnotu a kvalitu mäsa jahniat. Živoč. Výr., *37*, 463–473.

Perret G., Libert D., Roques J.M., Berny F. (1986): Essai de croisement terminal dans le Centre-Ouest. Comparaison de 4 races béliers avec des agneaux élevés a l'herbe ou en bergerie. 11-ème journées de la recherche ovine et caprine. I.N.R.A., 197–209.

Ploumi K., Christodoulu V., Vainas E., Giouzelyannis A., Katanos J. (1997): Performance analysis of the Florina (Pelagonia) sheep for lamb production and growth. Živoč. Výr., *42*, 391–397.

Pour M., Vrchlabský J., Ivánek J., Pulkrábek J., Smolák M. (1998): Prováděcí projekt zavedení objektivní klasifikace jatečných zvířat v České republice. MZe ČR, Praha. 8 s.

Puntila M.L., Fredlund M. (1992): Nordiska Fardagar Korsningsforok med Oxford Down ras. Farskotsel, *72*, 4–5.

Sanz M.R., Prieto I., Gil F., Fonolla J. (1995): Environmental temperature: composition and conformation of the carcasses of preruminant kid goats and lambs. Options Mediterraneens, No. 27, 191–195.

Scales G.H., Bray A.R., Baird D.B., O'Connel D., Knight T.L. (2000): Effect of sire breed on growth, carcass and wool characteristics of lambs born to Merino ewes in New Zealand. New Zeal. J. Agric. Res., *43*, 93–100.

Slaná O., Skřivan M., Štolc L. (1980): Výsledky analýzy svaloviny beránků z intenzivního výkrmu. Živoč. Výr., *25*, 311–318.

Speedy A.W. (1989): Sheep Production. Longman Handbooks in Agriculture. U.S.A. 77–89.

Stopka V., Ochodnický D., Margetínová J., Swartvagherová K., Margetín M. (1996): Vplyv rôznej úrovne výživy na produkčné parametre oviec. Živoč. Výr., *41*, 69–74.

Swartvagherová K., Ochodnický D., Margetínová J., Palanská O., Čerešňáková Z. (1996): Obsah bielkovin a zastúpenie aminokyselín v *m. longissimus dorsi* jahniat rôznych genotypov. Živoč. Výr., *41*, 87– 89.

Tafta V., Murat L. (1997): Main quantitative and qualitative indexes for the carcass of half-breeds F_1 (Texel × Merinos) and (Ile de France × Merinos) fattened intensively. In: Book of Abstracts of the 48th Annual Meeting of the EAAP, Wien. 291.

Vrchlabský J., Veselá V. (1985): Laboratorní metodiky. Výzkumný ústav pro chov skotu, Rapotín. 43 s.

Received: 00–11–29

Accepted after corrections: 01–10–01

Corresponding Author:

Dr. Ing. Jan Kuchtík, Mendelova zemědělská a lesnická univerzita v Brně, Zemědělská 1, 613 00 Brno, Česká republika

Tel. +420 5 45 13 32 30, fax +420 5 45 21 11 28, e-mail: kuchtik@mendelu.cz

The effect of age of pre-ruminant calves on digestibility of organic nutrients and nitrogen retention

Vliv věku telat na stravitelnost organických živin a retenci dusíku

D. Vrzalová[1], J. Zelenka[2], M. Šustala[1], E. Fajmonová[2]

[1]*Research Institute of Animal Nutrition, Ltd., Pohořelice, Czech Republic*
[2]*Mendel University of Agriculture and Forestry, Brno, Czech Republic*

ABSTRACT: Apparent digestibility of organic nutrients and nitrogen retention were studied in 23 three-day balance periods with five male calves of Czech Red Pied breed at the age of 9 to 91 days. Animals were fed on milk replacer *ad semi-libitum*. The digestibility and nitrogen retention were determined using the chromic oxide indicator method. The average values of digestibility were as follows: crude protein (CP) 0.642 ± 0.0162, crude fat (CF) 0.776 ± 0.0104, nitrogen-free extract (NFE) 0.940 ± 0.0027. Digestibility of nutrients under study changed highly significantly ($P < 0.01$) with the age of calves. The dependence of determined values on age was expressed by the 2nd degree parabola equations with the maximum values on Days 62, 67 and 74 for CF, NFE and CP, respectively. The most marked increase was observed in the first weeks of experiment. Percentage of nitrogen retention changed highly significantly ($P < 0.01$) with age and the dependences expressed by the concave parabola equation achieved their maxima on Days 81 and 63 for nitrogen consumed and digested, respectively.

Keywords: calves; effect of age; digestibility of organic nutrients; nitrogen retention

ABSTRAKT: Vliv věku na bilanční stravitelnost organických živin a na retenci dusíku byl sledován u pěti býčků českého strakatého plemene od 9. do 91. dne věku. Telata byla krmena mléčnou krmnou směsí *ad semi-libitum*. Stravitelnost byla zjišťována indikátorovou metodou s oxidem chromitým ve 23 třídenních bilančních periodách. V pokusu byla zjištěna průměrná stravitelnost dusíkatých látek 0,642 ± 0,0162, tuku 0,776 ± 0,0104 a bezdusíkatých látek výtažkových 0,940 ± 0,0027. Stravitelnost všech sledovaných živin se s věkem telat vysoce průkazně měnila ($P < 0{,}01$). Závislost koeficientů stravitelnosti tuku, bezdusíkatých látek výtažkových a dusíkatých látek na věku byla vyjádřena parabolami 2. stupně s maximem v 62., 67. a 74. dni věku. Nejvýraznější vzestup byl pozorován v prvních týdnech pokusu. Také využití dusíkatých látek se vysoce průkazně měnilo ($P < 0{,}01$); konkávní parabola vyjadřující závislost retence přijatého dusíku dosáhla maxima 81. den a dusíku stráveného 63. den života.

Klíčová slova: telata; vliv věku; stravitelnost organických živin; retence dusíku

INTRODUCTION

Digestibility is influenced by many factors and changes with the age of animals. Enzymatic secretion in the calf's immature digestive system is limited up to one month of age, restricting digestion of carbohydrates, fat and protein. After three weeks of age most calves digested relatively well all types of milk substitutes (Longenbach and Heinrichs, 1998). Cruywagen *et al.* (1990) found in two-to-four day old calves fed a milk replacer the values of apparent digestibility of crude protein and fat equal to 0.84 and 0.87, respectively. Vajda (1991) estimated apparent digestibility of nutrients in healthy calves and compared the measured values with data obtained in animals suffering from diarrhoea at the age of two and three weeks. The apparent digestibility of crude protein in healthy calves was found to be 0.935, fat 0.949 and carbohydrates 0.972. Edwards and Barre (1977) found that the respective values of carbohydrate digestibility were 0.819–0.888 and 0.857–0.928 at 4–5 and 9–10 weeks of age.

Supported by the Ministry of Education, Youth and Sports of the Czech Republic (Project MSM 432100001).

Guilloteau *et al.* (1986) recorded the values of nitrogen digestibility in the terminal ileum of calves to be 0.92–0.94, 0.83–0.87 and 0.75–0.88 with skim-milk powder protein, fish and soybean diets, respectively. Tukur *et al.* (1995) compared the effect of protein source in milk substitute on the apparent nitrogen digestibility in calves. They determined the values 0.86, 0.88 and 0.95 for milk replacer with soybean, lupine and only skim milk protein, respectively. Lalles *et al.* (1996) determined the apparent digestibility of soybean protein between 0.59 and 0.84 in pre-ruminant calves. Ulbrich *et al.* (1987) found out that digestibility of crude fat in calves fed on the whole milk was 0.91 and only 0.66 to 0.70 in calves fed on different fat mixtures added to milk replacer.

Terosky *et al.* (1997) administered to calves diets varying in the ratio of dried skim milk to whey protein concentrates during Weeks 2, 4, 6, and 8 and they found out that apparent digestibility of crude protein increased with age.

Akinyele and Harshbarger (1983) determined in two experiments with calves at the age of 10 to 15 days the following values of apparent digestibility for milk protein and soybean protein concentrate replacers: crude protein 0.805–0.901 and 0.566–0.572, crude fat 0.815–0.889 and 0.550–0.559, respectively. At the age of 30 to 35 days, a significant improvement was observed both for crude protein (0.929–0.952 and 0.633–0.818) and for crude fat (0.961– 0.975 and 0.761–0.906, respectively). Experiments of Bedö (1980) confirmed that the amount of consumed crude fat influenced markedly the digestibility of the crude fat. The values of digestibility were estimated at the age of 3, 5, 7, 9 and 11 weeks. At a constant daily dose of 139 or 208 g of fat the values recorded at the age of 5 and 7 weeks were practically the same and thereafter began to decrease. At the daily dose of 307 g, the digestibility increased up to the age of 7 weeks and thereafter began to decrease. Spanski *et al.* (1997) determined apparent digestibility of nutrients in calves at 6, 8 and 10 weeks of age. Digestibility of crude protein increased highly significantly with the age while the digestibility of ether extract did not change significantly. Retained nitrogen, expressed as a percentage of nitrogen intake, also increased linearly with age (26.7, 29.4, and 35.1 for Weeks 6, 8 and 10, respectively).

