Length of productive life and lifetime production of cows-daughters of high yielding dams in Poland

Délka produktivního života a celoživotní užitkovost dojnic-dcer vysokoprodukčních matek v Polsku

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ABSTRACT: Records of 19 017 Black-and-White and 10 135 Red-and-White cows and their daughters used in 1978–1993 in the South-West region of Poland were analysed. Cows-dams were classified to a group of cows with high performance if they exceeded the assumed production level ($\bar{x}$ +1.96*s* or 1.28*s*, respectively). The following traits of cows-daughters were examined: number of lactations, number of calves, lifetime production of milk and fat, lifetime, length of productive life and milk and fat yield per life day and per production day. Daughters of cows with high performance produced higher milk and fat yields per production day than daughters of other dams. Lifetime and length of productive life of those cows were shorter.

Keywords: dairy cattle; lifetime performance; length of productive life; high yielding dams

ABSTRAKT: V letech 1978 až 1993 jsme v jihozápadní oblasti Polska prováděli rozbor užitkovosti 19 017 dojnic černobílého skotu a jejich dcer a 10 135 dojnic červenobílého skotu a jejich dcer. Dojnice-matky jsme zařadili do skupiny vysokoprodukčních dojnic, jestliže překročily předpokládanou výši produkce ($\bar{x}$ +1,96s nebo 1,28s). U dojnic-dcer jsme sledovali tyto vlastnosti: počet laktací, počet telat, celoživotní produkci mléka a tuku, délku života, délku produktivního života a produkci mléka a tuku za den života a za produktivní den. Dcery vysokoprodukčních dojnic vyprodukovaly více mléka a tuku za produktivní den než dcery ostatních matek. Měly však kratší délku života i délku produktivního života.

Klíčová slova: mléčný skot; celoživotní užitkovost; délka produktivního života; vysokoprodukční dojnice

INTRODUCTION

The interest in the length of productive life and lifetime yield of dairy cattle has increased during the last two decades (Sieber *et al.*, 1987; Pawlina, 1993; Bünger *et al.*, 1997; Flak and Repka, 1997; Reklewski, 1998; Essl, 1997). It is connected with breeding and economic significance of these traits. Reklewski (1998) pointed out the necessity of productive life improvement in Poland and the inclusion of traits connected with longevity and productive life in breeding value estimation of bulls. In Scandinavian countries selection index includes the health of animals affecting their length of production life (Philipsson, 1998). In countries in which total breeding value evaluation of cattle included, besides dairy traits, reproduction and health traits economic effects have been reached. Allaire and Gibson (1992) showed that the absence of selection for longevity decreased general genetic gain by 5–9%. Other authors (Hibner, 1991; Pawlina, 1991) studied the traits connected with productive life in purebred cows and in crossbreds with Holstein-Fresian breed. They concluded that the productive life of crossbreds was longer than in purebred cows. In Polish literature, no articles with analysis of lifetime performance and length of productive life of cows in connection with the level of milk yield of their dams are available. Zwolińska-Bartczak *et al.* (1999) showed that high yielding dams had higher breeding values than other dams and that daughters of dams with high yield also achieved higher breeding values than other dams. The aim of this study was to find if lifetime yield, lifetime and length of productive life of cows-daughters of high yielding and of other dams were different.

MATERIAL AND METHODS

Records of 19 017 Black-and-White and 10 135 Red-and-White cows and their daughters were analysed. Daughters were born in 1978–1993. Cows were kept in herds of the South-West part of Poland (regions: Opole and Wrocław). Dams were classified into two groups: 1) with high performance – cows with milk yield in the first lactation higher than the mean of the population (for the whole data set) by 1.96 and 1.28 of standard deviation of this trait (level A, and B, respectively – Table1 and 2) other cows. A similar classification was used in a previous study (Zwolińska-Bartczak *et al.*, 1999). To examine if there were any differences between the cows-daughters of dams classified into the two groups, the analysis by the following model was performed:

$$y_{ijk} = \mu + h_i + d_j + e_{ijk}$$

where: y_{ijk} – observed yield
μ – mean of the population
h_i – effect of herd
d_j – effect of dam group
e_{ijk} – error

As a result, least–squares means of the following traits of cows-daughters were obtained: number of lactations, number of calves, lifetime production of milk and fat, lifetime, length of productive life (from first calving to culling) and milk and fat yield per life day and per production day. The analysis of variance by the above model and additionally sire effect was also carried out. Correlation coefficients between the breeding values of dams and values of analysed traits of daughters were estimated.

All calculations were performed using procedures of SAS System (6.12).

Table 1. Milk yield in the first lactation of cows-dams

Breed – Region		Milk yield mean (kg)	Milk yield standard deviation (kg)	Levels A	Levels B
Red-and-White	Opole	3 740	1 006	5 712	5 028
	Wrocław	3 554	955	5 426	4 777
Black-and-White	Opole	3 493	1 018	5 488	4 796
	Wrocław	3 384	913	5 173	4 553

RESULTS AND DISCUSSION

Results of research are presented in Tables 2–4. Least-squares means of analysed traits of Red-and-White cows in both regions are shown in Table 2. Daughters of high yielding dams produced significantly higher lifetime yield of milk and fat, milk yield per life day and per production day and also fat yield per production day regardless of the level. Differences in fat yield per life day were significant only at level B. The number of lactations and number of calves also differed significantly only at level B. In Wrocław region, daughters of dams with high performance lived shorter and their produc-

Table 2. Least-squares means of analysed traits of Red-and-White daughters in Opole and Wrocław regions

Region	Trait / Dams	Number of cows n	Number of cows %	Number of lactations	Number of live born calves	Lifetime milk yield (kg)	Lifetime fat yield (kg)	Lifetime (days)	Productive life (days)	Milk yield per life day (kg)	Milk yield per production day (kg)	Fat yield per life day (kg)	Fat yield per production day (kg)
Opole	Level A												
	High[1]	111	2.18	2.60	2.44	13 066*	514*	1 858	1 017	7.19*	12.77*	0.279	0.503*
	Others[2]	4 973	97.82	2.60	2.55	12 763*	505*	1 911	1 052	6.65	11.86*	0.267	0.474*
	Level B												
	High	348	6.85	2.69*	2.59*	13 173*	523*	1 893	1 042	7.07*	12.59*	0.281*	0.502*
	Others	4 736	93.15	2.59*	2.55*	12 765*	505*	1 913	1 054	6.64*	11.82*	0.266*	0.473*
Wrocław	Level A												
	High	150	2.97	2.49	2.42	11 563	451	1 789*	946*	6.00	11.87*	0.236	0.459*
	Others	4 901	97.03	2.76	2.70	12 648	501	1 920*	1 070*	5.96	11.29*	0.235	0.447*
	Level B												
	High	443	8.77	2.54*	2.49*	11 718	459	1 825*	978*	5.94	11.72*	0.233	0.461*
	Others	4 608	91.23	2.78*	2.72*	12 741	505	1 930*	1 079*	5.96	11.25*	0.236	0.446*

[1]high – daughters of dams with high yield
[2]others – daughters of other dams
*difference between the groups significant at $P \leq 0.05$

tive life was shorter. Similarly like in Opole region, cows-daughters of high yielding dams also achieved significantly higher milk and fat yield per production day, but not per life day. The number of lactations and number of calves differed significantly only at level B.

Least-squares means of analysed traits of Black-and-White cows in Opole and Wrocław regions are presented in Table 3. Cows-daughters of dams with high yield in Opole region had significantly higher milk yield per production day at both levels and fat yield per life day at level B. Lifetime and length of productive life, lifetime production, number of lactations and number of calves in the group of daughters of high yielding dams were lower than in other dams but these differences were not significant. In Wrocław region, daughters of dams with high performance produced significantly higher milk and fat yield per life day and per production day regardless of the level. Similarly like in Opole re-

Table 3. Least-squares means of analysed traits of Black-and-White daughters in Opole and Wrocław regions

Region	Trait / Dams	Number of cows *n*	Number of cows %	Number of lactations	Number of live born calves	Lifetime milk yield (kg)	Lifetime fat yield (kg)	Lifetime (days)	Productive life (days)	Milk yield per live day (kg)	Milk yield per production day (kg)	Fat yield per life day (kg)	Fat yield per production day (kg)
Opole	Level A												
	High[1]	193	2.29	2.54	2.44	11 171	448	1 873	993	6.54	12.08*	0.265	0.483
	Others[2]	8 243	97.71	2.78	2.68	12 492	503	1 998	1 121	6.30	10.89*	0.257	0.438
	Level B												
	High	609	7.22	2.61	2.52	11 847	474	1 901	1 038	6.62	11.84*	0.268*	0.474
	Others	7 827	92.78	2.78	2.69	12 512	504	2003	1 125	6.28	10.85*	0.256*	0.437
Wrocław	Level A												
	High	326	3.08	2.38	2.24	9 963*	397*	1 788	904	5.36*	11.08*	0.215*	0.443*
	Others	10 255	96.92	2.53	2.38	10 401*	420*	1 869	981	5.18*	10.34*	0.210*	0.417*
	Level B												
	High	937	8.86	2.41*	2.28*	10 042*	402*	1 790	912	5.36*	10.96*	0.216*	0.439*
	Others	9 644	91.14	2.53*	2.39*	10 412*	420*	1 875	986	5.16*	10.29*	0.209*	0.415*

[1]high – daughters of dams with high yield
[2]others – daughters of other dams
*difference between the groups significant at $P \leq 0.05$

Table 4. Correlation coefficients between the breeding values of dams and traits of their daughters in Opole region

Breed	Level		Number of lactation	Number of live born calves	Lifetime milk yield (kg)	Lifetime fat yield (kg)	Lifetime (days)	Productive life (days)	Milk yield per production day (kg)	Milk yield per day (kg)	Fat yield per life day (kg)	Fat yield per production day (kg)
Red-and-White	A	High[1]	0.23	0.18	0.35	0.32	0.34	0.31	0.32	0.29	0.24	0.12
		Others[2]	0.05	0.05	0.18	0.17	0.08	0.08	0.12	0.27	0.10	0.23
	B	High	0.10	0.07	0.23	0.22	0.13	0.13	0.30	0.34	0.24	0.25
		Others	0.04	0.05	0.16	0.15	0.08	0.08	0.10	0.23	0.08	0.19
Black-and-White	A	High	0.02	0.01	0.17	0.16	0.07	0.09	0.22	0.14	0.17	0.10
		Others	0.06	0.06	0.18	0.17	0.13	0.13	0.18	0.18	0.15	0.14
	B	High	0.07	0.06	0.19	0.17	0.12	0.12	0.21	0.19	0.19	0.15
		Others	0.06	0.06	0.15	0.14	0.14	0.13	0.14	0.12	0.11	0.08

[1]high – daughters of dams with high yield
[2]others – daughters of other dams

gion, these cows were productive for a shorter time and as a consequence their lifetime yields, number of lactations and number of calves were lower.

It should be noted that the level of performance traits of both breeds was higher in Opole region than in Wrocław region.

The number of lactations, number of calves and lifetime yield of milk and fat recorded in Red-and-White cattle in our research were lower than the results of Pawlina (1993) but his observations were conducted in herds with high average yield and on a smaller number of individuals. Łukaszewicz and Krencik (1994) received lower lifetime values of milk yield (above 9 000 kg) in their population.

Higher milk and fat yields per production day, indicated by our results, showed the positive effect of high yielding dams on the performance of their daughters. It is worth mentioning because, as we stated in an earlier study (Zwolińska-Bartczak *et al.*, 1999), daughters of dams with high yield had higher breeding values of milk traits than other dams. The beneficial effect of high yielding dams was also confirmed by positive values of correlation coefficients between their breeding values of milk yield and performance traits of daughters which are presented in Table 4. We show these correlation coefficients only for Opole region because of its higher standard of breeding work but the trends observed in Wrocław region were similar.

It is unfavourable that the lifetime and length of productive live of cows-daughters of high yielding dams were shorter than in other dams in both breeds and regions. It could be connected with the level of environmental conditions in which the cows were kept and with higher requirements of individuals with high performance. This thesis was confirmed by the results of Hibner (1991). He pointed out the longer productive life of Black-and-White cows and higher number of calves if the production level of the herd was higher.

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Improvement of meat efficiency in mother types of pigs in relation to their reproductive performance

Zvyšovanie mäsovej úžitkovosti materských typov ošípaných vo vzťahu k ich reprodukčnej úžitkovosti

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ABSTRACT: In the large-scale nucleus herd of the Large White (LW) breed 797 breeding gilts were evaluated in view of the proportion of lean meat (LM) *in vivo* determined with Piglog instrument. The proportion of LM in the evaluated gilts was 56.9%. Out of 797 gilts 323 farrowed in the first litter (40.5%). The remaining 474 gilts with average proportion of LM 59.5% were culled (infertility, abortion, emergency slaughter etc.). Because of no onset of oestrus and pregnancy 48% of gilts were culled. The culled gilts (due to of all reasons) were statistically significantly ($P \leq 0.05$) more meaty (LM 57.2%) than those which farrowed in the first litter (LM 56.5%). The set of 797 gilts was divided into 4 groups according to the level of their LM proportion *in vivo* determined with Piglog instrument (to 53%, 53.1–56%, 56.1–58%, and over 58%). The gilts of the most meaty group (LM over 58%) which came into the reproduction process after they became sows, achieved in the first litter a higher (statistically insignificant) number of all and live born piglets per litter (8.73 and 8.32) than a group of gilts with LM to 53% (8.10 and 7.60). In the group of gilts with LM values over 58% 32% farrowed in 1st litter, and 68% were culled for various reasons. In this group 57% gilts were culled because of no oestrus and pregnancy. In the group of the least meaty gilts (Piglog to 53%) 55% farrowed in 1st litter and 45% were culled totally (33% because of infertility). In the group of gilts with LM over 58% there were by 23% more culled animals, or by 23% less gilts farrowed in 1st litter, compared with the group with lower muscling (LM to 53%). The difference in the proportion of infertile gilts was 24% to the disadvantage of the extremely meaty group. Another experiment within the large-scale nucleus herd of the White Meaty breed showed that the gilts with low average backfat thickness (1.07) achieved on average by 0.6 litters less (the difference was statistically significant $P \leq 0.05$) than the group of gilts with higher backfat thickness (1.68 cm). However, the effect of the increase in meatiness of gilts was reflected in the increase of the proportion of culled sows (mainly because of disorders in reproduction cycle) and decrease of the lifetime number of piglets per litter.