The objective of this experiment was to determine how the digestibility of organic nutrients and nitrogen retention varied during the period of fattening of pre-ruminant calves. Until now, the studies on nutrient digestibility have been performed only several times within the first months of age and the intervals between individual estimations were relatively long (Edwards and Barre, 1977; Bedö, 1980; Akinyele and Harshbarger, 1983; Terosky *et al.*, 1997; Spanski *et al.*, 1997). For an exact evaluation of the effect of age it is necessary to make a great number of metabolic experiments in short time intervals during a longer period of life.

MATERIAL AND METHODS

The effect of age on apparent digestibility of organic nutrients and nitrogen retention were studied within 23 three-day balance periods from Day 9 of age to Day 91 using five male calves of Czech Red Pied breed.

Calves were fed on a practical-type commercial milk replacer containing spray-dried skim milk, buttermilk and whey, soybean-protein concentrate HP 100, lard and feed additive premix with addition of 5% of wheat starch. Milk replacer containing 206 g crude protein, 154 g crude fat, and 558 g nitrogen-free extract per 1 kg of dry matter was supplied *ad semi-libitum* three times a day.

Digestibility and retention of nitrogen were estimated using the chromic oxide indicator method. The faeces were collected every 24 h and samples were prepared from the pooled excrements collected within a period of 3 days. In all the three-day balance periods it proceeded one 24-h period in which the urine was quantitatively collected.

The content of crude protein in feed, freeze-dried faeces and urine was estimated using the Kjeldahl method, crude fat content was determined by extraction with diethylether and content of NFE was calculated using analytical data (Decree No. 222/1996 of the Czech Ministry of Agriculture). The content of chromic oxide was determined by means of the atomic absorption spectrophotometry (Williams *et al.*, 1962).

This experiment was the same as that in which the effect of age of calves on starch digestibility was studied (Vrzalová and Zelenka, 2001). For details about the materials and methods see the paper mentioned above.

The regression analysis of determined values was performed according to Snedecor and Cochran (1967).

RESULTS AND DISCUSSION

The dependence of the body weight of calves in kg (W) on age in days (t) was expressed by the exponential function (Brody, 1945)

$$W = 40.7 \times e^{0.0112\,t}$$

($r = 0.994$; $P < 0.01$; e = base of natural logarithms)

and the dependence of dry matter intake in kg on age

$$W = 0.448 \times e^{0.0194\,t}\ (r = 0.969;\ P < 0.01)$$

In the first balance period one calf suffered from diarrhoea and for that reason the measured values were not included in this analysis. The average values of digestibility of crude protein (CP), crude fat (CF) and nitrogen free extract (NFE) in the trial were 0.642 ± 0.0162, 0.776 ± 0.0104 and 0.940 ± 0.0027 (mean ± standard error of the mean, $n = 114$), respectively.

The digestibility of all nutrients under study varied with the age. The dependence of determined values (Y) on age

Table 1. Effect of age on the apparent digestibility of nutrients

Calf no.	Mean ± standard error of the mean	$Y = a + bX + cX^2$						
		a	*b*	*c*	*r*	*P*	$X_{extr.}$	$Y_{extr.}$
Digestibility of crude protein								
1	0.661 ± 0.0375	0.132	0.0187	–0.00013625	0.730	< 0.05	68.8	0.776
2	0.707 ± 0.0201	0.382	0.0125	–0.00010023	0.813	< 0.01	62.6	0.774
3	0.570 ± 0.0445	–0.041	0.0210	–0.00014040	0.890	< 0.01	74.8	0.745
4	0.652 ± 0.0326	0.408	0.0048**	–	0.721	> 0.05	–	–
5	0.624 ± 0.0373	0.119	0.0155	–0.00009178	0.851	< 0.05	84.6	0.776
1 – 5	0.642 ± 0.0162	0.151	0.0167	–0.00011393	0.771	< 0.01	73.3	0.763
Digestibility of crude fat								
1	0.779 ± 0.0238	0.669	0.0021*	–	0.446	> 0.05	–	–
2	0.705 ± 0.0265	0.611	0.0019	–	0.348	> 0.05	–	–
3	0.805 ± 0.0135	0.641	0.0072	–0.00006401	0.615	< 0.05	56.3	0.844
4	0.794 ± 0.0238	0.406	0.0154	–0.00012680	0.741	< 0.01	60.8	0.874
5	0.792 ± 0.0220	0.435	0.0139	–0.00011302	0.774	< 0.01	61.7	0.865
1 – 5	0.776 ± 0.0104	0.508	0.0105	–0.00008465	0.554	< 0.01	61.9	0.832
Digestibility of nitrogen-free extract								
1	0.943 ± 0.0079	0.839	0.0042	–0.00003468	0.591	< 0.05	60.2	0.965
2	0.956 ± 0.0029	0.912	0.0017	–0.00001313	0.779	< 0.01	63.7	0.965
3	0.926 ± 0.0073	0.837	0.0034	–0.00002583	0.700	< 0.05	65.4	0.947
4	0.931 ± 0.0048	0.859	0.0026	–0.00001875	0.774	< 0.05	68.5	0.947
5	0.947 ± 0.0031	0.923	0.0005**	–	0.752	> 0.05	–	–
1 – 5	0.940 ± 0.0027	0.872	0.0025	–0.00001870	0.587	< 0.01	66.7	0.955

X = age in days
Y = apparent digestibility of CP
a, b, c = parameters of equation
r = correlation coefficients
P = significance of the deviation from linearity
significance of linear regression $^*P < 0.05$, $^{**}P < 0.01$

of calves in days (X) within the period of Day 9 to Day 91 was expressed by means of linear regression equations and the 2nd degree parabola equations. The reduction in the sum of squares of deviations was tested against the mean square remaining after curvilinear regression by F-test (Snedecor and Cochran, 1967). In case that the reduction is significant, parameters a, b and c of parabola equation are included in Table 1. If the deviation from linearity is insignificant, Table 1 contains parameters a and b of linear regression.

When the dependence of CP digestibility on age was expressed by linear regression, the values highly significantly ($P < 0.01$) increased in all calves similarly like in experiments of Akinyele and Harshbarger (1983), Spanski *et al.* (1997) and Terosky *et al.* (1997). In four animals the dependence was significantly precisely described by the concave parabola equation (Table 1). When the values measured in all calves were involved, the apparent CP digestibility varied within the period of Day 9 to Day 91 highly significantly ($P < 0.01$) according to the parabola equation with the maximum on Day 74 (Figure 1).

We observed lower coefficients of CP digestibility than Cruywagen (1990), Vajda (1991), and Tukur *et al.* (1995). This could be caused by a relatively high content of soybean protein in the milk replacer used in our experiment (Guilloteau, 1986; Lalles *et al.*, 1996). With the increasing age calves are able to use soybean-based replacers more effectively (Akinyele and Harshbarger, 1983).

Similarly like in experiments performed by Longenbach and Heinrichs (1988) the most marked increase in CP digestibility was observed in the first weeks of observation. In the period of Day 9 to Day 28 the dependence on age was expressed by the equation

$$Y = -0.058 + 0.0247\,X;\ r = 0.647;\ P < 0.01$$

i.e. the increase was 2.47 per cent per day.

Within the period of Day 9 to Day 91, crude fat digestibility changed with increasing age in accordance with the linear equation

$$Y = 0.677 + 0.0020\,X;\ r = 0.412;\ P < 0.01$$

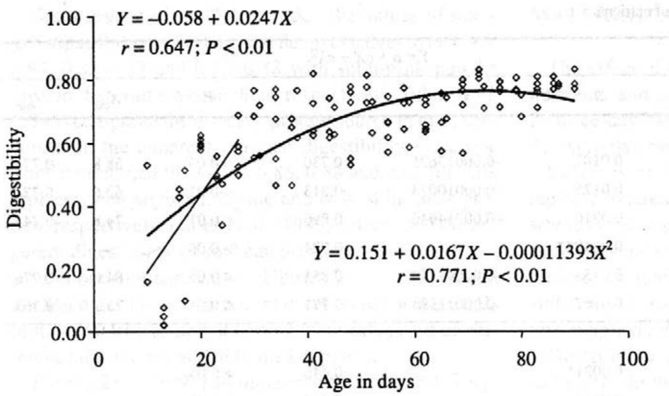

Figure 1. Apparent digestibility of crude protein

and the parabola equation with the maximum on Day 62 (Figure 2). The deviation from linearity was highly significant ($P < 0.01$). Lower fat digestibility could be associated with contents of soybean and added fat in milk replacer (Akinyele and Harshbarger, 1983; Ulbrich *et al.*, 1987; Bedö, 1980).

In the period of Days 9 to 28 a significant ($P < 0.05$) daily increase in fat digestibility by 0.0129 was recorded (Figure 2). An increase in fat digestibility observed within the first weeks of age corresponded with data recorded by Akinyele and Harshbarger (1983) while its later decrease corroborated the conclusions published by Bedö (1980).

In all calves the NFE digestibility increased significantly ($P < 0.01$); in four of them the deviation from linearity was significant. When including the values measured in all animals, the dependence of apparent NFE digestibility on age in days increased within the period of Days 9 to 91 in accordance with the linear equation

$$Y = 0.910 + 0.0006\ X;\ r = 0.495;\ P < 0.01$$

and the parabola equation with the maximum on Day 67 (Table 1). Changes associated with age were similar to those observed in experiments performed by Edwards and Barre (1977).

The quantitative urine collection in the 1st balance period was unsuccessful because of technical reasons. Retention of nitrogen significantly ($P < 0.01$) increased with age. The correlation with the age within the period of Days 12 to 91 was expressed by means of linear regression equations

$$Y = 0.362 + 0.0048\ X;\ r = 0.721;\ P < 0.01 \text{ and}$$

$$Y = 0.712 + 0.0035\ X;\ r = 0.343;\ P < 0.01$$

for the retention of consumed and digested nitrogen, respectively. Changes occurring with age were more accurately ($P < 0.01$) described by means of parabolas

$$Y = 0.165 + 0.0139\ X - 0.000087\ X^2;\ r = 0.766;\ P < 0.01;\ X_{extr.} = 80.1;\ Y_{extr.} = 0.723 \text{ and}$$

$$Y = 0.333 + 0.0210\ X - 0.000167\ X^2;\ r = 0.474;\ P < 0.01;\ X_{extr.} = 62.8;\ Y_{extr.} = 0.993, \text{ resp.}$$

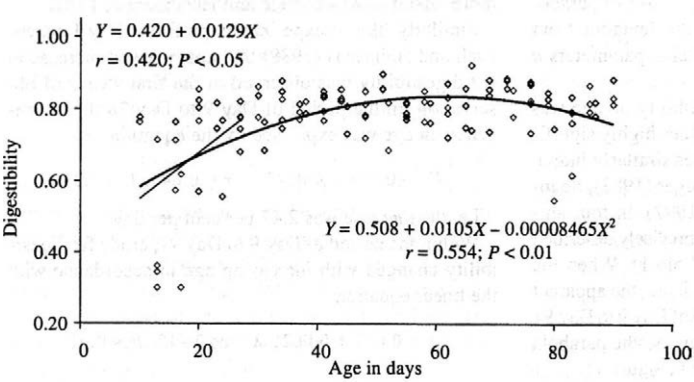

Figure 2. Apparent digestibility of crude fat

On average, the calves retained 0.615 ± 0.0142 of consumed and 0.895 ± 0.0215 of digested nitrogen. Changes in the retention of consumed nitrogen occurring with increasing age were similar to those observed by Spanski *et al.* (1997); their absolute values were, however, higher in our experiment. Changes in the retention of digested nitrogen were smaller, their variability was lower and the maximum value was reached earlier than that of consumed nitrogen.

REFERENCES

Akinyele I.O., Harshbarger K.E. (1983): Performance of young calves fed soybean protein replacers. J. Dairy Sci., *66*, 825–832.

Bedö S. (1980): Der Einfluss von verschiedenen Fett- und eiweisshaltigen Futtermitteln auf die Verdaulichkeit der Roh-nährstoffe bei jungen Kälbern. Arch. Tierernähr., *30*, 557–571.

Brody S. (1945): Bioenergetics and Growth. New York, Reinhold Publishing Corporation. 1023 pp.

Cruywagen C.W., Brisson G.J., Tremblay G.F., Meissner H.H. (1990): Effect of curd suppression in a milk replacer on physiological parameters in calves. 1. Digestibility of nutrients and body mass gain. S. Afr. J. Anim. Sci., *20*, 234–238.

Decree No. 222/1996 of the Czech Ministry of Agriculture, determining methods of sampling, laboratory tests of feeds, feed additives and premixes and methods of preservation of samples liable to spoilage (Vyhláška Ministerstva zemědělství ČR č. 222/1996 Sb., kterou se stanoví metody odběru vzorků, metody laboratorního zkoušení krmiv, doplňko-vých látek a premixů a způsob uchovávání vzorků podlé-hajících zkáze).

Edwards D.G., Barre P. (1977): The digestibility of wheat starch and maize starch by the pre-ruminant calf. Proc. Nutr. Soc., *36*, 144A.

Guilloteau P., Toullec R., Grongnet J.F., Patureau-Mirand P., Prugnaud J., Sauvant D. (1986): Digestion of milk, fish and soya-bean protein in the preruminant calf: flow of digesta, apparent digestibility at the end of the ileum and amino acid composition of ileal digesta. Brit. J. Nutr., *55*, 571–592.

Lalles J.P., Tukur H.M., Toullec R., Miller B.G. (1996): Analytical criteria for predicting apparent digestibility of soybean protein in preruminant calves. J. Dairy Sci., *79*, 475–482.

Longenbach J.I., Heinrichs A.J. (1998): A review of the importance and physiological role of curd formation in the abomasum of young calves. Anim. Feed Sci. Technol., *73*, 85–97.

Snedecor G.W., Cochran W.G. (1967): Statistical Methods. 6th ed. Ames, The Iowa State University Press. 593 pp.

Spanski N.A., Drackley J.K., Davis C.L., Jaster E.H. (1997): Utilization of supplemental triglycerides or free fatty acids by calves from 4 to 10 weeks of age. J. Dairy Sci., *80*, 573–585.

Terosky T.L., Heinrichs A.J., Wilson L.L. (1997): A comparison of milk protein sources in diets of calves up to eight weeks of age. J. Dairy Sci., *80*, 2977–2983.

Tukur H.M., Pardal P.B., Formal M., Toullec R., Lalles J.P., Guilloteau P. (1995): Digestibility, blood levels of nutrients and skin responses of calves fed soybean and lupine proteins. Reprod. Nutr. Dev., *35*, 27–44.

Ulbrich M., Eibicht R., Geissler C., Boldt E., Hoffmann M. (1987): Einfluss von Emulgatoren und Fettmischungen auf die Verdaulichkeit und den Ansatz von Fettsäuren bei Kälbern. Arch. Anim. Nutr., Berlin, *37*, 651–664.

Vajda V. (1991): Mliečna výživa a využiteľnosť živín u klinicky zdravých a hnačkujúcich teliat. Vet. Med. (Praha), *36*, 449–458.

Williams C.H., David D.J., Iismaa O. (1962): The determination of chromic oxide in faeces samples by atomic absorption spectrophotometry. J. Agric. Sci., *59*, 381–385.

Vrzalová D., Zelenka J. (2001): The effect of age of pre-ruminant calves on starch digestibility. Czech J. Anim. Sci., *46*, 310–312.

Received: 01–07–09

Accepted after correction: 01–10–19

Corresponding Author:

Prof. Ing. Jiří Zelenka, CSc., Mendelova zemědělská a lesnická univerzita, Zemědělská 1, 613 00 Brno, Česká republika

Tel. +420 5 45 13 31 59, fax +420 5 45 13 31 99, e-mail: zelenka@mendelu.cz

Effect of different ways of improvement of feeding rations for piglets

Vliv různých způsobů úpravy krmných dávek pro selata

M. Domaćinović, Z. Steiner, I. Bogut, P. Mijić, D. Kralik[1]

University of J. J. Strossmayer in Osijek, Faculty of Agriculture, Osijek, Croatia

ABSTRACT: Because of the specific structure of pigs' digestive tract, especially in baby pigs, animal feeds must be composed of highly concentrated digestible nutrients of high quality. There are numerous investigations to find the ways of increasing nutritive and energetic values of diets for piglets. One of the ways is to include different biostimulative substances in feeding rations. On the other hand, there is a possibility of preparing some components and complete feeding rations of higher quality. Since both the previously mentioned ways are scientifically based, the purpose of our investigation was to test the individual impact of the added enzyme(s) (experimental group I), thermal process of micronization of some feed ingredients in feeding rations (experimental group III) as well as joint effect of enzymes and thermally processed feed for piglets weanlings (experimental group II). The results of our investigations are as follows: if the quantity of feeding rations was consumed at approximately the same level in both experimental groups and the control group, better feed conversion was determined in experimental groups (the best results were obtained in experimental group II, 10% lower than the results obtained in the control group). Daily weight gain and body weight were also recorded in different phases and the results were better in all three experimental groups. Piglets from the second experimental group were characterised by the highest body weight, which was statistically significant ($P < 0.05$) in relation to experimental group I and the control group. Piglets from the second experimental group were also characterised by the highest daily weight gain, which was statistically highly significant ($P < 0.01$) in relation to experimental group I and the control group. As for the daily weight gain, positive results obtained in the third experimental group were statistically significant. Along with the positive results in production, a satisfactory health state of piglets should also be stressed. During our investigations 6 piglets were lost and 3 eliminated, which represents 5.6% of total piglets. Considering the evident positive effect of the joint impact of the two tested treatments (enzymes and micronization), these ways of treatment of feed ingredients in piglet feeding rations are justified according to our opinion, and should be used produced and commercially.