Keywords: pigs; meatiness; reproductive performance

ABSTRAKT: V šľachtiteľskom veľkochove plemena bieleho ušľachtilého (BU) bolo vyhodnotených 797 plemenných prasničiek z hľadiska podielu celkovej svaloviny *in vivo* (CS) stanoveného prístrojom Piglog. Následne sa uvedené prasničky hodnotili z hľadiska rôznych príčin vyradenia (z dôvodu jalovosti, zmetania, nutných zabití a iných príčin) a u tých, ktoré sa dostali do reprodukčného procesu (n = 323) sa vyhodnotila plodnosť na prvých vrhoch. Podiel CS hodnotených plemenných prasničiek bol (56,9 %). Zo 797 zaradených prasničiek sa na 1. vrhu oprasilo 323 (40,5 %). Zostávajúcich 474 prasničiek s priemerným zastúpením CS 59,5 % sa vyradilo (jalové, zmetanie, nutné porážky a iné). V dôsledku nenastúpenia ruje a prasnosti bolo vyradených 48 % prasničiek. Prasničky, ktoré boli vyradené (zo všetkých príčin) boli štatisticky preukazne ($P \leq 0,05$) mäsitejšie (CS 57,2 %) ako tie, ktoré sa oprasili na prvom vrhu (CS 56,5 %). Súbor 797 prasničiek bol rozdelený na štyri skupiny podľa úrovne ich podielu prístrojom Piglog stanovenej CS *in vivo* (do 53 %, 53,1 až 56 %, 56,1 až 58 % a nad 58 %). Prasničky najmäsovejšej skupiny (CS nad 58 %), ktoré sa po prevedení do stavu prasníc dostali do reprodukčného procesu dosiahli na prvom vrhu vyšší (štatisticky nepreukazne) počet všetkých a živo narodených prasiat vo vrhu (8,73 a 8,32) ako skupina prasničiek s CS do 53 % (8,10 a 7,60). Na druhej strane v skupine prasničiek s hodnotami CS nad 58 % sa ich na 1. vrhu oprasilo 32 % a 68 % bolo z rôznych príčin vyradených. V tejto skupine bolo 57 % prasničiek vyradených z dôvodu nedostavenia sa ruje a prasnosti (jalové). V skupine najmenej mäsitých prasničiek (Piglog do 53 %) sa na prvom vrhu oprasilo 55 % a celkove bolo vyradených 45 % (z dôvodu jalovosti 33 %). Prasničky s CS nad 58 % mali v porovnaní s menej osvalenými (CS do 53 %) o 23 % viac vyradených prasničiek resp. o 23 % menej oprasených na prvom vrhu. Rozdiel v podiele jalových prasničiek bol 24 % v neprospech extrémne mäsitej skupiny. Aj v ďalšom experimente v rámci šľachtiteľského veľkochovu bieleho mäsového plemena sa ukázalo, že znižovaním hrúbky slaniny, resp. zvyšovaním CS prasničiek, došlo k zvýšeniu počtu živo narodených aj odchovaných prasiat vo vrhu. Skupina prasničiek, ktoré mali v skúške vlastnej úžitkovosti najnižšiu hrúbku slaniny (do 1,2 cm; $\bar{x}$ = 1,07), resp. podiel CS 58,0 %, mali celoživotne priemerný počet živo narodených a odchovaných prasiat 9,6 a 9,4, zatiaľ čo v skupine s hrúbkou slaniny nad 1,5 cm ($\bar{x}$ = 1,68), resp. CS 52,8 %, to bolo 8,9 a 8,4 prasiat. Rozdiely v počte živo narodených a odchovaných prasiat boli medzi uvedenými skupinami štatisticky významné ($P \leq 0,05$). Na druhej strane skupina prasničiek s nižšou hrúbkou slaniny ($\bar{x}$ = 1,07 cm) dosiahla počas života v priemere 2,2 vrhu, kým skupina s vyššou hrúbkou slaniny ($\bar{x}$ = 1,68 cm) 2,8 vrhu. Rozdiel 0,6 vrhu bol štatisticky preukazný ($P \leq 0,05$). Z výsledkov vyplýva, že zvyšovaním podielu CS, resp. znižovaním hrúbky slaniny, nebola negatívne ovplyvnená plodnosť ani počet odstavených prasiat vo vrhu. Negatívny vplyv zvyšovania mäsitosti prasničiek sa však prejavil v náraste podielu vyraďovaných prasníc (predovšetkým v dôsledku porúch reprodukčného cyklu) a v znižovaní celoživotnej početnosti vrhov. Bolo odporučené, aby sa pre obnovu hodnotených šľachtiteľských veľkochovov materských plemien ošípaných nezaraďovali prasničky s podielom CS nad 58 %, resp. s hrúbkou slaniny pod 1,1 cm.

Kľúčové slová: ošípané; mäsitosť; reprodukčná úžitkovosť

INTRODUCTION

An excellent level of reproductive performance with average parameters of fattening ability were necessitated in mother breeds during the realization of the first stage of pig hybridization programme in Slovakia. Hardly any selection criteria were included in the evaluation of their meat efficiency. Gradually it has turned out that it is not enough to use only high quality meaty boars in the terminal sire position to produce final hybrids with high proportion of meaty parts, and in the selection for meat efficiency it is necessary to pay attention to mother breeds, as well. Mother breeds must also meet stricter parameters of meat efficiency at present. However, important is the fact that the increase in meat efficiency must not be detrimental to the reproductive performance which influences the economics of pork production decisively (Haley *et al.*, 1988; Baldvin, 1996). Favourable profitability of pork production is possible only after the high number of pigs per litter and creation of sufficient muscling are put in harmony (Lyczynski *et al.*, 1995; Webb, 1996; Tvrdoň *et al.*, 1998). According to Webb *et al.* (1998) the breeding gilts used for the remount of herd should not have backfat thickness lower than 11 mm, to avoid any negative effect on reproductive performance.

The aim of the work was to evaluate if there exist antagonisms between reproduction and meat efficiencies in pigs of mother breeds, and to limit the level of meatiness in gilts within the evaluated large-scale nucleus herds in such a way not to affect negatively their further reproductive performance.

MATERIAL AND METHOD

In the first experiment we evaluated the proportion of lean meat (LM) *in vivo*, which was determined with Piglog instrument in 797 classified gilts from the large-scale nucleus herd of the Large White breed. The measurements were performed after a field test finishing at 90–100 kg live weight. Then we evaluated the mentioned gilts with respect to various reasons for culling (infertility, abortion, emergency slaughter and other causes), and in those which got into the reproduction process (n = 323) the fertility in first parities was evaluated.

The number of all and live born piglets per litter as well as numbers and percentage of culled gilts and sows were evaluated within 4 groups created according to the achieved proportion of LM *in vivo*, measured with the Piglog instrument (group I to 53%, group II 53.1–56%, group III 56.1–58%, group IV over 58 %). All evaluated gilts were fed the same feed mixture (mixture for rearing of breeding pigs, containing 172 g crude protein and 12.8 MJ metabolizable energy) during the period of rearing from 25 kg to mating.

Besides the whole set of gilts we evaluated also the mentioned characteristics within the line groups of gilts after individual sires active in the given herd.

In the next similar experiment the gilts (n = 243) in the large-scale nucleus herd of the White Meaty breed (WM) were divided into 3 groups according to different backfat thickness (BF) in the field test (group I to 1.2 cm, group II 1.21–1.50 cm, group 3 over 1.5 cm). We studied the effect of back fat thickness on other parameters of field tests, and their subsequent lifetime reproductive performance.

RESULTS AND DISCUSSION

It follows from Table 1 that the proportion of *in vivo* lean meat (LM) in 797 gilts of the Large White breed from the large-scale nucleus herd was quite high for the mother breed (56.9%). The average daily gain of gilts in the whole herd (in field test) achieved 531 g.

Table 2 shows that only 323 (40.5%) gilts out of 797 breeding gilts farrowed in 1st litter. The remaining

Table 1. Evaluation of meatiness, reproduction parameters of gilts and correlations in a large-scale nucleus herd of Large White breed

Parameters	*n*	$\bar{x}$	*s*	Piglog	AB	LB
Lean meat *in vivo* – LM (%)	797	56.93	2.56	1.000		
Number of all born piglets (1st parities) – AB	323	8.29	2.85	0.083	1.000	
Number of live born piglets – LB	323	7.79	2.96	0.102	0.892	1.000

Table 2. Analysis of gilts concernig their meatiness and inclusion in the reproduction process

Line groups of gilts after various sires	*n*	Sows farrowed in 1st parity			Infertile gilts			Sows culled for all reasons		
		n	(%)	LM(%) $\bar{x}$	*n*	%	LM (%) $\bar{x}$	*n*	(%)	LM (%) $\bar{x}$
1. Gismar	194	70	36.1	55.5	91	46.9	56.4	124	63.9	56.4
2. Fazan	23	10	43.5	54.4	12	52.2	56.6	13	56.5	56.6
3. URK	37	25	67.6	55.1	11	29.7	55.7	12	32.4	55.8
4. Farmer	134	45	33.6	56.6	82	61.2	57.5	89	66.4	57.3
5. Holl	58	14	24.1	55.1	32	55.2	55.7	44	75.9	55.8
6. Loris	22	8	36.4	56.3	8	36.3	58.3	14	63.6	58.21
7. YK	135	72	53.3	57.3	42	31.1	58.5	63	46.6	58.21
8. Marshl	18	3	16.7	55.8	14	77.7	57.7	15	83.3	57.7
9. Soban	115	54	46.9	58.1	55	47.8	58.1	61	53.0	58.2
10. Agas	22	7	31.8	57.4	14	63.6	58.0	15	68.2	58.2
11. Žitav	7	3	42.8	56.0	4	57.1	55.3	4	57.1	55.3
14. Hafer	30	11	36.7	57.2	17	56.6	58.6	19	63.3	58.7
Total	797	323	40.5	56.5	383	48.0	57.3	474	59.5	57.2

Table 3. Comparison of differences in meatiness of gilts with regard to culling and farrowing

Line groups of gilts after various sires	*n*	Sows farrowed in 1st parity LM (Piglog)			Culled sows (infertile, other reasons) LM (Piglog)			Statistical significance of differences
		n	$\bar{x}$	*s*	*n*	$\bar{x}$	*s*	
1. Gismar	194	70	55.55	2.53	124	56.38	2.57	+
2. Fazan	23	10	54.38	2.34	13	56.58	2.40	++
3. URK	37	25	55.10	2.38	12	55.82	1.86	–
4. Farmer	134	45	56.58	2.63	89	57.32	2.40	+
5. Holl	58	14	55.14	1.88	44	55.77	2.19	–
6. Loris	22	8	56.29	2.84	14	58.21	2.61	++
7. YK	135	72	57.28	2.29	63	58.21	2.30	+
8. Marshal	18	3	55.77	1.85	15	57.66	2.46	++
9. Soban	115	54	58.07	2.11	61	58.15	2.12	–
10. AGAS	22	7	57.37	2.51	15	58.17	2.97	+
14. Hafer	30	11	57.25	1.42	19	58.67	2.10	+
Total	797	323	56.54	2.56	474	57.20	2.53	+

474 gilts with average LM proportion of 59.5% were culled (infertility, abortion, emergency slaughter and other causes). Up to 48% gilts were culled because of no onset of oestrus and pregnancy. Table 3 shows that the gilts which were culled (because of all reasons) were statistically more meaty (LM 57.2%) than those which

farrowed in the first litter (56.5%). In some line groups of gilts (Fazan, Loris, Marshal) there existed a difference in the proportion of muscling *in vivo*, a difference up to 2% was found between those that were culled and those that produced the 1st litter.

Table 4 shows the set of 797 gilts divided into 4 groups according to the level of their LM *in vivo* determined with Piglog instrument (to 53%, 53.1–56%, 56.1–58%, and over 58%). Unexpected were the findings that the gilts in the most meaty group (LM over 58%), which came into the reproduction process (after they became sows), achieved a higher (statistically insignificantly) number of all and live born piglets in 1st litter (8.73 and 8.32, resp.) than the group of gilts with LM to 53% (8.10 and 7.60, resp.). On the other hand, important is the fact that in the group of gilts with LM values over 58% only 32% farrowed in the first litter, and up to 68% were culled because of various reasons. In this group up to 57% gilts were culled because of no onset of oestrus and pregnancy (infertility). In the group with the least meaty gilts (Piglog to 53%) 55% farrowed in the first litter, and 45% were culled totally (33% no oestrus and pregnancy). This study documents that from the group of gilts with LM over 58% by 23% more animals were culled, or by 23% less gilts farrowed in the 1st litter, compared with the group with less LM (to 53%). The difference in the proportion of infertile gilts was 24% to the disadvantage of the extremely meaty group. Lyczynski *et al.* (1995) found out in a similarly oriented experiment that out of gilts with the smallest MLD area, measured instrumentally *in vivo* (31–35 cm^2), 16.4% gilts were culled (infertility and incapable of farrowing), and up to 31.5% gilts were culled out of the group with MLD over 47 cm^2.

Gráčik *et al.* (1997) found out, opposite to the mentioned results, that the gilts with higher meat proportion (LM over 58%) achieved a lower number of live born piglets per litter (by 0.3) compared with the group of gilts with LM to 53%. In the previous experiment the authors compared meatiness and fertility only in those gilts that were included in the reproduction process, and they did not evaluate the effect of meatiness in gilts on their inclusion in the reproduction process.

Table 1 shows that the correlations between the LM proportion of all evaluated gilts and the subsequent number of their all and live born piglets in 1st litter are very low ($r = 0.083$ and $r = 0.1020$). It is probably because there exist lines of gilts in the herd characterized by great meatiness and high fertility as well (Table 5 shows the line Hafer with LM 58.1% and number of live born pigs 9.09). However, there are lines with low proportion of meaty parts as well as low number piglets per litter (line Urk achieved LM 55.3% and number of live born pigs 7.44).

The next experiment within the large-scale nucleus herd of the Large White Meaty breed also showed that the number of live born and weaned piglets per litter rose after the backfat thickness decrease or LM increase in gilts (Table 6). Table 5 shows that in the group of gilts with the lowest backfat thickness in a field test (to 1.2 cm; $\bar{x} = 1.07$) or LM proportion 58.0% the lifetime average of live born and reared piglets was 9.6 and 9.4, whereas in the group with the backfat thickness over 1.5 cm ($\bar{x} = 1.68$) or LM 52.8% the respective numbers were 8.9 and 8.4 piglets. The differences in the number of live born and weaned piglets between the mentioned groups were statistically significant ($P \leq 0.05$). On the other hand, the group of gilts with lower backfat thickness ($\bar{x} = 1.07$ cm) achieved 2.2 litters on average during the life, and the group with higher backfat thickness ($\bar{x} = 1.68$ cm) achieved 2.8 litters. The difference 0.6 litter was statistically significant ($P \leq 0.05$). Gaughan *et al.* (1995) found out that the sows with back fat thickness 9–13 mm had the statistically significantly lower average number of litters than sows with backfat thickness over 17 mm. Similarly, Ten Napel *et al.* (1995) reports that the intensive selection aimed at a decrease in backfat thickness in pigs causes the extension of parturition interval in sows. Table 6 also

Table 4. Comparison of different levels of meatiness in breeding gilts with regard to their culling and inclusion in the reproduction process

Status of studied gilts and sows	Lean meat *in vivo* (LM)								Statistical significance of differences
	to 53% (n = 54)		53,1 – 56% (n = 238)		56,1 – 58% (n = 233)		over 58,1% (n = 272)		
Infertile	18	33%	102	43%	108	46%	155	57%	
Culled for various reasons (infertility, forced slaughter, abortion)	24	45%	129	54%	135	58%	186	68%	
Farrowed in 1st parity	30	55%	109	46%	98	42%	86	32%	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	
Number of all born pigs in 1st parity	8,10	3,04	7,76	3,12	8,55	2,63	8,73	2,56	–
Number of live born pigs in 1st parity	7,60	3,35	7,23	3,02	8,01	2,90	8,32	2,72	–

Table 5. Comparison of differences between the line groups of gilts with regard to their meatiness and following fertility

Line groups of gilts after various sires	LM (Piglog)			Number of live born pigs in 1st parity		
	n	$\bar{x}$	s	n	$\bar{x}$	s
1. Gismar	194	56.09	2.58	70	7.21	3.08
2. Fazan	23	55.63	2.57	10	8.20	2.30
3. URK	37	55.34	2.22	25	7.44	3.62
4. Farmer	134	57.07	2.49	45	8.09	3.31
5. Holl	58	55.62	2.12	14	7.78	2.12
6. Loris	22	57.51	2.79	8	7.62	3.66
7. YK	135	57.72	2.33	72	8.14	2.54
9. Soban	115	58.11	2.14	54	7.89	2.81
10. Agas	22	57.91	2.79	7	7.57	2.64
14. Hafer	30	58.15	1.97	14	9.09	2.21
Statistically significant differences	$1:4, 7, 9^{+}$ $2:7, 9^{+}$ $3:4, 7, 9, 10^{+}$ $5:4, 7, 9, 10^{+}$			$1:14^{+}$ $3:14^{+}$		

Table 6. Evaluation of reproductive performance of White Meaty breed sows in a large-scale nucleus herd with regard to backfat thickness and meatiness (in field test)

Parameters	BF to 1.2 cm		BF from 1.21 to 1.50 cm		BF over 1.5 cm		Statistical significance of differences
	1. $n = 51$		2. $n = 113$		3. $n = 79$		
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	
Backfat thickness-BF (cm)	1.07	0.09	1.37	0.08	1.68	0.12	
LM (Piglog) (%)	58.0	1.30	55.2	2.91	52.80	3.11	
Daily gain (g)	523.6	26.5	535.9	35.9	545.6	36.3	$2:3^{+}$ $1:2^{++}, 1:3^{+++}$
Num. of born piglets	9.6	1.70	9.4	2.02	8.9	2.41	$1:3^{+}$
Num. of weaned piglets on 21st day	9.4	1.80	9.0	2.32	8.4	2.71	$1:3^{+}$
Average number of litters per 1 sow	2.2	1.61	3.0	2.11	2.8	2.00	$1:2^{++}, 1:3^{+}$

shows that the group of sows with average backfat thickness 1.68 cm achieved higher daily gain (545.6 g) than the group with backfat thickness 1.07 cm (523.6 g).

Our results obtained in two large-scale nucleus herds of pigs show that the increase in lean meat proportion or decrease in fat thickness influenced negatively neither fertility nor number of weaned piglets per litter. However, the negative effect of meatiness increase in gilts became evident in the increase of the culled sows proportion (mainly because of disorders in reproduction cycle) and decrease of the number of piglets in litters during their lifetime.

It is difficult to determine a general optimum level of meatiness in mother types of pigs in spite of the number of significant results. It is obvious that the improvement of nutritive value in the used feed mixtures will enable to shift the limit of meatiness in mother breeds without any negative effect on their reproductive performance. We can recommend for both studied large-scale herds of mother breeds not to use gilts with lean meat proportion over 58% or backfat thickness below 1.1 cm for the replacement of herd.