Keywords: piglets; enzyme; micronization; cereals

ABSTRAKT: Prasata, zejména selata, mají specifickou stavbu trávicího traktu, proto musejí krmiva obsahovat velmi kvalitní, vysoce koncentrované stravitelné živiny. Uskutečňují se mnohá šetření ve snaze nalézt způsoby, jak zvýšit nutriční a energetickou hodnotu krmiv pro prasata. Jedním ze způsobů je přídavek různých biostimulačních látek do krmných dávek. Existuje však i možnost přípravy některých komponentů a kompletních krmných dávek vyšší kvality. Protože se oba uvedené způsoby opírají o vědecký základ, účelem našeho šetření bylo ověřit vliv přídavku enzymu (enzymů) (1. pokusná skupina), tepelného procesu mikronizace některých živočišných složek v krmných dávkách (3. pokusná skupina) a společný účinek enzymů a tepelně zpracovaného krmiva pro odstávčata (2. pokusná skupina). Naše šetření přineslo tyto výsledky: jestliže v obou pokusných skupinách i v kontrolní skupině byla výše spotřeby krmiva přibližně na stejné úrovni, lepší konverzi krmiva jsme zjistili v pokusných skupinách (nejlepší výsledky jsme zaznamenali ve 2. pokusné skupině, o 10 % nižší než byly hodnoty v kontrolní skupině). Denní přírůstek hmotnosti a tělesnou hmotnost jsme zjišťovali v různých fázích, lepších výsledků bylo dosaženo ve všech třech pokusných skupinách. Selata ve 2. pokusné skupině měla nejvyšší tělesnou hmotnost, a to statisticky významně ($P < 0,05$), ve srovnání s 1. pokusnou skupinou a kontrolou. Selata ve 2. pokusné skupině měla také nejvyšší denní přírůstek hmotnosti, opět statisticky významně ($P < 0,01$) proti 1. pokusné skupině a kontrole. Kladné výsledky u denního přírůstku hmotnosti ve 3. pokusné skupině byly statisticky významné. Zdravotní stav selat byl uspokojivý. Během našeho šetření došlo k úhynu šesti selat a k vyřazení tří selat, což představuje 5.6 % z celkového počtu selat. Vezmeme-li v úvahu zřejmý kladný vliv společného účinku obou ověřovaných způsobů (přídavek enzymů a mikronizace), tyto způsoby úpravy krmných komponentů do krmných dávek pro selata jsou dle našeho názoru opodstatněné a měly by se komerčně vyrábět a používat.

Klíčová slova: selata; enzym; mikronizace; obilniny

INTRODUCTION

Along with poultry, pig production represents an important part of livestock production, and it has become similar to industrial production by some of its characteristics in terms of technique and technology. Besides different breeds and hybrids, modern pork production is mostly based on the latest pig hybrids characterised by improved production performance. In order to obtain better results, the production performance must be accompanied by improvement of some external factors. Among other things, greatest attention has been paid to feeding because it produces the most positive effects.

Because of the anatomico-physiological characteristics of pigs' digestive tract, especially in piglets, animal feeds must be composed of highly concentrated digestible nutrients of high quality. There are numerous investigations to find the ways of increasing nutritive and energetic values of feeding rations for piglets.

One of the ways is to include various biostimulative substances in pig feed: enzymes are very often used, either separately or in form of polyenzymatic preparations. If an enzyme is added, its concentration in the digestive tract increases. In this way, the nutrient substances are digested faster and better.

On the other hand, it is supposed that not all nutrient substances are acceptable in their original, raw form with respect to decomposition and resorption in the pig's digestive tract. Hence, the improvement can be achieved if either a feed ingredient or a complete ration are of higher quality. Our paper reports on the preparation of some components based on the thermal process of micronization by which the complex structure of molecules of nutrient substances in pig feed is changed in order to improve the efficiency of digestion of the treated pig feed.

Since both the above-mentioned ways are scientifically based, the purpose of our investigation was to find out the following: firstly, to which way of feeding the piglets react better and secondly, whether both simultaneously applied ways act synergistically on the production performance in pig-breeding.

The idea of adding some biostimulative substances (enzymes) to pig feed is based on the fact that the concentration and activity of digestive enzymes are very low in the first weeks of piglet life and that their lack in the organism will be compensated by their addition. At the very beginning enzyme supplementation was solely applied in proteolytic (protein-splitting) and amylolytic preparations, whereas today enzymes are used for the nutritive purposes in polyenzymic preparations for younger piglet categories. The advantage of this complex enzymic preparation can be seen in the even and synergistic effects on different nutrient substances of the whole ingest. In the later development of enzymology an important role is played by the description of the endosperm's cell wall of grains: it is built of non-starch polysaccharides, β-glucanases, and pentosans, see Fengler *et al.* (1988). As the piglets, especially weanlings, do not have any enzymes for the decomposition of non-starch polysaccharides, they are now added to modern enzymic preparations although it has been a limiting factor in the consumption of some cereals for a long time in the case of weaned piglets and other monogastric animals.

Up to now numerous extensive investigations have been carried out in relation to the use of both simple and complex enzymic preparations, a special emphasis should be laid on some of which – Brown (1989), Deng *et al.* (1993), Inborr *et al.* (1993), Böhme (1990), Danielsen (1994). The results obtained from the above investigations show an improvement of the elementary fattening characteristics in the experimental groups, better feed efficiency (5–10%) and higher daily weight gain (7–12%).

There is also another approach how to increase the nutritive value of (pig) feeding ration: one of the modern methods for thermal processing of some animal feed ingredients or the complete diet can be applied. The most frequently used ways of thermal processing in practice are micronization, extruding and toasting, characteristic of which is the HTST principle (high temperature, short time). Micronization, as a way of thermal improvement of animal feeds, has a complex effect. Besides its positive effect on the nutritive value, micronization inactivates thermally unstable anti-quality components, see Rotter *et al.* (1989), Teitge *et al.* (1991), Poel and Melcion (1995), and improves the treated animal feed hygienically, so Kraft (1994). The thermal process of micronization works on the principle of infrared rays, and it has been known since 1975, when the first experiment was made in Finland. Investigations carried out by Schoch and Maywald (1967) proved that the increased temperature in animal feeds caused a destruction of the crystalline structure of starch, the result of which was its gelatinization.

The changed structure of nutrient substances of micronized cereals was tested in many experiments on baby pigs, see Bekrić (1980), Moreira *et al.* (1994), Lawrence (1973), Inborr and Ogle (1988). The positive results obtained in the experimental groups were related to better feed efficiency (8–11%) and higher daily weight gain (5–17%). Some authors reported better results of fattening performance, even in cases of lower feed consumption.

MATERIAL AND METHODS

Our investigation required biological testing on piglets which was conducted on a specialized pig breeding farm. The forty-three day investigation was done on 160 weanlings that were divided into four groups (40 animals in each group – Table 1). The experimental weanlings were three-breed crosses (Large White × Swedish Landrace × German Landrace) standardized in weight, age and sex.

Table 1. Scheme of the experiment

Groups	Experimental group I	Experimental group II	Experimental group III	Control group
Treatment	enzymes in the mixture	enzymes + thermally processed cereals	thermally processed cereals	standard mixture

Management in cages was applied in the practical part of our investigation; there were 10 animals in each cage. As given in the above table (Table 1), three experimental groups received partly modified mixtures (diets), whereas the control group was fed a standardized mixture (diet). The polyenzymic preparation Polizym® produced by "Krka", Novo Mesto (Slovenia) was added to the mixtures in the first and second group. According to the producer's instruction, the portion of enzymes in the experimental mixtures was 0.1%. The second way of feed treatment, thermal processing, was applied through micronization of maize and barley in the experimental mixtures. Cereals were treated thermally for 60 seconds and the temperature in a micronizer reached 110°C.

The choice as well as the portion of some diets in experimental groups and in the control group were the same. Table 2 shows the formulation of feed mixtures (in terms of ingredients and chemical composition). Chemical analysis of the proportions of nutrient substances in mixtures was done by usual chemical methods (AOAC, 1960). Piglets had a free choice of feed and water during the investigation.

Table 2. Feed mixture formulation (ingredients and chemical composition in %)

Feed ingredient (%)	Starter	Grower
Maize	23.5	24.2
Barley	24.5	35
Feeding flour	6	5
Dehydrated alfalfa	2	3
Soybean grits	14	15.5
Sunflower grits	7	5
Fish meal	3	4
Powdered milk	11	–
Oil meal	4	3.5
Limestone	2.2	2.0
Phosphonal	2.0	2.0
Salt	0.3	0.3
VAM + enzyme	0.5	0.5
Chemical composition (%)		
Crude protein	20.09	18.00
Crude oil	6.19	5.62
Crude fibre	5.32	5.78
Lysine	1.10	0.92
Methionine + Cystein	0.60	0.61
Tryptophan	0.25	0.22
Ca	1.25	1.09
P	0.92	0.83
ME (MJ/kg)	13.10	12.75

Every day individual body weight and daily weight gain were recorded in each group for every phase. Besides, records of feed consumption were also kept, according to which consumption per feeding day as well as consumption per kg of daily weight gain were calculated.

The results were processed on PC and SPSS for Windows was applied. In order to establish whether there are any statistically significant differences between arithmetic means of the investigated characteristics, Student's *t*-test was used.

RESULTS AND DISCUSSION

The growth of piglet body weight was recorded on the grounds of individual control weighing both at the beginning and at the end of each phase. Table 3 shows that at the beginning of the investigation piglets were of standardized weight in all groups. At the end of the starter phase an increase of body weight was characteristic of all three experimental groups. It was statistically significant at the level ($P < 0.05$) between experimental groups II and I as well as between experimental group II and the control group. Similarly like in the previous phase, in the grower phase the body weight of piglets in experimental groups was higher and the best results were obtained in experimental group II. Statistically significant differences at level ($P < 0.05$) were determined between experimental group II and the control group as well as between experimental groups I and II. A positive effect on body weight observed in experimental groups I and III was expected and it corresponds to that obtained by Berić *et al.* (1993), Inborr and Ogle (1988). Quantitatively speaking, the best result concerning body weight obtained in experimental group II is due to the fact that forage mixture was improved by addition of enzymes and by micronization.