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Histomorphological and histochemical analysis of some skeletal muscles in fattened bulls

Histomorfologická a histochemická analýza některých kosterních svalů u býků ve výkrmu

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ABSTRACT: White fast-twitch glycolytic (FG) fibres of large diameter, red slow-twitch oxidative (SO) fibres of small diameter and intermediate fast-twitch oxidative (FOG) glycolytic fibres of intermediate diameter were found in the samples of *m. obliquus abdominis externus*, *m. rectus abdominis*, *m. triceps brachii* (*caput longum*), *m. pectoralis superficialis*, *m. longissimus dorsi* (2 samples), *m. psoas major* and *m. semimembranaceus* taken from both body sides of 5 fattened bulls, 15 months old and weighing 400 kg. The white fibres dominate in all muscle samples and they show a strong activity of standard (S ATP) and alkaline stable adenosine triphosphatase (AL ATP), a weak activity of lactate and succinate dehydrogenase (LDH and SDH) and of acid stable adenosine triphosphatase (AC ATP), a low content of lipids and a high content of glycogen. In 4 muscles the red fibres are more numerous than the intermediate ones. They show a strong activity of LDH and SDH, of AC ATP, a weak activity of S ATP and AL ATP, a high content of lipids and a low content of glycogen. The FOG fibres are more numerous than the SO ones in 3 muscles (4 samples), and they show a strong activity of S ATP and AL ATP, a weak activity of AC ATP, a moderate activity of LDH and SDH as well as a varying content of lipids and glycogen. The muscle fibre diameters ranged from 20 to 115 µm, but the largest average diameter was found in *m. psoas major*, the smallest being in *m. obliquus abdominis externus*. The differences in muscle fibre diameters between the left and the right side of the body were not significant ($P > 0.05$).

Keywords: muscle fibre diameter; histomorphological analysis; histochemical analysis; oxidative enzymes; myosin adenosine triphosphatase; fattened bulls

ABSTRAKT: Ve vzorcích svalů *m. obliquus abdominis externus*, *m. rectus abdominis* (*caput longum*), *m. pectoralis superficialis*, *m. longissimus dorsi* (dva vzorky), *m. psoas major* a *m. semimembranaceus*, které jsme odebrali z obou stran těla pěti býků ve výkrmu ve věku 15 měsíců a o hmotnosti 400 kg, jsme zjistili bílá, rychle se smršťující glykolytická vlákna (FG) velkého průměru, červená, pomalu se smršťující oxidační vlákna (SO) malého průměru a střední, rychle se smršťující oxidační glykolytická vlákna (FOG) středního průměru. Ve všech vzorcích svalů mají dominantní postavení bílá vlákna, která vykazují silnou aktivitu standardní (S ATP) a alkalické stabilní adenosintrifosfatázy (AL ATP), slabou aktivitu laktát- a sukcinátdehydrogenázy (LDH a SDH) a kyselé stabilní adenosintrifosfatázy (AC ATP), nízký obsah lipidů a vysoký obsah glykogenu. Ve čtyřech svalech jsou červená vlákna početnější než střední vlákna. Vykazují silnou aktivitu LDH a SDH, AC ATP, slabou aktivitu S ATP a AL ATP, vysoký obsah lipidů a nízký obsah glykogenu. Vlákna FOG jsou početnější, než vlákna SO ve třech svalech (čtyři vzorky) a vykazují silnou aktivitu S ATP a AL ATP, slabou aktivitu AC ATP, mírnou aktivitu LDH a SDH, jakož i kolísavý obsah lipidů a glykogenu. Průměry svalových vláken se pohybovaly od 20 do 115 mm, ale největší průměrnou hodnotu průměru vlákna jsme zjistili v *m. psoas major*, nejmenší v *m. obliquus abdominis externus*. Rozdíly mezi průměry svalových vláken na levé a na pravé straně těla nebyly významné ($P > 0,05$).

Klíčová slova: průměr svalového vlákna; histomorfologická analýza; histochemická analýza; oxidační enzymy; adenosintrifosfatáza myosinu; býci ve výkrmu

INTRODUCTION

On the basis of various indicators (speed of contraction, quantity of sarcoplasm, density of myofibrils inside the sarcoplasm, quantity of mitochondria and myoglobin, activity of some oxidative enzymes and myosin adenosine triphosphatase, diameter of muscle fibres) it is possible to differentiate 3 types of muscle fibers in skeletal muscles: a) fibres of type I or red fibres or slow-twitch oxidative (SO) fibres, b) fibres of type II or white fibres or fast-twitch glycolytic (FG) fibres, and c) intermediate fibres or fast-twitch oxidative glycolytic (FOG) fibres (Ashmore and Doerr, 1971; Barnard *et al.*, 1971; Peter *et al.*, 1972; Hraste, 1991). Besides the mentioned nomenclature in the typology of muscle fibres, other nomenclatures exist as well (Brooke and Kaiser, 1970; Guth and Yellin, 1971; Ashmor *et al.*, 1972).

There are some differences between the muscle fibre types of vertebrates. Only a small number of muscles are homogeneously structured by one muscle fibre type. The proportion of muscle fibre types in muscles depends on many factors such as: species, race and age of the animal, function of muscle, way of keeping, use and feeding of animals, health conditions and genetic factors.

The proportion of some muscle fibre types in a muscle reflects its functional possibilities and the way it is involved in action as well as of what kind of action such muscle is capable.

Therefore in our investigations we wanted to establish histomorphometabolic characteristics of muscle fibres in some muscles of cattle of the Croatian Simmenthal race with different anatomical structure, physiological functions and adaptation capability. All selected muscles were taken from both, the left and the right side of the body as we wanted to know whether and to what extent the selected muscles differ as to the muscle fibre diameters and their metabolic properties according to either side of the body.

A sample histomorphological and histochemical analysis of the construction of muscles does not offer enough data concerning the distribution of muscle fibres within muscles. Therefore in our investigations we applied the method of frequency distribution of muscle fibres (Bego, 1994) by means of which it is possible to obtain a better view of functional capacity of muscle fibres within the investigated muscles.

MATERIAL AND METHODS

Our investigations were performed in the meat processing plant "Promes", Karlovac. The samples of muscles were taken after the slaughtering of 5 fattened bulls 15 months old and about 100 kg live weight. The samples of abdominal muscles (*m. obliquus abdominis externus* and *m. rectus abdominis*), shoulder muscles (*m. triceps brachii-caput longum*), thoracic muscles (*m. pectoralis superficialis*), muscles of the back and loins *(m. longissimus dorsi* and *m. psoas major*) and muscles of thigh (*m. semimembranaceus*) were taken from the left and the right side of the body. The samples were always taken from the same place. Samples of *m. obliquus abdominis externus* and *m. rectus abdominis* were taken from the middle of the muscle, samples of *m. triceps brachii* from the middle of *caput longum*, samples of *m. pectoralis superficialis* near by the second vertebra, samples of *m. longissimus dorsi* L_1 at the level of 10th thoracic vertebra and L_2 at the level of 3rd lumbar vertebra, samples of *m. psoas major* at the level of 3rd lumbar vertebra and samples *of m. semimembranaceus* at the level of the hip joint.

The samples were frozen in liquid nitrogen and cut on "Cryo-cut" into 10 μm thick slices. A part of them was stained with hematoxylin and eosin (Romeis, 1968) to show the muscle structure, and the rest was tested for the activity of lactate dehydrogenase (LDH) (Hess *et al.*, 1958), succinate dehydrogenase (SDH) (Padykula, 1952), standard, alkaline and acid stable adenosine triphosphatase (S, AL and AC ATP) (Padykula and Herman, 1955, modified according to Brooke and Kaiser, 1970) and for the presence of lipids by Sudan III (Daddi, 1968) and glycogen by PAS procedure (Romeis, 1968).

Diameters of muscle fibres were measured on the transversally cut sections of the selected muscles stained for the presentation of LDH, and the obtained results were processed statistically and presented in tables (Song *et al.*, 1963).

In order to obtain a better view of functional capacity of the investigated muscles, following the method of frequency distribution (Bego, 1994), muscle fibres were classified according to their diameters by 5 μm segments. For a simpler graphical view and a more accurate statistical account, groups of 100 fibres, i.e. 8 000 fibres in total, of different diameters and of different activity of the investigated enzymes were counted.

RESULTS

The muscle fibre diameters of investigated muscles taken from both body sides are presented in Table 1. Muscle fibre diameters of the muscles taken from the left and the right body side are presented in Tables 2 and 3. As shown in Table 1 and Figure 1 the muscle fibre diameters in the samples of *m. obliquus abdominis externus, m. rectus abdominis* and *m. triceps brachii* (*caput longum*) range from 20 to 95 μm, in *m. pectoralis superficialis* from 20 to 100 μm, in *m. semimembranaceus* from 20 to 105 μm, *in m. longissimus dorsi* L_1 from 25 to 100 μm, in L_2 from 25 to 105 μm, and in *m. psoas major* from 25 to 115 μm. The smallest muscle fibre diameter was 20 μm, and it is found in 5 muscles, the largest fibre diameter being 115 μm and it is was found in *m. psoas major*. The

Table 1. Presentation of muscle fibre diameters in muscles of the both sides of the body

Statistical evidence	OE	R	T	P	L_1	L_2	PM	S
N	1 000	1 000	1 000	1 000	1 000	1 000	1 000	1 000
$\bar{X}$	48.47	48.49	50.33	52.96	53.35	55.20	56.51	51.74
$\bar{X}_{min}-\bar{X}_{max}$	20–95	20–95	20–95	20–100	25–100	25–105	25–115	20–105
S	13.00	14.48	14.14	13.50	12.50	14.00	13.45	13.97
$S_{\bar{x}}$	0.41	0.46	0.45	0.43	0.40	0.44	0.43	0.40
V	26.82	29.62	28.09	25.49	23.43	25.36	23.80	27.00

Table 2. Presentation of muscle fibre diameters in muscles of the left side of the body

Statistical evidence	OE	R	T	P	L_1	L_2	PM	S
N	500	500	500	500	500	500	500	500
$\bar{X}$	48.80	49.47	50.41	53.65	53.16	54.92	55.83	52.17
$\bar{X}_{min}-\bar{X}_{max}$	20–95	20–95	20–95	20–95	25–100	25–105	25–110	20–105
S	13.64	15.17	14.47	13.68	12.63	13.80	13.78	14.74
$S_{\bar{x}}$	0.61	0.68	0.65	0.61	0.56	0.52	0.62	0.66
V	27.95	30.67	28.70	25.50	23.76	25.13	24.68	28.25

Table 3. Presentation of muscle fibre diameters in muscles of the right side of the body

Statistical evidence	OE	R	T	P	L_1	L_2	PM	S
N	500	500	500	500	500	500	500	500
$\bar{X}$	48.14	48.30	50.25	52.26	53.53	55.47	57.19	51.31
$\bar{X}_{min}-\bar{X}_{max}$	20–95	20–85	20–95	20–100	25–95	25–105	25–-115	20–90
S	12.36	13.79	13.81	13.31	12.37	14.20	13.11	13.20
$S_{\bar{x}}$	0.55	0.62	0.62	0.60	0.55	0.54	0.59	0.59
V	25.68	28.55	27.48	25.47	23.11	25.60	22.92	25.73

Legend for Tables 1–4:

OE = *m. obliquus abdominis externus*, R = *m. rectus abdominis*, T = *m. triceps brachii*, P = *m. pectoralis superficialis*, L_1 = *m. longissimus dorsi* – level of 10th thoracic vertebra, L_2 = *m. longissimus dorsi* – level of 3rd lumbar vertebra, PM = *m. psoas major*, S = *m. semimembranaceus*

N – sample size, $\bar{X}$ – mean value, $\bar{X}_{min}-\bar{X}_{max}$ – minimal and maximal mean value, S – standard deviation, $S_{\bar{x}}$ – standard error of the mean, V – variance

average diameter was as follows: *m. obliquus abdominis externus* 48.47 µm, m. *rectus abdominis* 48.49 µm, *m. triceps brachii* 50.33 µm, *m. pectoralis superficialis* 52.96 µm, *m. longissimus dorsi* L_1 53.35 µm and L_2 55.20 µm, *m. psoas major* 56.51 µm, and *m. semimembranaceus* 51.74 µm.

Tables 2 and 3 show that the values of muscle fibre diameters from the left and the right side of the body are different, these differences not being significant.

The red SO fibres, the white or FG fibres and the intermediate or FOG fibres were found in all investigated muscles. Table 2 shows a relation between the muscle fibre types and their diameters. In all samples of muscles the white fibers are dominant considering their number and diameters ranging from 55 to 115 µm: in *m. obliquus abdominis externus* (38.8%), in *m. rectus abdominis* (39.6%), in *m. triceps brachii* (41.0%), in *m. pectoralis superficialis* (44.5%), in *m. semimembranaceus* (43.1%), in *m. longissimus dorsi* L_1 (51.2%) and L_2 (55.0%), and in *m. psoas major* (57.8%).

The average fibre diameter in these muscles is 62.56 µm, 63.04, 64.15, 65.30, 65.09, 63.42 and 65.15 µm, respectively. The red fibres have smaller diameters and cover a lesser part of the muscle surface. Diameters of these fibres range within 20 to 40 µm. In 4 muscles these fibres are more numerous, while in 3 muscles they are less numerous than the intermediate fibres. As to the average diameter, the red fibers are smaller than the intermediate fibres. They account for 31.20% in *m. obliquus abdominis externus*, 31.00% in *m. rectus abdominis*, 30.60% in *m. triceps brachii* (*caput longum*), 24.60% in *m. pectoralis su-*

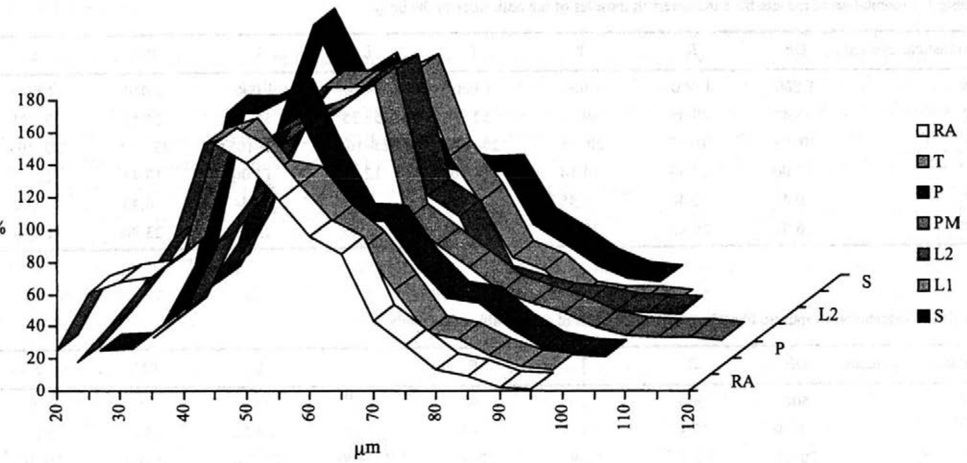

Figure 1. Frequency distribution of muscle fibres within m. obliquus abdominis externus (OE), m. rectus abdominis (RA), m. triceps brachii (T), m. pectoralis superficialis (P), m. psoas major (PM), m. longissimus dorsi – level of 10th thoracic vertebra (L_1), m. longissimus dorsi – level of 3rd lumbar vertebra (L_2), m. semimembranaceus (S) by 5 µm segments

perficialis, 30.00% in *m. semimembranaceus*, 21.40 % and 19.50% in *m. longissimus dorsi* (L_1 and L_2), and 16.60% in *m. psoas major*. The average diameters of the red fibres are 32.36, 32.21, 33.65, 36.40, 36.38, 36.75, 37.10 and 36.84 µm, respectively. The intermediate fibres have larger diameters than the red ones (their diameters ranging from 40 to 55 µm) and they make the smallest group of muscle fibres in 4 muscles and somewhat more numerous group in 3 muscles. Among all fibres the percentage of these fibres is 30.00, 29.40, 28.40, 30.90, 26.90, 27.40 (L_1), 25.50 (L_2) and 25.60%, with average diameters 47.00, 47.40, 49.52, 48.35, 47.47, 47.50 (L_1), 47.55 (L_2) and 47.66 µm (Table 4).

Table 4. Proportion (%) and average diameters (µm) of white (W), red (R) and intermediate (I) fibres in the investigated muscles

Fibre type		OE	RA	T	P	PM	L_1	L_2	S
W	%	38.80	39.60	41.00	44.50	57.80	51.20	55.00	43.10
	µm	62.56	63.04	64.15	65.30	66.08	63.42	65.15	65.09
R	%	31.20	31.00	30.60	24.60	16.60	21.40	19.50	30.00
	µm	32.36	32.21	33.65	36.40	36.84	36.75	37.10	36.38
I	%	30.00	29.40	28.40	30.90	25.60	27.40	25.50	26.90
	µm	47.00	47.40	49.52	48.35	47.66	47.50	47.55	47.47

The activity of LDH and SDH as well of the acid stable ATP is strong in the red muscle fibres, but the activity of standard and alkaline stable ATP is weak. These fibres contain more lipids and few glycogen. The white fibers show a weak activity of LDH and SDH as well as of acid stable ATP, the strong activity of standard and alkaline stable ATP, some glycogen and few lipids. The intermediate fibres show a stronger activity of standard and alkaline stable ATP, the weak activity of acid stable ATP, the moderate activity of LDH and SDH while the contents of lipids and glycogen vary.

DISCUSSION

Already Ranvier (1874) noted that muscles could be divided into white and red ones but this division was not sharp. Because of muscle adaptation to different funtions, a lot of muscles have a heterogeneous structure, that means they contain white, red and intermediate muscle fibres (Wander *et al.*, 1990). It could be said that the muscles having a uniform structure are rare, such as *m. pectoralis superficialis* in chicken broilers of Jata line (Kaufman *et al.*, 1997 and Jelić *et al.*, 1998).

Differentiation of muscle fibres on the basis of their histochemical reaction, either to metabolic enzymes or myosin adenosine triphosphatase, does not exclude possible errors concerning the interpretation of such reactions (Nemeth and Pette, 1980; Spurway, 1981). Therefore in our investigations we performed some histochemical reactions that make possible a view into the metabolic type and contractile capacities of fibres within the investigated muscles. We were also interested whether and to what extend the fibre diameter depends on metabolic or contractile properties of the investigated muscles.

The results of our investigations have shown a heterogeneous structure of all investigated muscles with three types of muscle fibres: red or SO (with 20–40 µm diameters), white or FG (55–115 µm) and intermediate or FOG (40–55 µm). Since the proportion of single muscle fibre types could suggest some functional capability of a muscle, we have tried to analyse each of the investigated muscles with regard to the muscle structure and the fibre type proportion.

Simple histomorphologic and histochemical analyses cannot provide enough data concerning the distribution of muscle fibres within the investigated muscles. One of the ways to classify muscle fibres is the frequency distribution method (Bego, 1994). By this method muscle fibres are classified according to their diameters divided into selected segments. In this way it is possible to get a better view of the distribution of fibres within the investigated muscles as well as of the functional capacities of such muscles. By applying the frequency distribution method clear functional differences between the costal and lumbar parts of diaphragm were shown in horse (Zobundžija *et al.*, 1994; Bego *et al.*, 1996), in bovines (Zobundžija *et al.*, 1998) and in lambs (Gjurčević-Kantura *et al.*, 1996) as well as in some muscles of broilers (Kaufman *et al.*, 1997).

In the abdominal muscles, i. e. in *m. obliquus abdominis externus* and *m. rectus abdominis*, no statistically significant differences concerning the muscle fibre diameters exist. Namely, the function of these two muscles is compression of abdominal organs acting as an "abdominal press"; they help expiration, urination, defecation and parturition and they also control ventro- and lateroflexion of the dorsolumbar part of the spine, and in ruminants they act on rumination by short and fast contractions. Since the abdominal muscles contract frequently and because of a frequent compression of abdominal organs which are massive in cattle (specially the rumen), these muscles contain relatively the highest percentage of FG muscle fibres, and almost an equal percentage of SO and FOG fibres. These muscles contain relatively the highest number of white muscle fibres of a big diameter, possessing great strength and serving for fast shortlasting contractions in the afore mentioned physiological activities, particularly in rumination.

M. triceps brachii caput longum acts on the shoulder and elbow joint so that while moving it extends, and while standing it fixes the elbow joint and also the carpal and digital joints. The results of our investigations show that most fibres are muscle fibres of a big diameter, i. e. FO or white fibres (41.00%), which is in accordance with the investigations of these muscles in cows (Hraste, 1976), in lambs (Gjurčević-Kantura *et al.*, 1999) and in pigs (Morse *et al.*, 1987). These fibres play a great role in the shortlasting actions of animal standing up or laying down, or in shorter fast movements of animals. Such actions of white fibres are possible because of their big diameter and great strength. Other fibres are of smaller diameters and metabolically they are FOG or SO, those being able to act without fatigue accomplishing other functions such as slow walking of animals or fixation of the elbow joint.

M. pectoralis superficialis connects the foreleg with the trunk and it serves for the elastic reception of the trunk weight while moving or for carrying the trunk during standing and moving the foreleg while walking. In this muscle also dominate fibres of a big diameter with weak oxidative and strong glycolytic activity (41.00%). This finding suggests that this muscle belongs to so called dynamic muscles, which is in concordance with the findings of Alečković *et al.* (1989). A metabolic part of *m. pectoralis superficialis* also consists of SO or red fibres (30.60%). These fibres possess a low contraction speed and they are capable to develop and to keep the isometric tension. These fibres are responsible for the bearing of the body and for performing slow repeated movements of the forearm, these fibres being economical and efficient in performing these functions. Besides the mentioned fibre types, the intermediate or FOG fibres participate with 28.40% in *m. pectoralis superficialis*. These fibres together with red fibres make more than one half of all fibres indicating an oxidative activity, which is in concordance with the findings of Hraste *et al.* (1981) who found more than one half of the oxidative fibres in *m. pectoralis superficialis* of fattened bulls. On the other hand, the intermediate fibres together with the white fibres of larger diameter make about 60% of fast-twitch fibres.

M. longissimus dorsi is the largest and the longest muscle of the body. Its function is to fasten the thoracic and lumbar parts of the spine, to bend the spine laterally, and with its neck ending it extends the cervical part of the spine. White fibres dominate in *m. longissimus dorsi*, in both parts (L_1 and L_2). Since the content of these fibres makes more than 50% of all fibres, this muscle is a white dynamic muscle, which is also in concordance with the observations of Hraste *et al.* (1980) in bullocks, and Rahelić and Puac (1980) in pigs. Besides the white fibres, the muscle contains intermediate (27.4 and 25.5%) and red fibres (21.4 and 19.5%) with moderate or strong activity of oxidative enzymes, which is in concordance with the findings of Eisenhut *et al.* (1965), who described three types of muscle fibres in *m. longissimus dorsi* of the Simmenthal cattle with domination of large diameter muscle fibres. The comparison of the findings in *m. longissimus dorsi* shows that the average diameter at the level of 3rd lumbar vertebra is statistically larger and that in this region there are more white fibres than in the region of 10th thoracic vertebra. These findings could be explained by higher movability of the spine in its lumbar region than in the thoracic one, and by greater necessity for faster and shorter movements in that region. Some differences with regard to the place of sampling were observed; the muscle samples were described by Eisenhut *et al.* (1965) and May *et al.* (1977), who found that diameters of muscle fibres in samples from inner parts of *m. longissimus dorsi* were significantly larger than in samples from outer parts of the muscle.

M. psoas major is positioned on the ventral side of the lumbar part of the spine. Its function is flexion of the hip joint, rotation of the thigh laterally and ventro- or lateroflexion of the lumbar part of the spine. The muscle contains three types of muscle fibres among which dominate white FG fibres (50.7%), which is in accordance with the findings of Gjurčević-Kantura *et al.* (1999) in lambs. These fibres show a weak activity of investigated dehydrogenases and a strong activity of standard and alkaline stable ATP, which is in concordance with the findings of Hraste *et al.* (1980), who found most white fibres in the same muscle of fattened bulls. In our investigations *m. psoas major* contained more intermediate fibres (25.6%) than red ones (16.6%). The metabolic structure of the muscle indicates that this massive muscle is mainly involved in shortlasting fast movements of the pelvis (coition, urination, defecation) or hind legs (running, jumping, scratching the head). In longlasting movements its role is probably limited. Since the white muscle fibres make more than one half of all fibres, one can say that *m. psoas major* is also a white dynamic muscle.

M. semimembranaceus is a large trigonal pelvicofemoral muscle. Its function is an extension of the hip joint and an adduction of the hind leg. White fibres of large diameter prevail (43.1%) in the structure of the muscle. The red fibres with the smallest diameter make 30.0% and the intermediate fibres make 26.9% of all fibres, which is in accordance with the findings of Gjurčević-Kantura *et al.* (1999) in lambs, and Morse *et al.* (1987) in pigs. The red and intermediate fibres make together 56.9% of all fibres and it represents the same percent of oxidative muscle fibres capable of longlasting slow movements (walking around). On the other hand, the white and intermediate fibres make together 70% of all fibres, which represents the same percent of glycolytic muscle fibres capable of fast shortlasting movements (running, standing up).

It is possible to confirm the close connection between the muscle fibre diameters and their metabolic and contractile characteristics. The proportion of some muscle types in muscles reflects the working capacity of the analyzed muscles. Muscle fibres of larger diameter possess greater strength and higher quantity of such fibers, which proves the strength of such muscle. On the other hand, stronger activity of S and AL ATP suggests a higher speed of contractions, while stronger activity of oxidative enzymes indicates greater endurance and resistance to fatigue. The average muscle fibre diameters taken from the left and right side of the body vary although the differences are not significant ($P > 0.05$). With regard to the way of keeping of the investigated animals and since the animals use both sides of the body in the same way, it is understandable that no significant differences were observed as to the muscle fibre diameters in the muscles taken from the left and right side of the body.

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Calcium, magnesium and phosphorus retention in chickens with different growth rate fattened to higher age

Retence vápníku, hořčíku a fosforu u kuřat s rozdílnou intenzitou růstu během výkrmu do vyššího věku

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ABSTRACT: Utilisation of calcium, magnesium and phosphorus was examined in broilers and laying type cockerels from Day 23 to Day 100. In meat type chickens coefficients of apparent Ca and P retention decreased highly significantly ($P < 0.01$) during the whole experiment while that of Mg decreased till the age of 93 days. In egg type chickens the dependence of Ca retention on age was expressed by the parabola of the 2nd degree with a minimum on Day 70. Utilisation of Mg and P decreased linearly and highly significantly. Content of Ca and Mg in body gains of broilers increased ($P < 0.01$) with age. Concentration of P culminated on Day 45. In laying type chickens the level of Mg increased highly significantly and that of P decreased ($P < 0.01$). The Ca content in body gains decreased till Day 43; thereafter, an increase was recorded. Differences in average coefficients of Ca and P retention and retention per unit of body gain in slow growing hybrid and broiler chickens were not significant ($P > 0.05$) while retention of Mg was highly significantly higher in laying type chickens.

Keywords: chickens; calcium; magnesium; phosphorus; retention of macrominerals

ABSTRAKT: U kohoutků masného a nosného typu jsme od 23. do 100. dne života sledovali využití vápníku, hořčíku a fosforu. U masného typu kuřat se koeficienty bilanční retence Ca a P vysoce průkazně ($P < 0,01$) snižovaly během celého experimentu, zatímco u Mg klesaly jen do věku 93 dní. U kuřat nosného typu byla závislost retence Ca na věku kuřat vyjádřena rovnicí paraboly 2. stupně s minimem v 70. dni věku. Využití Mg a P se vysoce průkazně lineárně snižovalo. Obsah Ca a Mg v přírůstcích živé hmotnosti brojlerů se s věkem zvyšoval ($P < 0,01$). Koncentrace fosforu kulminovala ve 45. dni života. Hladina Mg se u kuřat nosného typu vysoce průkazně zvyšovala a hladina P naopak klesala ($P < 0,01$). Obsah Ca v přírůstcích se snižoval do 43. dne a pak byl zaznamenán jeho vzestup. Rozdíly v průměrných koeficientech bilanční retence Ca a P a retence na jednotku přírůstku u pomalu rostoucích hybridů a u brojlerových kuřat nebyly průkazné ($P > 0,05$), zatímco retence Mg byla vysoce průkazně vyšší u kuřat nosného typu.

Klíčová slova: kuřata; vápník; hořčík; fosfor; retence makroprvků

INTRODUCTION

Determination of changes in utilisation of minerals during the growth of animals is essential for the formulation of nutrient requirements.

In our experiments with broilers the utilisation of Ca significantly decreased from the 2nd to the 8th week of age when the level of this element in the diet was sufficiently high. Percentages of P and Mg utilisation decreased, too. The content of Mg in body gains increased with age. The content of P did not change when its content in the diet was low and decreased when the feed was rich in this element (Zelenka, 1987, 1991a, 1992).

A review by Vogt *et al.* (1985) stated that the body of meat type cockerels contained 7.5, 10.0 and 11.5 mg Ca per gram live weight at the age of 6, 12 and 20 weeks. The corresponding levels of Mg and P were 0.54, 0.51 and 0.47 mg and 5.1, 6.35 and 7.0 mg, respectively. At the age of 6 weeks the contents of Ca and P were slightly higher in light breeds (8.25 and 5.7 mg, resp.) and that

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of Mg was lower (0.52, 0.39 and 0.35 mg at 6, 12 and 20 weeks, respectively).

In our experiment (Zelenka, 1988), chickens showing a lower growth rate accumulated significantly more P per unit body gain than those with a higher growth rate. Edwards and Lanza (1981, ex McDowell, 1992) found that light breeds had higher requirements for P than the broiler chickens.

In the experiment in which daily changes of utilisation of macrominerals in meat and laying type chicks were studied in the first three weeks of age (Zelenka and Fajmonová, 2001), retention of Ca, Mg and P decreased in the 3rd week of age. Differences in Ca, Mg and P retention per unit of body gain between laying type hybrids and broiler chicks were not significant ($P > 0.05$). In the present experiment we tried to determine coefficients of utilisation of these elements and their retention per unit of body gain till 14 weeks of age.

MATERIAL AND METHODS

Effect of age on the apparent calcium, magnesium and phosphorus retention was studied within 26 subsequent three-day balance periods from Day 23 of age to Day 100 using 95 Isa Brown laying type cockerels and 52 Ross 208 meat type male chicks. The diet contained 8.63, 0.60 and 6.16 g Ca, Mg and P per kg, respectively. The feed was supplied *ad libitum* and its consumption was recorded. The body weight of chickens was estimated at the end of each balance period. The coefficients of utilisation of investigated macrominerals were estimated using the chromic oxide indicator method. The content of chromic oxide in feed and freeze-dried excreta was estimated iodometrically (Mandel *et al.*, 1960). Calcium and magnesium were estimated by the atomic absorption spectrometry and phosphorus spectrophotometrically as vanadate yellow. The composition of the diet and methods of chemical analyses were described in our earlier paper dealing with retention of macrominerals in young chicks (Zelenka and Fajmonová, 2001).

The contents of Ca, Mg and P in the live body gains (mg/g) were calculated using feed intake, contents of macrominerals in the diet, coefficients of their utilisation and body weight increments in each of the three-day balance periods.

The regressions of determined values were computed according to Snedecor and Cochran (1967).

RESULTS AND DISCUSSION

The dependence of live weight in grams on age of chickens in days from Day 23 to Day 100 was expressed by the parabola (Figure 1) for

Isa Brown $Y = -52 + 8.4\,X + 0.31\,X^2 - 0.0015\,X^3$; $r = 1.000$; $P < 0.01$, and for

Ross 208 $Y = 566 - 33.6\,X + 2.27\,X^2 - 0.0133\,X^3$; $r = 0.999$; $P < 0.01$

and the dependence of feed dry matter consumption from hatch per unit of body gain on age of chickens by the equation for

Isa Brown $Y = 1.57 + 0.0143\,X$; $r = 0.968$; $P < 0.01$, and for

Ross 208 $Y = 1.16 + 0.0101\,X$; $r = 0.972$; $P < 0.01$.