Table 4 shows daily weight gains of piglets according to the phases of our investigation. During the starter phase average daily weight gains were higher in experimental groups, whereas significant differences at level ($P < 0.05$) were established between experimental groups I and II as well as between experimental group II and the control group. The best results in daily weight gain were obtained in the second experimental group, which was statistical-

Table 3. Body weight of piglets in different phases of our investigation (kg)

Groups		Experimental group I	Experimental group II	Experimental group III	Control group
Beginning of investigation	$\bar{x}$	**9.03**	**9.03**	**9.02**	**9.02**
	sd	0.92	0.98	1.12	1.19
	kv	10.19	10.85	12.42	13.19
End of starter phase	$\bar{x}$	**17.91**	**18.96**	**18.53**	**17.53**
	sd	1.85	2.33	2.21	2.76
	kv	10.33	12.29	11.93	15.74
			1*,4 *		
End of grower phase	$\bar{x}$	**24.41**	**25.94**	**25.19**	**23.90**
	sd	2.74	3.09	2.71	4.02
	kv	11.22	11.91	10.76	16.82
			1*, 4*		

* $P < 0.05$

Table 4. Daily weight gains of piglets in different phases of our investigation (g)

Groups		Experimental group I	Experimental group II	Experimental group III	Control group
Starter phase	$\bar{x}$	**294**	**329**	**317**	**285**
	sd	53.74	66.12	54.53	79.55
	kv	18.28	20.09	17.20	27.91
			1**, 4**	1*, 4*	
Grower phase	$\bar{x}$	**504**	**532**	**516**	**489**
	sd	120.4	139.8	103.7	151.1
	kv	23.88	26.28	20.09	30.89
Starter + grower phases	$\bar{x}$	**358**	**392**	**377**	**345**
	sd	61.62	69.18	54.09	84.40
	kv	17.21	17.64	14.34	24.46
			1*, 4**	4*	

* $P < 0.05$

** $P < 0.01$

ly highly significant ($P < 0.01$) in comparison with experimental group I and the control group. As for the second phase of our investigation, the results obtained in experimental groups in relation to daily weight gain were also better, but the differences were not statistically significant ($P < 0.05$). If the results concerning daily weight gain and those obtained during both phases are to be interpreted as a whole, it may be said that group II achieved the best results, which was significant ($P < 0.05$) with regard to experimental group I and highly significant ($P < 0.01$) in relation to the control group. During the whole breeding period statistically significant weight gain was achieved in experimental group III in relation to the control group. Higher daily weight gain in experimental groups is a result of the expected positive effect of the individual impact of added enzymes to the first group and the process of micronization in the third group. Of considerable importance is daily weight gain in experimental group II: the biological test proved our presumption of the possible synergistic effect of enzymes and thermal treatment of feed. The results of daily weight gain obtained in experimental groups are consistent with those from previous investigations done by Adams (1989), Berić (1993), Danielsen (1994) on polyenzymic preparations and by Lawrence (1973) and Bekrić (1980) on micronized maize.

In our investigation feed conversion plays an important role because the tested treatments should increase digestibility of some ingredients and the complete feeding ration. As shown in Table 5, feed conversion in the starter phase was significantly improved in experimental groups (in the second experimental group even 13.2%

Table 5. Feed conversion (kg/kg)

Groups		Experimental group I	Experimental group II	Experimental group III	Control group
Starter phase	kg/kg	**1.52**	**1.38**	**1.42**	**1.59**
	%	95.6	86.8	89.3	100.0
Grower phase	kg/kg	**2.35**	**2.21**	**2.28**	**2.41**
	%	97.5	91.7	94.6	100.0
Starter + grower phases	kg/kg	1.93	1.80	1.85	2.00
	%	**96.5**	**90.0**	**92.5**	**100.0**

Table 6. Daily feed consumption (kg)

Groups		Experimental group I	Experimental group II	Experimental group III	Control group
Starter phase	kg	**0.448**	**0.445**	**0.458**	**0.448**
	%	100.0	99.3	102.2	100.0
Grower phase	kg	**1.18**	**1.16**	**1.17**	**1.18**
	%	100.0	98.3	99.2	100.0
Starter + grower phases	kg	**0.814**	**0.802**	**0.812**	**0.814**
	%	100.0	98.5	99.7	100.0

higher than in the control group). In the grower phase, experimental groups were characterised by lower feed conversion (the lowest in the second experimental group). If the breeding period were not divided into the above-mentioned phases, but seen as a whole, feed conversion was the lowest in experimental group II, which is even 10% better than in the control group.

Significantly lower feed conversion is the result of an improved diet preparation for experimental groups, especially for the second experimental group (both treatments were applied to feed preparation). Our results agree with those obtained by Deng *et al.* (1993) and Lawrence (1973), since they also recorded better feed conversion by 8.2% and 8.0%, respectively, when the influence of individual enzymes or micronization was evaluated.

The above results of the tested values are also partly given in Table 6. In the starter phase the increase in daily feed consumption was recorded only in the third experimental group (2.2%) in relation to the control group. It is characteristic of the grower phase that feed was equally consumed in all groups, with a slight deviation in experimental group II with regard to the control group. Average daily feed consumption was recorded during the whole breeding period and the results show that there was no difference between experimental groups I and III in relation to the control group. In the second experimental group feed consumption was lower than in the control group (1.5%).

According to Danielsen (1994) and Berić *et al.* (1993), enzymes added to feeding rations for piglets resulted in higher daily feed consumption (4.4% and 9.0%, respectively). Slightly lower feed consumption in experimental groups II and III is explained by an increase in the amount of dry matter, total nutritive value of treated cereals and better consumption of feed (Table 5). Investigations done by Kordić *et al.* (1977) and Bekrić (1980) confirm that less feed is consumed if micronized cereals are added to feeding rations for piglets.

CONCLUSION

With the same or slightly lower daily feed consumption (experimental groups II and III), weanlings in the experimental groups were characterised by better feed efficiency, which also resulted in better feed conversion in experimental group II (10% more than in the control group).

Better feed conversion of tested feeding rations also resulted in higher daily weight gain in experimental groups. Statistically significant daily weight gains ($P < 0.05$) were recorded in the third experimental group in comparison with the control group and experimental group I. Highly significant differences ($P < 0.01$) in daily gains were recorded in experimental group II in relation to the control group and the first experimental group.

Higher daily weight gain in experimental groups (during the same period) resulted in higher body weight of piglets in experimental groups. Significantly higher body weight ($P < 0.05$) was determined in experimental group II in relation to the control group and the first experimental group.

Along with the positive results in production, the satisfactory health state of piglets should also be stressed. During our investigation 6 piglets were lost and 3 eliminated, which represents 5.6% of total piglets.

The results of our investigation prove that the joint impact of the two tested treatments (enzymes and micronization) has a positive effect on piglets, and that this way of improvement of feeding rations for piglets may be characterized as justified.

REFERENCES

Adams C.A. (1989): Kemzyme and animal feed digestio. Kemzyme i probava stočne hrane. Krmiva, *31*, 139–144.

Bekrić V., Kasalica T., Ddokor Č. (1980): Efekat upotrebe mikroniziranog kukuruza i kukuruza sa povećanim sadržajem ulja na proizvodnost prasadi od odbijanja do 20 kg težine. Neka aktualna pitanja upotrebe kukuruza u ishrani svinja i ocjena mesnatosti na liniji klanja. Institut za primenu nauke u poljoprivredi 1980, Beograd.

Berić B., Seneić D., Steiner Z., Domaćinović M. (1993): Enzimatski dodatak "Kemzyme" u hranidbi prasadi. Stočarstvo, *47*, 281–284.

Böhme H. (1990): Untersuchungen zur Wirksamkeit von Enzymzusätzen in der Ferkelaufzucht. Landbauforschung Völkenrode, *3*, 213–217.

Brown R.H. (1989): Enzymology may lead to new feed industry technology. Feedstuffs, *59*, 19.

Danielsen V. (1994): Microbially produced enzymes in diets for piglets: studies with Porzyme SP. Tjele, Denmark; Statens Husdyrbrugsforsog Forskningsrapport fra Statens Husdyrbrugsforsog 19.

Deng Y.L.,Zhomg J.I., Yuan J.K. (1993): Comparison of two multi-enzyme preparations on the performance of early weaned piglets. J. Anim. Sci., *29*, 8–10.

Fengler A.J., Marquardt R.R. (1988): Water-soluble pentosans from rye: II. Effects of rate of dialysis and on the retention of nutrients by the chick. Cereal Chem., *65*, 298–302.

Inborr J., Ogle R.B. (1988): Effect of enzyme treatment of piglet feeds on performance and post weaning diarrhoea. Swed. J. Agric. Res., *18*, 129–133.

Inborr J., Schmitz M., Ahrens F. (1993): Effect of adding fibre and starch degrading enzymes to a barley, wheat based diet on performance and nutrient digestibility in different segments of the small intestine of early weaned pigs. Anim. Feed Sci. Technol., *44*, 113–127.

Kordić Branka, Jović M., Vlatković M., Pavlović A., Marković M. (1977): Ispitivanje efikasnosti hidrotermički obrađenog kukuruza u ishrani mlade prasadi. Krmiva, *10*.

Kraft A.M. (1994): APC Sistem kondicioniranja krmnih smjesa. In: Medunarodno savjetovanje "KRMIVA 94", 8.–10. lipnja, 1994. Opatija, Croatia.

Lawrence T.L.J. (1973): An evoluation of the micronization process for preparing cereals for the growing pigs. Anim. Prod., *16*, 99–107 and 109–116.