The mean values of coefficients of apparent retention of macrominerals and retention per one gram of body gain are presented in Table 1. Dependences of the above values (Y) on age of chickens in days (X) within the period of Day 23 to Day 100 were 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 curvi-

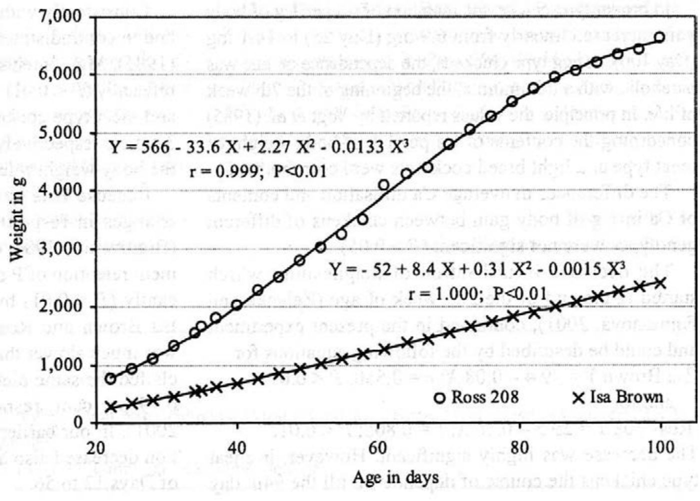


Figure 1. Body weight of chickens

Table 1. Apparent retention of calcium, magnesium and phosphorus

Mean and regression equation			Mean ± standard error of the mean	$Y = a + bX + cX^2$						
				a	b	c	r	P	$X_{extr.}$	$Y_{extr.}$
Coefficients of retention	Calcium	Isa Brown	35.60 ± 1.255	64.3	–0.93	0.0066	0.594	< 0.01	70.0	31.88
		Ross 208	36.87 ± 1.886	56.8	–0.32**	–	0.762	> 0.05	–	–
	Magnesium	Isa Brown	24.42 ± 0.653	29.4	–0.08**	–	0.550	> 0.05	–	–
		Ross 208	19.30 ± 0.908	38.5	–0.49	0.0026	0.847	< 0.05	93.2	15.47
	Phosphorus	Isa Brown	13.36 ± 1.813	33.2	–0.32**	–	0.788	> 0.05	–	–
		Ross 208	12.45 ± 1.592	33.2	–0.33**	–	0.939	> 0.05	–	–
Retention per 1 g of body gain	Calcium (mg)	Isa Brown	10.93 ± 0.635	13.35	–0.227	0.002665	0.843	< 0.01	42.6	8.52
		Ross 208	10.50 ± 0.824	4.57	0.095**	–	0.518	> 0.05	–	–
	Magnesium (mg)	Isa Brown	1.90 ± 0.096	0.87	0.016**	–	0.769	> 0.05	–	–
		Ross 208	1.40 ± 0.113	0.50	0.014**	–	0.578	> 0.05	–	–
	Phosphorus (mg)	Isa Brown	2.74 ± 0.301	5.25	–0.040**	–	0.600	> 0.05	–	–
		Ross 208	2.16 ± 0.275	0.89	0.098	–0.001098	0.740	< 0.05	44.5	3.07

X = age in days; a, b, c = parameters of equation; r = correlation coefficients; P = significance of the deviation from linearity; **significance of linear regression ($P < 0.01$)

linear regression by F-test (Snedecor and Cochran, 1967). In case that the reduction was significant, parameters a, b and c of parabola equation were presented in Table 1. When the deviation from linearity was insignificant, parameters a and b of linear regression were presented in this table.

Dependence of coefficients of apparent calcium retention on age of chickens was significant and was expressed by means of the 2nd degree parabola with a minimum on Day 70 in laying type chickens and by the equation of linear regression in meat type chickens. In a study with very young chicks fed the same diet (Zelenka and Fajmonová, 2001) Ca utilisation started to decrease after the 14th day of age. In Isa Brown and Ross 208 chickens this downtrend continued till the age of 10 weeks and to the end of this experiment, respectively. However, a similar decrease was not registered in chickens fed the diet with a suboptimum level of Ca (Zelenka, 1991a).

In broiler type chicks, the retention of Ca per 1 g of body gain increased linearly from 6.9 mg (Day 25) to 14.1 mg (Day 100). In egg type chickens, the dependence on age was parabolic with a minimum at the beginning of the 7th week of life. In principle, the values reported by Vogt *et al.* (1985) concerning the contents of Ca per 1 g of body weight of meat type and light breed cockerels were corroborated.

The differences in average Ca utilisation and contents of Ca in 1 g of body gain between chickens of different genotypes were not significant ($P > 0.05$).

The decrease in utilisation of magnesium, which started at the end of the 2nd week of age (Zelenka and Fajmonová, 2001), continued in the present experiment and could be described by the following equations for

Isa Brown $Y = 29.4 - 0.08\,X$; $r = 0.550$; $P < 0.01$,

and for

Ross 208 $Y = 29.5 - 0.16\,X$; $r = 0.805$; $P < 0.01$.

The decrease was highly significant. However, in meat type chickens the course of dependence till the 94th day of age could be expressed much better ($P < 0.05$) by the descending branch of parabola

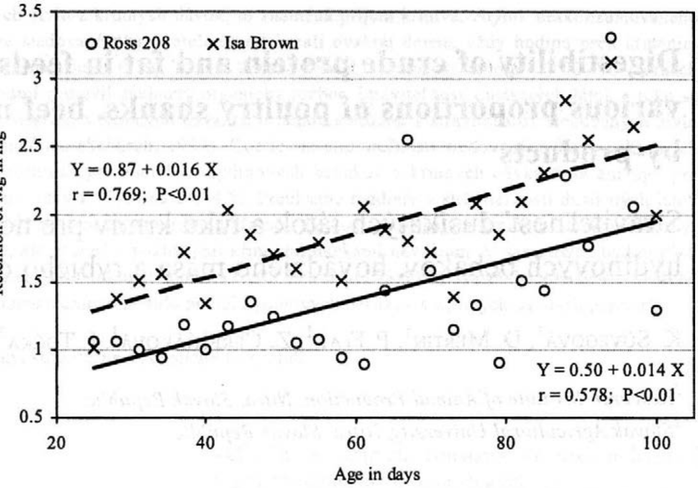
$Y = 38.5 - 0.49\,X + 0.0026\,X^2$; $r = 0.847$; $P < 0.05$.

The average coefficients of Mg retention in laying chickens and broilers were 24.42 ± 0.653 and 19.30 ± 0.908 (mean ± standard error of the mean; 26 determinations), respectively. The contents of Mg in 1 g of body gain were 1.90 ± 0.096 and 1.40 ± 0.113 mg, respectively. Both differences between various types of chickens were highly significant ($P < 0.01$). While in young chicks of laying hybrid combination and in faster-growing broiler chicks the contents of Mg in body gains were practically the same (Zelenka and Fajmonová, 2001), in our experiments with older animals (Zelenka, 1991b) chickens with a lower growth rate accumulated significantly ($P < 0.001$) more Mg per unit of body gain than those with a higher growth rate similarly like in the present trial.

Consistently with results published by Zelenka (1992) and in contradistinction to data mentioned by Vogt *et al.* (1985), Mg contents in body gains increased highly significantly ($P < 0.01$) with the age (Figure 2). In light breed and meat type cockerels they were 3 to 5-times and 2 to 3-times, respectively, higher than the contents per 1 g of the body weight referred by Vogt *et al.* (1985).

Because P is actively transported, absorption of P changes in response to the demand for this element (Braithwaite, 1984, ex McDowell, 1992). In this experiment retention of P decreased linearly and highly significantly ($P < 0.01$) by 0.32 and 0.33 per cent per day in Isa Brown and Ross 208, respectively. This decrease was much slower than that observed in the same cockerels fed the same diet from Day 3 to 22 of life (0.96 and 0.79 per cent, respectively; Zelenka and Fajmonová, 2001). In our earlier experiment (Zelenka, 1987), retention decreased also highly significantly within the period of Days 12 to 56.

Figure 2. Retention of Mg per 1 g of body gain



The light breeds show higher requirements of P than the meat type chickens (Edwards and Lanza, ex McDowell, 1992). Zelenka (1988) found that faster growing chickens retained highly significantly less P in their body gains than slowly growing animals. In an experiment conducted by Zelenka and Fajmonová (2001) Isa Brown chicks accumulated more P per unit body gain than the broilers in the first 3 weeks of age. However, this difference was not significant ($P > 0.05$). A similar result ($P > 0.05$) was obtained also in this experiment with older chickens. For Ross 208 the dependence on age was expressed by the second degree parabola with a maximum on Day 45. In chickens with a lower growth rate, accumulation of P decreased every day by 0.04 mg per 1 g of body gain.

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Digestibility of crude protein and fat in feeds for minks with various proportions of poultry shanks, beef meat and fish by-products

Stráviteľnosť dusíkatých látok a tuku krmív pre norky pri rôznom podiele hydinových behákov, hovädzieho mäsa a rybieho odpadu

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ABSTRACT: The experiment was performed in the Research Institute of Animal Production Nitra. Five male standard minks were used in the experiment at the age of four months. The animals were clinically healthy and examined for plasmocytosis. The objective of this experiment was to determine the digestibility of crude protein and fat from feed rations for minks with various proportions of poultry shanks, as well as the digestibility of these nutrients in the feed. The experiment consisted of three individual stages. The animals were fed the control feed mixture which is characterized by the lowest content of poultry shanks – 19.6% at the first stage. At the second stage the content of poultry shanks rose to 40.4%, and at the third stage to 50.4% against the original content. Each stage of the experiment consisted of two periods – the preparatory one and the experimental one. The individual periods followed each other immediately during the experiment. The preparatory period lasted seven days, the animals adapted themselves to the new feed ration, and the experiment lasted five days. The animals were fed twice a day – at 9.00 o'clock and 15.00 o'clock. Parameters necessary to calculate the digestibility coefficients of the studied nutrients from feed rations were recorded in animals, i.e. feed intake, residues of unconsumed feed and quantity of excrements. Samples to determine the studied parameters were taken twice a day, always one hour before feeding (i.e. at 8.00 o'clock and 14.00 o'clock), and they were weighed to the nearest 0.1 g. The excrements were preserved by freezing at the temperature –17°C. Basic organic chemical analyses were performed in samples of excrements. Crude protein and fat digestibility was determined by means of apparent digestibility in feed rations by a direct method, and digestibility of the studied nutrients in poultry shanks by an indirect method (Schürch, 1969). The digestibility coefficient of the studied nutrients decreases with increasing percentual proportion of poultry shanks in feed rations for minks: for crude protein from 80.75 to 70.35%, and for fats from 90.14 to 84.24%. Significant differences in digestibility of crude protein and fats on the level of significance $P \leq 0.01$ were between the control feed ration and experimental feed rations with the increased proportion of poultry shanks, and between the experimental feed rations as well. The digestibility coefficient in poultry shanks achieved the value 61.73% of crude protein and 78.50% of fats. On the basis of our results we recommend 40% proportion of poultry shanks in feed rations for minks as a maximum for the agricultural practice.

Keywords: minks; poultry shanks; digestibility; crude protein; fat

ABSTRAKT: Experiment sa realizoval vo Výskumnom ústave živočíšnej výroby v Nitre. Do pokusov bolo zaradených päť samcov norky štandardnej vo veku štyroch mesiacov. Zvieratá boli klinicky zdravé a vyšetrené na plazmocytózu. Cieľom experimentu bolo zistiť stráviteľnosť dusíkatých látok a tuku z kŕmnych dávok pre norky pri rôznom percentuálnom podiele hydinových behákov, a tiež stráviteľnosť týchto živín v samotnom krmive. Pokus sa skladal z troch samostatných etáp. V prvej etape sa vychádzalo z kŕmenia zvierat kontrolnou kŕmnou dávkou, ktorá je charakterizovaná najnižším podielom hydinových behákov – 19,6 %. V druhej etape obsah hydinových behákov sa zvýšil na 40,4 %, a v tretej etape na 50,4 % z pôvodného obsahu. Každá etapa pokusu sa skladala z dvoch období – prípravného obdobia a vlastného pokusu. V priebehu experimentu jednotlivé etapy bezprostredne nasledovali za sebou. Prípravné obdobie trvalo sedem dní, počas ktorých si zvieratá zvykali na novú kŕmnu dávku, a vlastný pokus trval päť dní. Zvieratá sa kŕmili dvakrát denne – o 9. a 15. hodine. V priebehu vlastného pokusu sa u zvierat sledovali parametre potrebné pre výpočet koeficientov stráviteľnosti sledovaných živín z kŕmnych dávok, to znamená príjem krmiva, zbytok neskonzumovaného krmiva a množstvo trusu. Vzorky pre sledované ukazovatele sa odoberali dvakrát denne, vždy hodinu pred kŕmením (teda o 8. a 14. hodine) a vážili sa s presnosťou na 0,1 g. Trus sa konzervoval mrazením pri teplote –17 °C. Vo vzorkách krmiva a trusu sa chemickými analýzami stanovil základný organický rozbor. Stráviteľnosť dusíkatých látok a tuku sa zisťovala bilančnou látkovou stráviteľnosťou, v kŕmnych dávkach priamou metódou a stráviteľnosť sledovaných živín v hydinových behákoch nepriamou metódou (Schürch, 1969). Koeficient stráviteľnosti sledovaných živín v kŕmnych dávkach pre norky so stúpajúcim percentuálnym podielom hydinových behákov v kŕmnych dávkach sa znižuje: pre dusíkaté látky z 80,75 na 70,35 % a pre tuky z 90,14 na 84,24 %. Preukazné rozdiely v stráviteľnosti dusíkatých látok a tukov na hladine významnosti $P \leq 0,01$ boli medzi kontrolnou kŕmnou dávkou a pokusnými kŕmnymi dávkami so zvýšeným podielom hydinových behákov, ale aj medzi pokusnými kŕmnymi dávkami navzájom. V samotných hydinových behákoch koeficient stráviteľnosti dusíkatých látok mal hodnotu 61,73 % a tukov 78,50 %. Na základe našich výsledkov pre poľnohospodársku prax doporučujeme maximálne 40% podiel hydinových behákov v kŕmnych dávkach pre norky.

Kľúčové slová: norky; hydinové beháky; stráviteľnosť; dusíkaté látky; tuk

INTRODUCTION

Proteinous nutrition of carnivorous fur-bearing animals is based mainly on utilization of secondary raw materials of animal origin from food industries, and it differs in individual countries. A number of authors were engaged in digestibility of nutrients in food rations for minks based predominantly on fish and fish waste. Jorgensen and Glem-Hansen (1973) designed special cages for metabolic experiments with minks. Glem-Hansen (1979) studied the suitability and digestibility of nutrients in basic and supplementary feeds in feed rations for minks used in Scandinavia. Jorgensen and Eggum (1971), Jorgensen and Glem-Hansen (1972), Skrede (1978), Glem-Hansen (1980a, b) were engaged in the need of proteins, their digestibility and biological value for growing minks. Dahlman *et al.* (1996) pointed out the necessity of research in the sphere of digestibility of crude protein from proteinous feeds for minks with regard to changes in nutrition of minks during the recent years, since the proportion of expensive proteinous feeds in feed ration decreases and it is necessary to emphasize their quality and balance of the feed ration. Skřivan *et al.* (1973) studied the digestibility of crude protein in dry feeds for minks.

MATERIAL AND METHODS

An experiment was conducted on the Experimental Farm of Fur-bearing Animals at the Research Institute of Animal Production in Nitra. Five male standard minks were included into the experiment at the age of four months. The animals were clinically healthy and they were examined for plasmocytosis.

The objective of the experiment was to determine the digestibility of crude protein and fat from the feed rations for minks at various percentual proportions of poultry shanks, and digestibility of these nutrients in the feed as well. The experiment consisted of three individual stages according to the following scheme:

	control group	experimental groups	
	A_1	A_2	A_3
content of poultry shanks in feed ration (%)	19.6	40.4	50.4

Feed rations for minks are given in Table 1.

Table 1. Feed rations for minks at individual stages of the experiment

Components (g/animal/day)	Control group	Experimental groups	
	A1	A2	A3
Poultry shanks	39.0	84.0	108.0
Beef	105.0	45.0	3.0
Fish by-products (cod)	21.0	46.5	72.0
Barley meal	28.5	28.5	27.0
Dried milk	5.4	3.6	3.6
Roboran H	0.5	0.5	0.5
Total	199.4	208.1	214.1

Roboran H – commercially produced vitamin and mineral premix composition (in 1000 g): vit. A 500 000 i.u., D_3 100 000 i.u., K_3 20 mg, E 750 mg, B_1 25 mg, B_2 40 mg, B_6 20 mg, B_{12} 0.5 mg, Biotin 10 mg, niacin 200 mg, calcium pantothenate 200 mg, choline chloride 20 000 mg, Fe 380 mg, Cu 150 mg, Zn 140 mg, Mn 110 mg, Co 6 mg, I 20 mg, Ca 180 mg, P 58 mg, Saccharin 250 mg

The animals were housed in special balance cages one month before the beginning of the experiment to adapt themselves to the new environment. Each stage of the experiment consisted of two periods – a preparatory period and the experiment. The individual stages succeeded each other. The preparatory period lasted seven days, the animals adapted themselves to the new feed ration, and the experiment lasted five days. The animals were fed twice a day – at 9.00 and 15.00 o'clock. The nutritive

Table 2. Nutritive the value of feed rations for minks at individual stages of experiment

Nutrients	A_1	A_2	A_3
ME (kJ/animal/day)	1 241.73	1 277.01	1 277.72
Digestible crude protein (N. 6.25) (g/animal/day)	26.49	25.44	25.01
Digestible fat (g/animal/day)	14.21	15.48	15.68
Digestible carbohydrate (g/animal/day)	11.15	11.48	11.54
Dry matter (%)	35.30	30.14	31.59

ME = metabolizable energy

$ME_{(kJ)}$ = (18.81 Dig. crude protein) + (38.87 Dig. fat) + (17.14 Dig. carbohydrate) (Pereldik *et al.*, 1987)

value of feed rations is given in Table 2 and it corresponds with the standard for the given age category and physiological stage of animals as mentioned by Mertin *et al.* (1994).

Parameters necessary to calculate digestibility coefficients of the studied nutrients from feed rations were recorded in animals during the experiment, it means feed intake, residues of unconsumed feed and quantity of excrements. Samples were taken twice a day to determine the studied parameters, always an hour before feeding (i.e. at 8.00 and 14.00 o'clock), and they were weighed to the nearest 0.1 g. The excrements were preserved by freezing at the temperature –17°C. The content of nutrients was determined in samples of feed and excrements by chemical analyses in accordance with Decree No. 1497/1–4/1997–100 of the Ministry of Agriculture SR of 7th October, 1997 on official sampling and laboratory tests and evaluation of feeds.

The digestibility of crude protein and fat was determined by means of apparent digestibility, by a direct method in feed rations, and the digestibility of the studied nutrients in poultry shanks by an indirect (differential) Schürch's method (1969).

The results were processed by a two-factor analysis of variance.

RESULTS AND DISCUSSION

Basic variation and statistical characteristics of digestibility of nutrients in the studied feed rations are given in Table 3, and the results of two-factor analysis of variance with selected comparisons of feed digestibility are in Table 4.

The digestibility coefficient of crude protein was 80.75% in the first period of the experiment with control feed ration, 73.72% in the second period with 40.4% proportion of poultry shanks, and 70.35% in the third period with 50.4% proportion of poultry shanks. Signifi-

Table 3. Basic variation and statistical characteristics of digestibility of crude protein and fat in studied feed rations for minks

Digestibility coefficient		Stage of experiments (groups of animals)		
		A_1	A_2	A_3
Crude protein	$\bar{x}$	80.75	73.72	70.35
	$s_{\bar{x}}$	0.31	0.14	0.29
	%	1.95	0.96	2.05
Significance of differences		$1:2^{++}$ $1:3^{++}$ $2:3^{++}$		
Fat	$\bar{x}$	90.14	85.45	84.24
	$s_{\bar{x}}$	0.32	0.41	0.25
	%	1.77	2.42	1.46
Significance of differences		$1:2^{++}$ $1:3^{++}$ $2:3^{++}$		

$^{+}P \leq 0.05$, $^{++}P \leq 0.01$

Number of observations of animals in group A_1 to A_3, n = 25 (5 animals x 5 days)

Table 4. Two-factor analysis of variance with some observations of digestibility of feed rations

Source of variability	f	Digestibility of crude protein		Digestibility of fat	
		MS	F	MS	F
	14				
Groups A	2	704.1459	665.850++	242.1676	70.376++
Animals Z : A	12	10.0575		3.4411	
	60				
Days B	4	3.2088	2.366	7.1008	4.785++
Interaction AB	8	3.8285	2.823	7.3837	4.975++
Error of experiment BZ : A	48	1.3564		1.4840	
Significance of differences	$1:2^{+}$ $1:3^{++}$ $2:3^{++}$			$1:2^{++}$ $1:3^{++}$ $2:3^{+}$	

F	(f1	f2)
	0.05	0.01
A	3.885	6.927
B	2.565	3.737
AB	2.138	2.907

cant differences in digestibility of crude protein were between the control feed ration (A_1) and experimental feed rations with increased proportion of poultry shanks (A_2, A_3) as well as between the experimental feed rations.

The values of fat digestibility coefficient were 90.14, 85.45 and 84.24% at the studied stages of the experiment or groups of animals. In digestibility of fats we observed significant differences between the control feed ration and experimental feed rations, and between the experimental feed rations as well, similarly like in the digestibility of crude protein.

Results of digestibility of the studied nutrients in poultry shanks in dependence on their proportion in feed rations are given in Table 5. Digestibility coefficients of crude protein in poultry shanks were 63.33% and 60.13%, the differences being statistically significant on the level of significance $P \leq 0.01$. Digestibility of fat in poultry shanks was approximately on the same level, its values were 78.53 and 78.46%.

Table 5. Digestibility of crude protein and fat in poultry shanks (%)

Digestibility coefficient	Stage of experiment (group of animals)			Significance of differences
	A2	A3	Average	
Crude protein	63.33	60.13	61.73	2 : 3++
Fat	78.53	78.46	78.50	

Sample size N = 5
$^{+}P \leq 0.05$, $^{++}P \leq 0.01$

CONCLUSION

1. The digestibility coefficient of the studied nutrients in feed rations for minks decreases with increasing percentage proportion of poultry shanks in feed rations: for crude protein from 80.75 to 70.35%, and for fat from 90.14 to 84.24%.
2. The digestibility coefficient of crude protein in poultry shanks was 61.73%, and in fat 78.50%.
3. We recommend 40% proportion of poultry shanks in feed rations for minks as a maximum for the agricultural practice.

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Analysis of sport fishing yields from the Mže and Berounka rivers in 1975 to 1998

Analýza úlovků sportovních rybářů z Mže a Berounky v letech 1975 až 1998

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ABSTRACT: Based on sport fishery statistics from 1975 to 1998, fish yield in nine sections of the rivers Mže and Berounka (West Bohemia), relationships between yield of particular species, and yield changes in the longitudinal profile and years were evaluated. In the longitudinal profile of both rivers significantly decreased the total yield of all the fish species (average value of 74.0 kg/ha/year), the average biomass of stocked carp and their yield (61.6 kg/ha/year and 48.3 kg/ha/year, respectively), and the average yield of all the species without carp (26.0 kg/ha/year). The yield of the chub and bream decreased too (3.6 and 3.1 kg/ha/year, respectively), the yield of the fresh-water eel (2.6 kg/ha/year) was higher in upper sections with maximum values in the first half of the 1980's. The grayling was caught only in the Mže River (3.8 kg/ha/year). Out of carnivorous fish species, the pike (7.8 kg/ha/year) and the pike perch (1.0 kg/ha/year) were most frequently caught. The yield of the other species (perch, brown trout, tench and barbel) did not exceed 1.3 kg/ha/year. The yield of all the species except for the carp in medium-sized rivers accounts only for 2 to 5% of their biomass.

Keywords: sport fishing yield; dynamics; carp; other species; medium sized river

ABSTRAKT: Na základě sportovně rybářských statistik z období 1975 až 1998 byl hodnocen výlov ryb z devíti úseků Mže a Berounky, vztahy mezi výlovem jednotlivých druhů a změny výlovu v podélném profilu obou řek a čase. V podélném profilu statisticky významně klesal celkový výlov všech druhů ryb, (průměr 74,0 kg/ha/rok), biomasa nasazených i vylovených kaprů (průměr 61,6 a 48,3 kg/ha/rok), výlov všech druhů mimo kapra (26,0 kg/ha/rok) a výlov jelce tlouště a cejna velkého (3,6 a 3,1 kg/ha/rok). Výlov úhoře říčního (2,6 kg/ha/rok) byly nejvyšší v horních revírech Mže s maximem v první polovině 80. let. Lipan podhorní byl loven pouze v úsecích Mže (3,8 kg/ha/rok). Z dravců byla nejčastěji lovena štika obecná (7,8 kg/ha/rok) a candát obecný (1,0 kg/ha/rok). Výlov ostatních druhů (okoun říční, pstruh potoční, lín obecný a parma říční) nepřesáhl 1,3 kg/ha/rok). Výlov všech druhů, mimo kapra, nepřesahuje v řekách střední velikosti 2 až 5 % jejich biomasy.

Klíčová slova: sportovní rybolov; dynamika; kapr; ostatní druhy; středně velká řeka

INTRODUCTION

Statistical data from commercial fishing frequently contain time series of several tens of years (Wolter *et al.*, 2000), some of them go back as long as to the beginning of the 19th century (Iversen, 1996). Pond fisheries kept statistical data as long as for several centuries (Šusta, 1995). In addition there also exist published data on changes of the abundance, biomass and production of river ichthyocoenoses published in the special ichthyological studies, e.g. Libosvárský, 1989; Penczak *et al.*, 1998; Korte *et al.*, 1999. It is very advantageous to have the fishery statistics as well as original estimates for particular sections independently of each other. Careful analysis of all these data is one of the main assumptions for maintaining the sustainable yield, diversity and stability of ichthyocoenoses. When studying river ichthyocoenoses, it is possible to assume increasing values of the abundance, biomass, and production as well in stream longitudinal profiles. It is further known that values

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of all these parameters are higher in the rivers than those in lakes or artificial reservoirs (Randall *et al.*, 1995).

Out of this country's streams, estimates of fish abundance and biomass are available from medium-sized streams of the Jihlava River (Lusk, 1977; Losos *et al.*, 1980), Svratka and Svitava rivers (Lusk, 1980). A general summarization for these streams in the Czech Republic and Slovak Republic was published by Pivnička (1988). Yields from the Morava River have recently been published by Baruš *et al.* (2000).

In the work presented, yields of sport fishermen in sections of the rivers Mže and Berounka up to Berounka 7 are analyzed for a period of 1975 to 1998. For Berounka 7, there are independent estimates of the species structure and biomass of the fish from the locality Třímany near Radnice.

MATERIAL AND METHODS

The Berounka River belongs to large rivers with its average flow rate of 36 m^3/s at its mouth, length of 246.1 km and river basin area of 10 690 km^2 (together with the Mže River). All the ten fishing sections of the Berounka are coarse fishing waters. The upper part of the Berounka – Mže has at the mouth of the Mže into the Berounka in Plzeň its average flow rate of 8.55 m^3/s, length of 107 km, river basin area of 1 829 km^2 (Vlček, 1984). It is divided into seven coarse fishing waters and three trout zones.

The following common names of fish and their Latin equivalents were used: carp (*Cyprinus carpio*), pike (*Esox lucius*), chub (*Leuciscus cephalus*), bream (*Abramis brama*), eel (*Anguilla anguilla*), grayling (*Thymallus thymallus*), pike-perch (*Stizostedion lucioperca*), perch (*Perca fluviatilis*), brown trout (*Salmo trutta* morpha *fario*), barbel (*Barbus barbus*).

The data on stocked fish and yield were taken from long-term statistical records of the West-Bohemian Fishing Association. Out of them, five sections of coarse fishing waters of the Mže and four sections of the West-Bohemian part of the Berounka (Berounka 10 to 7) were evaluated. The evaluation did not include any coarse fishing waters of Mže 4 (Hracholusky reservoir) and Mže 7A (only ponds). The statistics include data from the period of 1975 to 1998. The yield as well as biomass of stocked fish are presented in kg/ha/year, exceptionally the stocked pike and pike-perch in number of specimens ha/year.

The estimates of the fish abundance at the locality Třímany were acquired by the mark and recapture method (Ricker, 1975). The preliminary estimate of the biomass was based on a ratio between the number of fish and their biomass for the other streams in the Czech Republic and Slovak Republic (Pivnička, 1988).

RESULTS

Total of 74.0 kg (57.6–104.4 kg) of the fish was caught in average on the river sections of interest. The yield of all the species in particular sections is summarized in Table 1. In the longitudinal profile of the stream the total yield considerably decreased (Figure 1). The yield of the fish except for the carp decreased in the same way (Figure 2). In the yield, the carp was unambiguously prevalent, 71.3 kg of the carp per each 100 kg of the fish were caught (Figure 3). The carp yield in all the sections was completely dependent on the stocked biomass, from each 100 kg/ha/year of stocked carp, 76.9 kg were caught on average (Figure 4). On average, 116.7 kg of the fish were stocked into the upper sections of Mže 7 to Mže 2, into the lower sections (Mže 1 to Berounka 7) only 17.5 kg of the carp were stocked (Table 1). The mean biomass of the carp caught was negatively correlated to the amount of the biomass stocked and increased from 1.44 kg in sections of the Mže and 1.64 kg in those of the Berounka to 1.97–2.12 kg. In particular years (1975 to 1998), the average yield of the carp varied from 30.4 kg to 65.0 kg (Figure 5).

The average yield of pike was 7.8 kg, the yield and the mean weight of specimens (2.12 kg) in the longitudinal

Table 1. The average yield of fish species and carp stocked in 1975 to 1998 (kg/ha/year) in particular sections of the Mže and Berounka rivers

Section	Distance from the source (km)	Carp	Pike	Chub	Bream	Eel	Grayling	Perch	Brown trout	Pike perch	Tench	Barbel	Carp stocked
Mže 7	23.0	107.6	7.7	2.7	4.8	2.6	5.3	5.0	1.4	1.6	1.7	0.1	121.6
Mže 5	55.0	65.0	10.6	5.4	3.5	4.5	4.1	0.7	0.9	1.8	1.0	1.3	111.0
Mže 3	82.0	50.4	2.9	1.3	4.0	3.7	1.5	0.9	6.3	1.6	0.4	0.4	66.1
Mže 2	90.5	130.8	8.2	2.4	5.2	6.6	6.6	0.6	2.1	0.6	1.0	0.4	168.2
Mže 1	104.5	24.5	3.0	1.7	4.9	1.0	1.3	0.3	0.2	0.3	0.3	0.4	19.6
Berounka 10	124.5	13.0	5.9	2.9	1.3	0.7	0.0	0.7	0.0	0.3	0.4	0.2	12.9
Berounka 9	142.5	11.9	11.0	4.2	1.6	0.8	0.0	0.6	0.0	0.6	0.6	0.5	17.0
Berounka 8	154.5	7.8	8.1	4.4	0.8	1.2	0.0	0.5	0.0	0.6	0.6	0.7	13.1
Berounka 7	164.0	23.7	12.5	7.6	1.3	2.3	0.0	1.8	0.1	1.2	1.2	1.7	24.8
Average		48.3	7.8	3.6	3.1	2.6	2.1	1.2	1.2	1.0	0.8	0.6	61.6

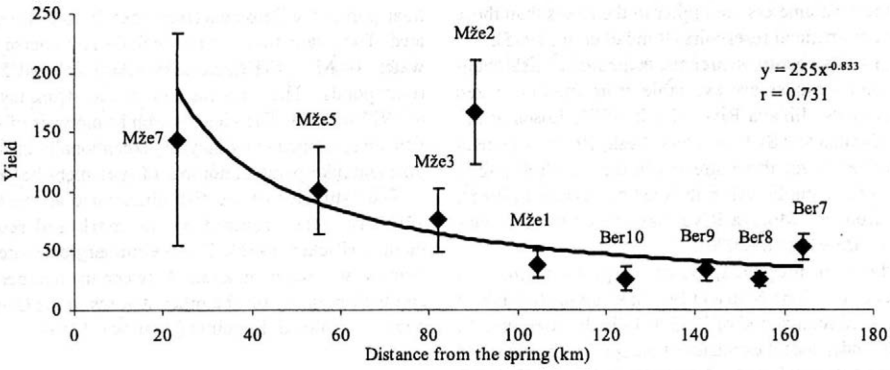

Figure 1. Total yield (kg/ha/year) of all fish species in sections of the Mže and Berounka rivers, the vertical lines represent ± standard deviation

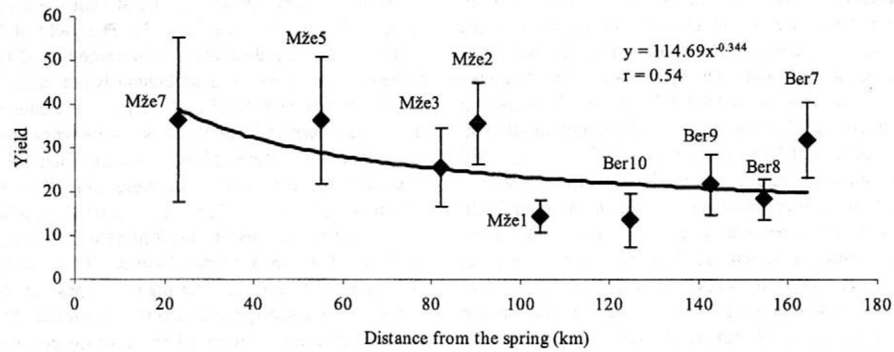

Figure 2. Total yield without carp in sections of the Mže and Berounka rivers, the vertical lines represent ± standard deviation