Moreira I., Rostagno H.S., Tafuri M.L., Costa P.M.A. (1994): Uso de milho processado a calor na alimentacao de leitoes. Rev. Soc. Brasil. Zoot., *23*, 412–421.

Poel T., Melcion J.P. (1995): Antinutritional factors and process technology – principles, adequacy and optimization. Feed Mix, *3*, 17-21.

Rotter B.A., Marquardt R.R., Guenter W. (1989): Enzymes in feed – they really can be made to work. Feed Compound., *9*, 32–36.

Schoch T.J., Maywald E.C. (1967): Gelatinization temperatures of various starches. Academic Press, *11*, 643.

Teitge A., Campbell G.L., Classen H.L., Thacker P.A. (1991): Heat pre-treatment as a means of improving the response to dietary pentosanase in chicks fedrye. Can. J. Anim. Sci., *71*, 507–513.

Received: 01–04–03

Accepted after corrections: 01–10–09

Corresponding Author:

Doc. dr. sc. Matija Domaćinović, University of J.J. Strossmayer in Osijek, Faculty of Agriculture, P. O. Box 117, Trg Sv. Trojstva 3, 31 000 Osijek, Croatia

Tel. +385 31 22 42 00, fax +385 31 20 70 17, e-mail: mdomacin@pfos.hr

The effect of point mutation in *RYR1* gene on the semen quality traits in boars of Large White and Landrace breeds

Vliv bodové mutace v genu *RYR1* na ukazatele kvality spermatu u kanců plemene bílé ušlechtilé a landrase

T. URBAN, J. KUCIEL

Mendel University of Agriculture and Forestry, Department of Genetics, Brno, Czech Republic

Abstract: The experiment involved 34 boars of Large White (LW) and 25 Landrace (L) breeds reared at three A.I. stations in the first year of their use in breeding of known *RYR1* genotypes (*NN* and *Nn*). Altogether 2 772 ejaculates were examined. The results corroborated the existence of significant associations of *RYR1* genotypes with all semen quality parameters under study. Significant effects were demonstrated for the effects "breed", "*RYR1* gene × breed interaction" and "A.I. station × month × year interaction". If compared with heterozygous individuals, homozygous boars with *NN* genotype produced the semen with larger volume ($P \leq 0.05$), highly better motility ($P \leq 0.001$), lower sperm concentration (insignificantly), lower number of abnormal spermatozoa ($P \leq 0.01$) and higher number of A.I. doses ($P \leq 0.001$). When classified into individual genotype and breed categories, a significantly smaller semen volume and higher sperm concentrations ($P \leq 0.001$) were found out in homozygous LW boars with the *NN* genotype than in those with the heterozygous genotype *Nn*. On the other hand, among the boars of L breed, *NN* boars produced semen with larger volume ($P \leq 0.05$) and lower sperm concentrations than those with the heterozygous genotype *Nn* ($P \leq 0.001$). In other parameters under study the same tendencies were observed in both breeds. Boars with homozygous *NN* genotypes showed significantly better parameters of semen quality than the heterozygous (*Nn*) ones.

Keywords: pig; boars; genetic marker; *RYR1* gene; semen parameters

ABSTRAKT: Sledovali jsme 34 kanců plemene bílé ušlechtilé a 25 kanců plemene landrase ve třech inseminačních stanicích po dobu prvního roku jejich využívání, s celkovým počtem 2 772 hodnocených ejakulátů. Výsledky této práce potvrdily významné asociace genotypů *RYR1* genu se všemi sledovanými ukazateli spermatu kanců. Významný vliv byl prokázán u efektů plemeno, interakce *RYR1* gen × plemeno a interakce inseminační stanice × měsíc × rok. Vyšší objem spermatu ($P \leq 0,05$), větší motilitu spermií ($P \leq 0,001$), nižší koncentraci (neprůkazné), méně abnormálních spermií ($P \leq 0,01$) a větší počet inseminačních dávek ($P \leq 0,001$) měli kanci genotypu *NN* než kanci heterozygotního genotypu. Při rozdělení podle plemene a genotypu měli *NN* kanci plemene bílé ušlechtilé průkazně nižší objem spermatu a vyšší koncentraci spermií ($P \leq 0,001$) než kanci genotypu *Nn* a naopak u plemene landrase měli kanci genotypu *NN* průkazně vyšší objem spermatu a nižší koncentraci spermií ($P \leq 0,001$) než kanci genotypu *Nn*. U ostatních ukazatelů byly tendence stejného směru bez ohledu na plemeno. Podle všech ukazatelů měli kanci s *NN* genotypem průkazně výhodnější hodnoty kvality spermatu než kanci s heterozygotním genotypem (*Nn*).

Klíčová slova: prase; kanci; genetický marker; *RYR1* gen; kvalita spermatu

INTRODUCTION

Genetic changes in production parameters can be induced in different ways, e.g. on the basis of utilisation of genetic differences between the breeds or by means of direct or indirect selection of animals showing changes in parameters under study. In recent years, techniques of molecular genetics have been used as a supplement to traditional quantitative methods. When selecting according to the phenotype, the genetic progress is relatively

Supported by the Ministry of Education, Youth and Sports of the Czech Republic (Grant No. MSM 432 100001).

slow due to low heritability of fertility traits. Molecular techniques using candidate genes and quantitative trait loci (QTL) may be applied to accelerate the genetic progress in the case of polygenetically determined quantitative parameters.

Of the total genetic variability of fertility traits, one part can be explained by means of QTL and the other on the basis of the existence of polygenes (Přibyl, 1995). As described by Rothschild *et al.* (1997) QTL are single genes showing a "major" effect on the given trait. Using a genetic marker, it is possible to perform selection for that QTL with which this marker is linked up (MQTL). However, this linkage must not be strong and may be dependent on the ratio of recombination. QTL may be directly detectable in individual cases, so that they become a genetic marker.

The gene of ryanodine receptor (*RYR1*) is one of the so-called candidate genes. This gene is localised in the chromosome 6q12 (Chowdhary *et al.*, 1994). Based on the discovery of point mutation 1843 C → T (Fujii *et al.*, 1991), a new DNA test was elaborated that enables its direct identification on the molecular level. It is known that this point mutation is significantly associated with malignant hyperthermia, pig stress and PSE syndrome, meat performance traits and reproduction in sows.

Although the association with *RYR1* gene is probably predominating, QTL analyses demonstrated the association of the 6th chromosome with growth characteristics and parameters of carcass quality (Geldermann *et al.*, 1996). Some authors, however, expect the existence of some other, yet unknown genes and/or microsatellites in the neighbourhood of *RYR1* gene (Moser *et al.*, 1996; Zhao *et al.*, 1999).

Relationships between semen quality and genotypes of *RYR1* gene were studied by Schlenker *et al.* (1984), who found that the halothane-negative boars (*NN*, *Nn*) produced ejaculates with significantly larger volumes, higher sperm concentrations, higher numbers of normal spermatozoa and better motility than the halothane-positive ones (*nn*). Lengerken *et al.* (1988) also observed a significant difference between halothane-positive and negative boars. In their experiments, halothane-negative boars produced ejaculates of larger volumes with better qualitative parameters.

Hardge and Gregor (1995) evaluated the effects of *RYR1* genotype, as determined by methods of molecular genetics, in 84 boars reared at three A.I. stations. This analysis involved boars of two breeds (German Landrace and Leicoma). The genotype of *RYR1* gene significantly influenced the variability of semen quality parameters. Boars with *NN* genotype produced semen with an increased volume and higher sperm concentration than those with the genotype nn and boars with heterozygous (*Nn*) genotypes occupied the intermediate position between both homozygous groups. As far as the absolute numbers of spermatozoa were concerned, stress-resistant boars produced semen with quality parameters higher by 21.7% than stress-susceptible ones. The number of A.I. doses obtained per ejaculate of stress-resistant boars was higher by 5.

The aim of our study was to determine the differences between NN and Nn genotypes of the *RYR1* gene of Large White and Landrace boars in relation to quality traits of their semen in the first year of their stay at the A.I. station.

MATERIAL AND METHODS

Animals

In this experiment, ejaculates from 59 boars of two breeds (Large White, Landrace) with the known genotype of the *RYR1* gene were investigated in the first year of their stay at three A.I. stations (Table 1 and 2) by standard methods in the years 1990–1996. Altogether 2 772 ejaculates were evaluated, i.e. 45 and 50 in average per boar of either breed according to the standard. The *RYR1* genotypes were identified by haplotyping and DNA test.

Traits investigated

The following parameters of semen quality were evaluated: semen volume in ml (Volume), forward motility in % (Motility), sperm concentration – 10^3/mm^3 (Concentration), percentage of sperm abnormalities (Abnormalities) and number of produced semen doses per ejaculate: 1.5– 2.10^9 spermatozoa (Semen Doses).