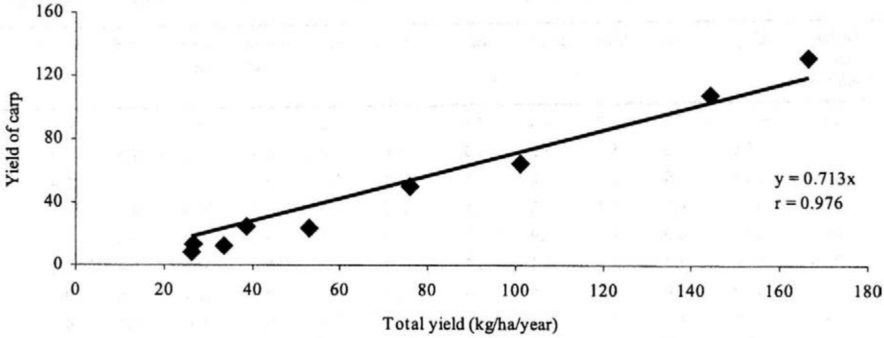

Figure 3. The relationship between the total yield of all fish species and yield of carp

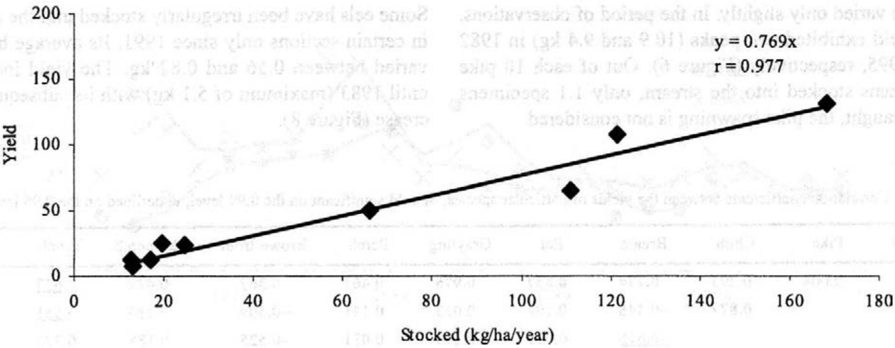

Figure 4. The relationship between stocked and caught carp

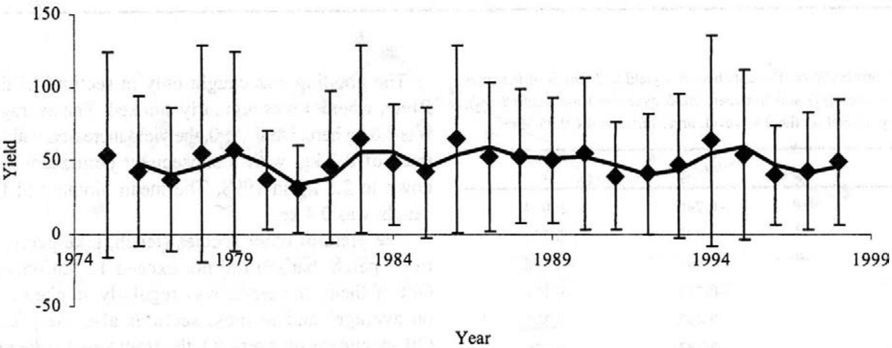

Figure 5. Yield of carp in different years, the vertical lines represent ± standard deviation

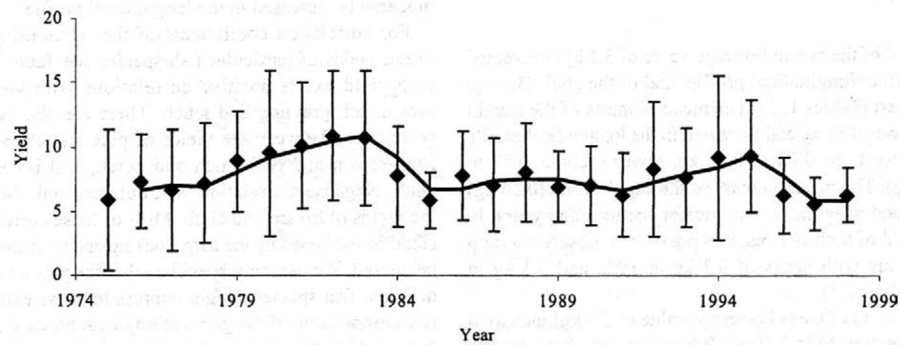

Figure 6. Yield of pike in different years, the vertical lines represent ± standard deviation

profile varied only slightly. In the period of observations, the yield exhibited two peaks (10.9 and 9.4 kg) in 1982 and 1995, respectively (Figure 6). Out of each 10 pike specimens stocked into the stream, only 1.1 specimens were caught, the pike spawning is not considered.

Some eels have been irregularly stocked into the streams in certain sections only since 1991. Its average biomass varied between 0.56 and 0.82 kg. The yield increased until 1983 (maximum of 5.1 kg) with its subsequent decrease (Figure 8).

Table 2. Correlation coefficients between the yields of particular species, in bold significant on the 0.99 level, underlined on the 0.95 level

Species	Pike	Chub	Bream	Eel	Grayling	Perch	Brown trout	Pike-perch	Tench	Barbel
Carp	0.004	–0.293	**0.774**	**0.837**	**0.975**	0.463	0.367	0.422	0.637	–0.265
Pike		**0.877**	–0.448	0.102	0.013	0.141	–0.509	0.185	0.551	0.654
Chub			–0.615	–0.091	–0.279	0.031	–0.525	0.188	0.372	0.877
Bream				0.606	**0.795**	0.254	0.461	0.288	0.233	–0.380
Eel					**0.826**	0.036	0.491	0.470	0.383	0.097
Grayling						0.387	0.268	0.407	0.599	–0.234
Perch							0.038	0.491	**0.823**	–0.190
Brown trout								0.510	–0.135	–0.253
Pike–perch									0.529	0.305
Tench										0.171

Table 3. Correlation coefficients between yield and length of the river from its source (r_1) and between yield over the time studied (r_2), in bold significant on the 0.99 level, underlined on the 0.95 level

Species	r_1	r_2
Carp	**–0.740**	0.064
Pike	0.278	–0.201
Chub	0.451	**–0.548**
Bream	**–0.777**	–0.111
Eel	–0.492	–0.392
Grayling	**–0.782**	0.235
Perch	–0.540	**–0.664**
Brown trout	–0.414	**–0.504**
Pike-perch	–0.622	0.138
Tench	–0.449	**–0.747**
Barbel	0.383	0.106

Yield of the bream (average value of 3.1 kg) decreased in the river longitudinal profile, that of the chub (3.6 kg) increased (Tables 1, 3). The mean biomass of the caught bream was 0.51 kg and increased in the longitudinal profile (upper sections 0.28 to 0.43 kg, lower sections 0.57 to 0.71 kg). The mean biomass of the caught chub (0.56 kg) fluctuated irregularly in particular sections and years. In the yield of both species, it is possible to observe certain synchrony with peaks of 6.7 kg in 1982 and 5.3 kg in 1986 (Figure 7).

The yield of the eel (average value of 2.6 kg) increased up to section Mže 2 (from 2.6 to 6.6 kg), from section Mže 1 to Berounka 7 the yield was lower (0.7 to 2.3 kg).

The grayling was caught only in sections of the Mže River, where it was regularly stocked. The average yield was 3.8 kg here. Until 1990, the yield increased with a maximum of 8.7 kg, with a subsequent permanent decrease down to 2.5 kg in 1998. The mean biomass of the fish caught was 0.4 kg.

The yield of other species (tench, pike-perch, brown trout, perch, barbel) did not exceed 1.3 kg on average. Out of them, the tench was regularly stocked (1.56 kg on average) and in most sections also the pike perch (20 specimens on average), the trout was stocked only in two sections, the perch and barbel were not stocked at all. In all the sections studied, the yields of the perch, tench and pike-perch were 1.2, 0.8 and 1.0 kg, respectively, the highest values being achieved in upper sections, the lower values in middle sections – Mže 1 and Berounka 10 (Figure 9). The yield of barbel (0.6 kg) moderately increased in the longitudinal profile.

For correlation coefficients of the relationships between yields of particular fish species see Table 2. The carp yield exerts positive correlations with yields of bream, eel, grayling and tench. There are also positive correlations between the yields of pike and chub, grayling, bream and eel, tench and perch, and barbel and chub. Negative correlation was obtained only between the yields of bream and chub. Most of these correlations could be explained by the carp stocking and by fishermen's behaviour. We can only speculate that the proportions of different fish species caught express to some extent the real composition of the given ichthyo-coenoses. Correlation coefficients of the relationships between the yield of particular fish species, the river length and time pe-

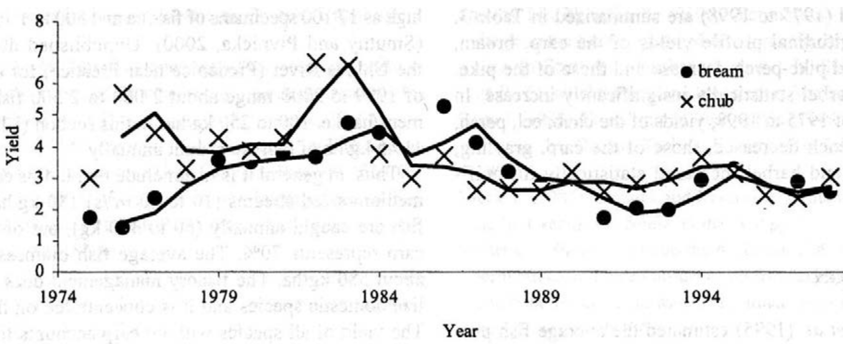

Figure 7. Yield of bream and chub in different years

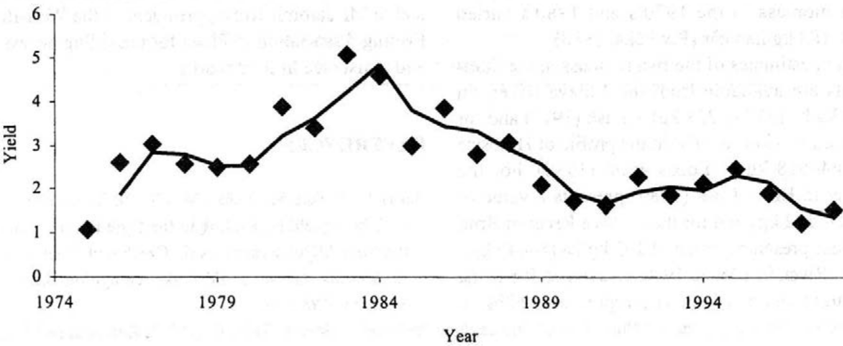

Figure 8. Yield of eel in different years

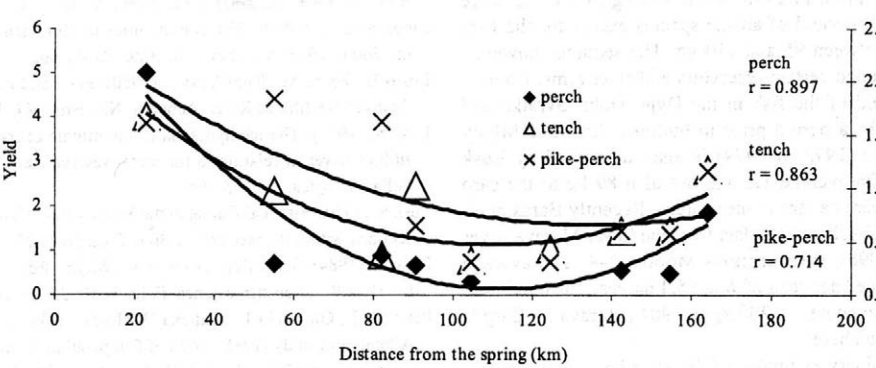

Figure 9. Yield of perch, tench, and pike perch in sections of the Mže and Berounka rivers

riod studied (1975 to 1998) are summarized in Table 3. In the longitudinal profile yields of the carp, bream, grayling and pike-perch decrease and those of the pike, chub and barbel statistically insignificantly increase. In the period of 1975 to 1998, yields of the chub, eel, perch, trout and tench decreased, those of the carp, grayling, pike-perch and barbel increased statistically insignificantly.

DISCUSSION

Randall *et al.* (1995) estimated the average fish production from 55 river localities throughout the world as 273 kg/ha/year. He explained the high production in comparison with lakes or valley reservoirs by higher values of the abundance as well as biomass of the fish in the rivers connected with a higher difference of habitats and numerous allochthonous energy sources. In medium-sized streams of the Czech Republic and Slovak Republic, the fish biomass in the 1970's and 1980's varied within 408 ± 189 kg/ha/year (Pivnička, 1988).

Independent estimates of the fish biomass in medium-sized streams are available from the Jihlava River, on average 597 kg/ha (377–1 223 kg) – Lusk (1977) and for the same stream in 1971 to 1978 in the profile of Hrubšice 246 kg/ha (64–818 kg) – Losos *et al.* (1980). For the Svratka River in Brno, Lusk (1980) presents a value of 222 kg/ha (27–562 kg) and for the Svitava River in Brno the same author presents a value of 192 kg/ha (8–449 kg). In the Svratka River, in 1969 to 1976, on average 308 kg/ha fish were caught, out of which carp represented 63%, in the Svitava River 96 kg/ha, out of this 78% of the carp (Lusk, 1980).

The average yield in sections of the Mže and Berounka (74 kg) was considerably lower than that from the Dyje in a period of 1984 to 1998 in sections below the water reservoir Nové Mlýny (Baruš *et al.*, 2000). The yield ranged between 75 and 300 kg/ha/year here with the only exception in 1996, when 450 kg of the fish were caught. The yield of all the species except for the carp ranged between 95 and 110 kg. The sections, however, also included certain reservoirs and river arms. Comparable yield of the fish in the Dyje, Dolní Svratka and Jihlava for a period prior to building the Nové Mlýny reservoirs (1975 to 1979) is also mentioned by Lusk (1984). On average 123 kg, out of it 89 kg of the carp (72%), were caught in these areas. Recently Baruš *et al.* (2000) published yield data from the lower Morava River (1970–1998), river sections Morava 2–4. The average yield ranged between 28.6 to 95.4 ha/year, the maximum yield attained nearly 200 kg in 1984 (Morava 3). Carp is not stocked here.

Preliminary estimates of the abundance and biomass of the fish from the river section Berounka 7 between 1998 and 1999 below the weir in Třímany near Radnice are as high as 17 100 specimens of fish/ha and 800 to 1 700 kg/ha (Smutný and Pivnička, 2000). Unpublished data from the Úhlava River (Předenice near Přeštice) for a period of 1999 to 2000 range about 2 000 to 2 500 fish specimens/ha, i.e. 100 to 250 kg/ha. In this section (Úhlava 2), 119.5 kg/ha of fish are caught annually.

Thus, in general it is to conclude that in this country's medium-sized streams (10 to 40 m^3/s) 130 kg/ha of the fish are caught annually (60 to 300 kg), out of this the carp represents 70%. The average fish biomass attains about 580 kg/ha. The fishery management does not utilize domestic species and it is concentrated on the carp. The yield of all species without carp accounts for about 2–5% of their biomass.

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Impact of selection of dual purpose cattle on secondary traits

Dopad šlechtění skotu s kombinovanou užitkovostí na druhotné vlastnosti

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ABSTRACT: The selection of dual purpose cattle is simulated by selection indices. It includes milk (amount of milk, milk protein) and beef production (daily gain, valuable meat cuts, growth capacity, feed conversion) and secondary traits (fertility, longevity, mastitis, calving difficulty). Partial breeding values for traits are combined into selection indices. Economic values of 1, 1.5, 2 and 4 multiples of results of the profit function are assigned to secondary traits in the indices. In the case of basic variant, the genetic gain of milk production is 58 kg and effects of selection on milk and beef production and secondary traits are at a ratio 81 : 20 : –1. The most important traits in the indices are amount of milk, feed conversion, milk protein content and daily gain. Most secondary traits show worse values. In the case of 1.5 multiple overvaluation of secondary traits, the genetic gain is 51 kg of milk and ratios of selection are 72 : 19 : 9. In the case of 2 multiple overvaluation the genetic gain of milk is 43 kg and ratios of effects for groups of traits are 59 : 18 : 23. In the case of 4 multiple overvaluation the genetic gain is 15 kg and the ratios are 17 : 10 : 73. With overvaluation of secondary traits, the ratio of milk to beef production is decreased.