Statistical analysis

The associations were investigated by GLM procedure (SAS, 2000) with three fixed effects (of *RYR1* genotype, breed and A.I. station × month × year of semen collection interaction) and one random effect (numerical order of semen collection) using the equation:

$$y_{ijkl} = \mu + RYR1_i + B_j + RYR1{*}B_k + \text{A.I.}{*}\text{M}{*}\text{Y}_l + O_{ijkl} + e_{ijkl}$$

where:
y_{ijkl} = observed values
μ = expected mean value of y
$RYR1_i$ = effect of *RYR1* genotypes (i = 1, 2)
B_j = effect of breed (j = 1, 2)
$RYR1{*}B_k$ = *RYR1* genotype × breed interaction
$\text{A.I.}{*}\text{M}{*}\text{Y}_l$ = interaction between three A.I. stations, twelve months and years (1990–1996) of semen collection
O_{ijkl} = numerical order of semen collection
e_{ijkl} = residual error

RESULTS AND DISCUSSION

The frequencies of genotypes and alleles of *RYR1* gene in the basic set of animals are presented in Table 1. The most frequent was genotype *NN*, followed by genotype *Nn* (0.83 and 0.17, resp.). Percentages of both alleles were $N = 0.91$ and $n = 0.09$; the relatively low frequency of recessive *n* allele resulted from the absence of recessive homozygous genotypes and small number of heterozygous ones due to negative selection of allele *n*. Percentages of boars and ejaculates in individual breeds and genotypes of *RYR1* gene were very similar (Table 2).

Table 1 Genotype and allele distribution of the *RYR1* gene in the population of boars

	n	Relative frequency
RYR1 genotypes		
NN	49	0.83
Nn	10	0.17
Total	59	1.00
Alleles		
N	108	0.91
n	10	0.09
Total	118	1.00

Table 2. Number of boars and ejaculates by breeds (Large White, Landrace) and genotypes of the *RYR1* gene

Breed	*RYR1* genotype	Number of boars	Number of ejaculates
LW	*NN*	28	1 240
	Nn	6	282
L	*NN*	21	1 093
	Nn	4	157
Total		59	2 772

Table 3 shows effects of *RYR1* gene, breed, and A.I. station × month × year interaction on the parameters of semen quality in the first year of the use of boars in A.I., as evaluated by means of a general linear model (GLM). The *RYR1* gene was associated with all parameters of semen quality with the exception of sperm concentration and semen volume; in the second case the difference between both genotypes was near the limit of significance ($P = 0.0587$). Breed did not affect only the proportion of sperm abnormalities. On the other hand, the *RYR1* gene × breed interaction was significant ($P \leq 0.001$) for all parameters under study, similarly like the A.I. station × month × year interaction ($P \leq 0.001$). The numerical order of semen collection showed the effect on Volume, Motility and Semen Doses ($P \leq 0.001$); it did not influence Concentration and Sperm Abnormalities. The values of determination coefficients ranged between 25% and 40%.

Table 4 shows differences in the parameters of semen quality as determined in boars with various genotypes of *RYR1* gene. Heterozygous individuals produced ejaculates with smaller volumes ($P \leq 0.05$) and lower motility ($P \leq 0.001$). In *NN* boars, the percentage of sperm abnormalities was significantly lower than in animals with the *Nn* genotype ($P \leq 0.01$). Homozygous (*NN*) boars produced more semen doses per ejaculate than heterozygous animals ($P \leq 0.001$). There were no significant differences in sperm concentrations obtained from both genotypes of the *RYR1* gene. With the exception of sperm concentration, boars with the *NN* genotype showed better parameters of semen quality than the other animals.

A more detailed differentiation of semen quality parameters, as analysed on the basis of genotype of *RYR1* gene × breed interaction is presented in Table 5. Heterozygous *Nn* boars of LW breed produced semen with larger volumes and lower concentrations than those of the *NN* genotype ($P \leq 0.001$) while opposite results were obtained in boars of the L breed; boars with the homozygous *NN* genotype produced semen with larger volumes and lower concentrations than *Nn* ones ($P \leq 0.001$). There were

Table 3. GLM analysis of boar semen parameters – value of determination coefficients (R^2) and significant values (*P*) of the effects

Semen parameters	*n*	Model (*P*) R^2 (%)	*RYR1*	B	*RYR1**B	AI*M*Y	O
Volume	2 768	28.1	0.0587	0.0001	0.0001	0.0001	0.0001
Motility	2 760	40.2	0.0001	0.0001	0.0025	0.0001	0.0008
Concentration	2 768	27.6	0.6600	0.0001	0.0001	0.0001	0.9307
Abnormality	716	31.6	0.0025	0.5136	0.0058	0.0001	0.2686
Semen Doses	2 648	24.9	0.0001	0.0008	0.0001	0.0001	0.0001

Note:
Volume = semen volume (ml)
Motility = forward motility (%)
Concentration = sperm concentration (10^3/mm^3)
Abnormality = percentage of sperm abnormalities
Semen Doses = number of produced semen doses per ejaculate

Table 4. Associations of the genotypes of the *RYR1* gene with semen parameters of boars (least-squares means LSM ± standard error SE)

Semen parameters	Genotypes of the *RYR1* gene			
	n	*NN*	*n*	*Nn*
Volume	2 329	$230.95^{a} \pm 2.77$	439	$211.98^{a} \pm 3.77$
Motility	2 326	$82.93^{A} \pm 0.20$	434	$80.76^{A} \pm 0.40$
Concentration	2 329	460.77 ± 4.30	439	464.75 ± 8.63
Abnormality	600	$11.02^{A} \pm 0.61$	116	$14.97^{A} \pm 1.20$
Semen Doses	2 249	$28.75^{A} \pm 0.31$	399	$25.70^{A} \pm 0.61$

Values with the same exponents show significant differences in the rows: $^{a} = P \leq 0.05$; $^{A} = P \leq 0.01$; $^{A} = P \leq 0.001$

Note: see Table 3

Table 5. Differences between semen parameters of boars according to the genotypes of the *RYR1* gene and breed (Large White, Landrace) (least-squares means LSM ± standard error SE)

Semen parameters	Large White		Landrace	
	NN	*Nn*	*NN*	*Nn*
Volume	$217.9^{ABC} \pm 2.42$	$243.96^{aAD} \pm 4.86$	$233.03^{aBE} \pm 2.78$	$190.92^{CDE} \pm 6.73$
Motility	$83.42^{AB} \pm 0.24$	$82.61^{D} \pm 0.48$	$82.43^{AC} \pm 0.28$	$78.90^{BCD} \pm 0.66$
Concentration	$488.09^{ABC} \pm 5.16$	$333.90^{ADE} \pm 10.34$	$433.90^{BDF} \pm 5.92$	$595.60^{CEF} \pm 14.32$
Abnormality	$13.40^{A} \pm 0.71$	$13.51^{A} \pm 1.68$	$8.65^{AAB} \pm 0.88$	$16.43^{B} \pm 1.85$
Semen Doses	$29.10^{A} \pm 0.37$	$23.05^{ABC} \pm 0.72$	$28.39^{B} \pm 0.42$	$28.32^{C} \pm 1.02$

Values with the same exponents show significant differences in rows: $^{a} = P \leq 0.05$; $^{A} = P \leq 0.01$; $^{A, B, C, D, E, F} = P \leq 0.001$

Note: see Table 3

no differences either between genotypes of *RYR1* gene or breeds in other parameters.

Only several papers dealing with the effects of *RYR1* gene on semen quality parameters in boars have been published until now. However, the studies on identification of stress sensitivity by means of a halothane test revealed the effect of *RYR1* gene on the parameters of semen quality in boars. Schlenker *et al.* (1984) found significantly higher semen volumes in halothane-negative (HN) boars than in halothane-positive (HP) ones. Differences in the number of progressively motile spermatozoa and in their concentration were negligible. In HP boars, however, the total average numbers of spermatozoa were markedly higher (+10%). Lengerken *et al.* (1988) also observed significant differences between HN and HP boars. According to these authors, however, the activity of spermatozoa was practically the same in both groups. These data corresponded with our results.

Hardge and Gregor (1995) found significant differences in the parameters of semen quality between the genotypes of *RYR1* gene as defined by means of molecular genetics methods. In *NN* boars, these authors observed significantly higher semen volumes than in animals with *Nn* and *nn* genotypes. Boars with *Nn* genotype occupied the intermediary position. As far as the average sperm concentration was concerned, significant differences were found only between the *nn* genotype on the one hand and other genotypes on the other. Significant differences between all three genotypes (*NN* > *Nn* > *nn*) were found only in the number of A.I. doses produced per ejaculate.

Similarly like we in this paper, Hardge and Gregor (1995) described differences in the parameters of semen quality between the A.I. stations and breeds and concluded that they could be caused by different percentages of the recessive n allele in individual populations and breeds. They also deduced that it was not clear if the mutations of *RYR1* gene could show a direct effect on the parameters of semen quality or if the selection processes would result in the occurrence of this correlation. The obtained results corroborate that the semen quality is dependent both on environmental stresses and genetically determined stress susceptibility resulting from mutations in *RYR1* gene. The hypothesis that the *RYR1* gene is associated with the variability of quantitative traits through a pleiotropic effect seems to be corroborated.

REFERENCES

Fujii J., Otsu K., Zorzato F., DeLeon S., Khanna V.K., Weiler J.E., O'Brien P.J., MacLennan D.H. (1991): Identification of a mutation in porcine ryanodine receptor associated with malignant hyperthermia. Science, *253*, 48–51.

Geldermann H., Müller E., Beeckmann P., Knorr C., Yue G., Moser G. (1996): Mapping of quantitative-trait loci by means of marker genes in F_2 generations of Wild Boar, Piétrain and Meishan pigs. J. Anim. Breed. Genet., *133*, 381–387.

Hardge T., Gregor G. (1995): The influence of *RYR1* genotype on male fertility in pigs. In: 46th Annual Meeting of the EAAP, Prague, September 4–7, 1995, Session P 2.11, Pig production. Abstracts, p. 268 .

Chowdhary B.P., Thomsen P.D., Harbitz I., Landset M., Gustavsson I. (1994): Precise localisation of the genes for glucose phosphate (*GPI*), calcium release channel (*CRC*), hormone-sensitive lipase (*LIPE*), and growth hormone (*GH*) in pigs, using nonradioactive *in situ* hybridisation. Cytogenet. Cell Genet., *67*, 211–214.

Lengerken V.G., Schwalbe M., Fodisch K., Henn W. (1988): Egebnisse der Selektion gegen die Halothanempfindlichkeit in der Stamzucht der Landrasse des VEG (T)Eizenburg. Tierzucht, *42*, 259–261.

Moser G., Knorr C., Müller E., Cepica S., Schröffel J. Jr., Stratil A., Hojny J., Gelderman H. (1996): Mapping of quantitative trait loci on chromosome 6 for performance traits in pigs. Anim. Genet., *27*, Suppl. 2, 115.

Přibyl J. (1995): Use of markers in selection of farm animals (in Czech). Živoč. Výr., *40*, 375–382.

Rothschild M.F., Messer L.A., Vincent A. (1997): Molecular approaches to improved pig fertility. J. Reprod. Fertil. Suppl., *52*, 227–236.

SAS. SAS/STAT® (2000): User's Guide (Release 8.1). SAS Inst. Inc., Cary, NC.

Schlenker G., Jugert L., Mudra K., Pohle M., Heinze Ch. (1984): Spermaqualität von Ebern unterschiedlicher Halothanempfindlichkeit. Mh. Vet. – Med., *39*, 760–763.

Zhao F., Ambady S., Ponce de Leon F.A., Miller L.M., Lunney J.K., Grimm D.R., Schook L.B., Louis C.F. (1999): Microsatellite markers from a microdissected swine chromosome 6 genomic library. Anim. Genet., *30*, 251–255.

Received: 01–06–07

Accepted after corrections: 01–10–02

Corresponding Author:

Dr. Ing. Tomáš Urban, Mendelova zemědělská a lesnická univerzita, Zemědělská l, 613 00 Brno, Česká Republika

Tel. +420 5 45 13 31 82, fax +420 5 45 13 31 76, e-mail: urban@mendelu.cz

INSTRUCTIONS FOR AUTHORS

Original scientific papers, short communications, and selective reviews (i.e. papers based on the study of agricultural literature and reviewing recent knowledge in the given field) are published in this journal. Papers are published in English. Each manuscript must contain a English and a Czech (Slovak) summary (including key words). Czech abstracts will be provided for foreign authors. The author is fully responsible for the originality of his paper, for its subject and format. The author should make a written declaration that his paper has not been published in any other information source. The board of editors of this journal will decide on paper publication, with respect to expert opinions, scientific importance, contribution and quality of the paper. The paper should not exceed 10 typescript pages, including tables, figures and graphs.

Manuscript layout: paper of standard size (210 × 297 mm), double-spaced typescript. A PC diskette should be provided with separate text and graphic files. Tables, figures and photos should be enclosed separately. The text must contain references to all these appendices.

If any abbreviation is used in the paper, it is necessary to mention its full form for the first time it is used, abbreviations should not be used in the title or in the summary of the paper.

The **title** of the paper should not exceed 85 characters. Subheadings are not allowed.

Abstract should contain the subject and conclusions of the paper, not a mere description of the paper. It must present all substantial information contained in the paper. It should not exceed 170 words. It should be written in full sentences and contain basic numerical data including statistical data. It must contain keywords. It should be submitted in English and, if possible, also in Czech.

Introduction has to present the main reasons why the study was conducted, and the circumstances of the studied problems should be described briefly.

Review of literature should be a short section, containing only references closely related to the main topic of the paper.

Only original **methods** should be described, in other cases cite the method used and any modifications. This section should also contain a description of experimental material.

In the **Results** section figures and graphs should be used rather than tables for presentation of quantitative values. A statistical analysis of recorded values should be summarized in tables. This section should not contain either theoretical conclusions or deductions, but only experimental data.

Discussion contains an evaluation of the study, potential shortcomings are discussed, and the results of the study are compared with previously published results (only those authors whose studies are closely related to the published paper should be cited). The section Results and Discussion may be presented as one section.

The **References** section contains citations arranged alphabetically according to the surname of the first author. References in the text include the author's name and year of publication. Only the papers cited in the text of the study should be included in the list of references.

The author should give his full name (and the names of other collaborators), academic, scientific and pedagogic titles, full address of his workplace and postal code, telephone and fax number or e-mail.

The manuscript will not be accepted by the editorial office in case its format does not comply with these instructions.

Detailed instructions to authors are published in No. 2 of this volume.

POKYNY PRO AUTORY

Časopis uveřejňuje původní vědecké práce, krátká sdělení a výběrově i přehledné referáty, tzn. práce, jejichž podkladem je studium literatury a které shrnují nejnovější poznatky v dané oblasti. Práce jsou uveřejňovány v angličtině. Rukopisy musí být doplněny anglickým a českým (slovenským) abstraktem (včetně klíčových slov). Autor je plně odpovědný za původnost práce a za její věcnou i formální správnost. K práci musí být přiloženo prohlášení autora o tom, že práce nebyla publikována jinde. O uveřejnění práce rozhoduje redakční rada časopisu, a to se zřetelem k lektorským posudkům, vědeckému významu a přínosu a kvalitě práce. Rozsah vědeckých prací nesmí přesáhnout 10 strojopisných stran včetně tabulek, obrázků a grafů. V práci je nutné používat jednotky odpovídající soustavě měrových jednotek SI (ČSN 01 1300).

Vlastní úprava rukopisu: formát A4, mezi řádky dvojité mezery. K rukopisu je třeba přiložit disketu s prací pořízenou na PC a s grafickou dokumentací. Tabulky, grafy a fotografie se dodávají zvlášť. Na všechny přílohy musí být odkazy v textu.

Pokud autor používá v práci zkratky jakéhokoliv druhu, je nutné, aby byly alespoň jednou vysvětleny (vypsány), aby se předešlo omylům. V názvu práce a v souhrnu je vhodné zkratky nepoužívat.

Název práce (titul) nemá přesáhnout 85 úhozů. Jsou vyloučeny podtitulky článků.

Abstrakt je informačním výběrem obsahu a závěru článku, nikoliv však jeho pouhým popisem. Měl by vyjádřit vše podstatné, co je obsaženo ve vědecké práci, a má obsahovat základní číselné údaje včetně statistických hodnot. Musí obsahovat klíčová slova. Nemá překročit rozsah 170 slov. Je třeba, aby byl napsán celými větami, nikoliv heslovitě. Je uveřejňován a měl by být autory dodán v angličtině a češtině.

Úvod má obsahovat hlavní důvody, proč byla práce realizována, a velmi stručnou formou má být popsán stav studované otázky.

Literární přehled má být krátký, je třeba uvádět pouze citace mající úzký vztah k problému.

Metoda se popisuje pouze tehdy, je-li původní, jinak postačuje citovat autora metody a uvádět jen případné odchylky. Ve stejné kapitole se popisuje také pokusný materiál.

Výsledky – při jejich popisu se k vyjádření kvantitativních hodnot dává přednost grafům před tabulkami. V tabulkách je třeba shrnout statistické hodnocení naměřených hodnot. Tato část by neměla obsahovat teoretické závěry ani dedukce, ale pouze faktické nálezy.

Diskuse obsahuje zhodnocení práce, diskutuje se o možných nedostatcích a práce se konfrontuje s výsledky dříve publikovanými (požaduje se citovat jen ty autory, jejichž práce mají k publikované práci bližší vztah). Je přípustné spojení v jednu kapitolu spolu s výsledky.

Literatura by měla sestávat hlavně z lektorovaných periodik. Citace se řadí abecedně podle jména prvních autorů. Odkazy na literaturu v textu uvádějí jméno autora a rok vydání. Do seznamu literatury se zařadí jen práce citované v textu.

Na zvláštním listě uvádí autor plné jméno (i spoluautorů), akademické, vědecké a pedagogické tituly a podrobnou adresu pracoviště s PSČ, číslo telefonu a faxu, e-mail.

Rukopis nebude redakcí přijat k evidenci, nebude-li po formální stránce odpovídat těmto pokynům.

Podrobné pokyny pro autory jsou uveřejněny v čísle 1 tohoto ročníku.

CZECH JOURNAL OF ANIMAL SCIENCE

Volume 46, No. 10 **October 2001**

CONTENTS

OBSAH

Vědecký časopis CZECH JOURNAL OF ANIMAL SCIENCE (ŽIVOČIŠNÁ VÝROBA) ● Vydává Česká akademie zemědělských věd – Ústav zemědělských a potravinářských informací ● Redakce: Slezská 7, 120 56 Praha 2, tel.: +420 2 27 01 03 52, fax: +420 2 27 01 01 16, e-mail: edit@uzpi.cz ● Sazba a tisk: ÚZPI Praha ●

Rozšiřuje Ústav zemědělských a potravinářských informací, referát odbytu, Slezská 7, 120 56 Praha 2, tel.: +420 2 27 01 03 85, e-mail: finance@uzpi.cz