Keywords: cattle; selection indices; functional traits; breeding value; genetic gain

ABSTRAKT: Šlechtění skotu s kombinovanou užitkovostí je simulováno selekčními indexy, zahrnujícími mléčnou užitkovost (množství mléka, mléčná bílkovina), masnou užitkovost (přírůstek, složení jatečného trupu, kapacita růstu, konverze krmiv) a druhotné funkční vlastnosti (plodnost, dlouhověkost, mastitidy, obtížnost telení). Plemenné hodnoty pro jednotlivé vlastnosti jsou kombinovány do selekčního indexu. Druhotným vlastnostem v indexu je přidělena ekonomická hodnota ve výši 1, 1,5, 2 a 4násobků výsledků ze ziskové funkce. V případě základní varianty je genetický zisk mléčné užitkovosti 58 kg. Souhrnné selekční efekty u mléčné a masné užitkovosti a druhotných vlastností jsou v poměru 81 : 20 : –1. Nejdůležitějšími vlastnostmi v indexu jsou množství mléka, konverze krmiv, obsah mléčné bílkoviny, denní přírůstek. U většiny druhotných vlastností dochází ke zhoršení. V případě 1,5násobném ekonomickém nadhodnocení druhotných vlastností je genetický zisk 51 kg mléka a poměry selekce jsou 72 : 19 : 9. V případě 2násobného nadhodnocení je genetický zisk u mléka 43 kg a poměry efektů pro skupiny vlastností jsou 59 : 18 : 23. V případě 4násobného nadhodnocení je genetický zisk 15 kg a poměry 17 : 10 : 73. S nadhodnocením druhotných vlastností se zužuje poměr mezi mléčnou a masnou užitkovostí. Ekonomické hodnoty druhotných vlastností a chyby v jejich určení významně neovlivňují šlechtitelský cíl a selekční efekty získané u hlavních užitkových vlastností. Ke změnám v poměrech dosahovaných genetických zisků dochází pouze v případě drastické změny (nadhodnocení) ekonomických hodnot druhotných vlastností. Zvýšení selekčního tlaku u druhotných vlastností se více projeví v selekčním efektu u mléčné než u masné užitkovosti. Mléčná užitkovost je i v případě skotu s kombinovanou užitkovostí nejdůležitější vlastností při šlechtění, a to i při velké změně v ekonomických hodnotách jednotlivých vlastností. Zvýšení selekčního efektu u druhotných vlastností je možné dosáhnout jen v případě jejich podstatného ekonomického nadhodnocení.

Klíčová slova: skot; selekční indexy; funkční vlastnosti; plemenná hodnota; genetický zisk

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INTRODUCTION

Breeding is always based on the complex of traits when selection indices are constructed with an intention or without any indices, based on subjective evaluation. Selection of breeding cattle is presently carried out mainly on the basis of objective indices. A survey and comparison of the milk production indices used in different countries were compiled e.g. by Leitch (1994). In different countries the breeding goal is rather different (it is not always identical) and therefore partially different indices are used although an extensive international trade takes place. The impact of these differences on the applicability of selected individuals in other countries was discussed by Powell (1995). Comparison of selection by different indices of the same population of bulls of dual purpose cattle was provided by Averdunk *et al.* (1996). Selection indices for the European Pied Cattle (Simmental type) were elaborated by Miesenberger (1997). Selection indices for the Czech Pied Cattle were proposed by Váchal *et al.* (1975) or recently by Přibyl (1994) and Přibyl and Přibylová (1998). A survey of procedures used in individual countries for the evaluation of non-dairy (meat production and other traits) traits of cattle is published in Interbull Bulletin No. 13 (1996). The farmers' policy does not always follow the optimal strategy of selection according to a complex of traits. Selection pressure is frequently practised only on principle characters (Přibyl *et al.*, 1995).

The attention has recently been focused on secondary functional traits of dairy cattle. In 1996 a seminar about secondary traits took place (Gembloux, Belgium, 21–23. 1., Interbull Bulletin No. 12).

A simulation study of selection programme including functional traits and conformation as for early predictors was made by Soelkner *et al.* (1999), Soerensen *et al.* (1999) and Egger-Danner *et al.* (1999).

A system of recording and collecting of data on functional traits was presented by Cassandro *et al.* (1999). Selection indices with functional traits for a wide complex of traits were presented by Pryce *et al.* (1999), Juga *et al.* (1999), Van der Beek (1999), Pedersen and Aamand (1999) and Steine and Sehesten (1999).

One of the basic problems in breeding is determination of economic values of traits which are the basis for suggestion of a breeding goal. The procedures used for determination of economic values were summarised by Groen *et al.* (1997). Breeding is ahead of the productivity manifestation. Therefore stable economic values are important even under changing production conditions. An algorithm for calculation of economic values with the special efforts on functional traits was developed by Colleau and Moureaux (1999). Wolfová *et al.* (1994) compared the economic value of the Czech Pied and Black Pied Cattle on the basis of EU (German) prices before and after the introduction of the agrarian reform and based on the prices in the Czech Republic in 1989 and in 1992. In spite of considerable differences in economy, the economic values determined on the basis of profit functions do not differ very much. Economic values including functional traits for beef cattle were elaborated by Coopman *et al.* (1999).

Objective

The aim of the present paper is to assess what can be expected in the case of a different (possibly also incorrect) orientation of cattle breeding. Namely to compare the expected selection effect of the Czech Pied Cattle in dependence on the alternatively substituted economic values of secondary functional traits within the range of normal up to extreme levels.

METHODS

The work is based on the simulation of selection effect on the basis of genetic parameters, economic values, selection intensity and extent of performance recording. Selection is carried out by two-stage selection indices according to methodology of Cunningham (1970, 1975). In the first stage there are traits for which the information is available at the age of selection of young animals (heifers, young bulls). In the second stage are all traits. Breeding values of traits are combined in selection indices with maximal exploitation of information sources (Přibyl, 1994). Traits in indices are shown in Table 1.

Selection effect of two-stage selection is according to Roenningen (1969)

$$\Delta = d_1 \cdot \sqrt{b_1 \cdot P_1 \cdot b_1} + d_2 \cdot \sqrt{b_2 \cdot P_2^* \cdot b_2} = d_1 \cdot \delta_1 + d_1 \cdot \delta_2, \quad (1)$$

where: d_1, d_2 – standardised selection differences in the first and second stage of selection,

b_1, b_2 – vector of weights for traits in indices,

P_1 – covariance matrix of information sources in the first stage index

P_2^* – covariance matrix of information sources in the second stage index, after correction of variability through selection in the previous stage.

δ1, δ2 – standard deviation of indices in the first and second stage.

By substitution in (1) for each trait

$$\Delta_{gi} = d_1 \cdot \frac{b_1 \cdot G_{1i}}{\delta_1} + d_2 \cdot \frac{b_2 \cdot G_{2i}^*}{\delta_2}, \quad (2)$$

where: Δ_{gi} – effect of selection for trait (i),

G_{1i},G^*_{2i} – i-th columns from genetic covariance matrices of corresponding indices for the first and second stage (*correction of variability through selection in the previous stage).

The expected genetic gain (Dickerson and Hazel, 1944; Rendel and Robertson, 1950) is calculated according to

Table 1. Traits and sources of information included in indices.

Trait	Unit	Heifers	Cows (dams of sires)	Young bulls	Proven bulls (sires of bulls)
1. Gain in test	g	S	S	V,S	V,S,P
2. Gain until selection	g	S	S	V,S	V,S,P
3. Milk	kg	M	V,M,S	M	M,S,P
4. Milk fat	%	M	V,M,S	M	M,S,P
5. Milk protein	%	M	V,M,S	M	M,S,P
6. Growth capacity	kg	V,M,S	V,M,S	–	S,P
7. Calving difficulty =	%	S	V,S	–	S,P
8. Heifer delay to conception +	days	S	V,S	–	S,P
9. Calving interval	days	S	V,S	–	S,P
10. Survival until 48 m	%	S	S	–	S
11. Mastitis	%	S	V,S	–	S,P
12. Net gain	g	S	S	–	P
13. Heifer insemination index		O	O	–	V
14. Cow insemination index		O	O	–	V
15. Calving difficulty *	%	O	O	–	V

V = performance; M = dam; O = father; S = halfsibs, P = progeny
= dam's component, * sire's component, + from insemination to conception.

$$\Delta_G = \frac{\sum k_j \cdot \Delta_j}{\sum k_j \cdot L_j}, \quad (3)$$

where: k_j – proportion of progeny from j-th path of selection
Δ_j – genetic gain from j-th path of selection (money or natural units)
L_j – average generation interval from j-th path of selection.

Intensities of selection and generation intervals are shown in Table 2.

Table 2. Generation intervals and intensities of parent selection

Parents	k	L	i_1 (%)	i_2 (%)
Parents of cows:				
Heifers	0.25	2.4	70	–
Cows	0.75	5.7	70	80
Young bulls	0.25	2.2	60	–
Proven bulls	0.75	8.4	60	10
Parents of bulls:				
Dams of bulls	1.00	6.8	70	3
Sires of bulls	1.00	8.4	60	5

i_j (%) = selection intensity in selection stages 1 or 2 in %

The basic economic values of the traits in the aggregate genotype are defined in Table 3. The economic values of 1, 1.5, 2 and 4 multiple of the result of profit function are assigned to the secondary traits in the indices, while the economic values in milk and meat production are constant in all variants.

Table 3. Basic economic values of traits (modified according to Wolfová *et al.*, 1994)

Trait	Unit	sg	Economic value in CZK	
1. Amount of milk	kg	350.00	2.57	M
2. Milk protein content	%	0.125	2310.00	M
3. Daily gain in fattening	g	55.00	3.78	B
4. Proportion of valuable meat cuts	%	0.95	56.00	B
5. Growth capacity	kg	17.50	3.23	B
6. Delay of heifers = +	days	5.47	–5.92	F
7. Calving interval =	days	7.04	–15.91	F
8. Delay of heifers * +	days	5.47	–5.92	F
9. Calving interval *	days	7.04	–15.91	F
10. Nutrient consumption per production unit	MJ	1.50	–175.18	B
11. Productive life	lactation	0.63	404.25	F
12. Mastitis	%	5.59	–9.25	F
13. Calving difficulty = a	%	8.67	–16.50	F
14. Calving difficulty *a	%	8.67	–16.50	F

a = percentage proportion of calving in the 3rd category
\+ delay of heifers from the first insemination to conception
= dam's component, * sire's component
M = milk production, B = beef production, F = secondary functional traits

RESULTS

The present paper is based on Přibyl and Přibylová (1998), who calculated selection indices for the mentioned cattle category. Table 4 shows the yearly genetic gains and Table 5 the proportion of single traits in the total gain depending on the assigned economic values. In the case of the basic variant, the genetic gain of milk reached 57.74 kg and this particular trait represents 73.9% of the total genetic gain of the complex of all traits. The second most important trait is feed conversion which participates in the total gain with 12.06%. The following traits, according to their importance, are daily gain (7.02%) and milk protein content (6.77%).

Table 4. Genetic gains in individual traits in dependence on economic values

Trait	1 x	1.5 x	2 x	4 x
1. Amount of milk	57.74	50.89	43.20	15.08
2. Milk protein content	0.01	0.01	0.01	0.01
3. Daily gain in fattening	3.73	3.54	3.54	2.84
4. Proportion of valuable meat cuts	–0.07	–0.07	–0.06	–0.04
5. Growth capacity	2.09	1.99	1.91	1.32
6. Delay of heifers =	0.10	–0.03	–0.15	–0.43
7. Calving interval =	0.08	–0.11	–0.27	–0.68
8. Delay of heifers *	0.04	–0.05	–0.13	–0.32
9. Calving interval *	0.04	–0.08	–0.18	–0.42
10. Feed conversion	–0.14	–0.13	–0.13	–0.11
11. Productive life	–0.01	–0.00	0.01	0.03
12. Mastitis	0.22	0.15	0.08	–0.13
13. Calving difficulty=	–0.56	–0.70	–0.81	–0.97
14. Calving difficulty*	0.17	0.08	0.00	–0.21

Table 5. Proportion of traits in % in the total gain in dependence on the economic values

Trait	1 x	1.5 x	2 x	4 x
1. Amount of milk	73.90	64.96	52.44	13.19
2. Milk protein content	6.77	6.94	6.63	4.05
3. Daily gain in fattening	7.02	6.65	6.33	3.65
4. Proportion of valuable meat cuts	–1.83	–1.87	–1.68	–0.85
5. Growth capacity	3.37	3.19	2.91	1.45
6. Delay of heifers =	–0.29	0.14	0.82	3.49
7. Calving interval =	–0.65	1.26	4.08	14.64
8. Delay of heifers *	–0.11	0.23	0.73	2.58
9. Calving interval *	–0.30	0.96	2.72	9.16
10. Feed conversion	12.06	11.47	10.85	6.28
11. Productive life	–2.10	–0.60	2.24	14.15
12. Mastitis	–1.02	–1.01	–0.66	1.68
13. Calving difficulty=	4.60	8.62	12.65	21.89
14. Calving difficulty*	–1.42	–0.94	–0.06	4.64

Secondary traits mostly show worse values with the exception of maternal components of calving difficulty. Milk production in general participates in the total genetic gain with 80.67%, meat production with 20.62% and secondary traits show a general loss of 1.29% (Table 6).

Table 6. Proportion of gains according to groups of traits in %, in dependence on the level of economic values for secondary traits

Group of traits	1 x	1.5 x	2 x	4 x
Milk production	80.67	71.90	59.07	17.24
Meat production	20.62	19.44	18.41	10.53
Secondary traits	–1.29	8.66	22.52	72.23

The majority of effects for milk and beef production is in accordance with Egger-Danner *et al.* (1999).

In the case of 1.5 multiple overvaluation (whether due to a change in the economic environment or inaccurate determination of economic values) of secondary traits, the genetic gain in milk decreased to 50.89 kg (Table 4), which represents 64.96% of the total gain (Table 5). The importance of milk in breeding in general decreased to 71.90% (Table 6), meat retained approximately the same position (19.44%), but the importance of secondary traits increased to 8.66%.

In the case of 2 multiple overvaluation of secondary traits the importance of milk decreased to 59.07%, meat to 18.41% and the importance of secondary traits increased to 22.52%. It results from the given data that meat production has mostly retained its importance in the selection, while milk production has been decreasing, but still keeps the greatest importance in the selection.

In the case of rather extreme 4 multiple economic overvaluation of secondary traits, the genetic gain of milk decreased to 15.08 kg. Milk production in general represents 17.24% of the total gain, meat production 10.53% and secondary traits 72.23%. It is only this variant where all the secondary traits are improved.

CONCLUSION

The economic values of secondary traits and mistakes in their determination do not significantly influence the breeding goal and selection effects obtained for the main production traits. The influence occurs only in the case of drastic changes.

The increased stress in selection of secondary traits is reflected in the selection effect on milk rather than on meat production.

Milk production is the most important breeding trait also in the dual purpose cattle, even in conditions of substantial changes in economic values of single traits.

The improvement of secondary traits occurs only in the case of their substantial economic overvaluation.

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Relationship between growth and milk production in dairy cattle

Vztah růstu a mléčné užitkovosti dojeného skotu

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ABSTRACT: Relationships between growth and milk production in dairy cows were reviewed. Some studies revealed a negative relationship between increased prepubertal growth intensity and subsequent milk production. Other studies did not confirm that relation. Growth intensity is highly variable, lowly heritable, and a poor indicator of milk production. First lactation milk yield is related to body weight, age, and body condition score at the first calving. Generally recommended optimal body weight and age at the first calving are 570 kg (i.e. 85% of mature weight) and less than 24 months, respectively. The costs of dairy replacement heifer rearing can be reduced by altering feeding programmes, accelerated growth intensity, and early breeding. Genetic variability in the shape of the growth curve can be used for improvement of an individual ability to mature at the early age. In selection for early maturity, decreasing mature size would be expected. Investigation of biological fundaments of growth and particularly its hormonal control is an opportunity for further studies of the relationship between growth and milk production in dairy cattle.

Keywords: heifers; growth; milk production; early maturity; GH gene polymorphism

ABSTRAKT: Byl sestaven přehled poznatků o vztahu růstu a mléčné užitkovosti krav. V některých studiích byl prokázán negativní vztah zvýšené intenzity růstu v prepubertálním období na následnou mléčnou užitkovost. V jiných studiích tento vztah prokázán nebyl. Intenzita růstu je velmi variabilní ukazatel s nízkou dědivostí, a proto ho nelze použít k předpovědi budoucí mléčné užitkovosti. Produkce mléka na první laktaci je ovlivněna hmotností, věkem a tělesnou kondicí při prvním otelení. Úpravou krmných režimů, a tím i průběhu růstu, lze dosáhnout při prvním otelení obecně doporučované optimální hmotnosti (570 kg, 85 % hmotnosti v dospělosti) a věku (méně než 24 měsíců). Tato optimalizace je založena na minimalizaci nákladů na odchov jalovic při zajištění jejich dostatečného vývinu a přípravy na budoucí produkci mléka. Pro zlepšení individuální schopnosti zabřeznout a otelit se v optimálním věku a hmotnosti by mohla být využita genetická variabilita v ranosti růstu. Šlechtění na ranost by pravděpodobně přineslo zmenšení velikosti těla v dospělosti. Nové poznatky o biologické podstatě procesu růstu, zvláště jeho řízení, jsou významnou příležitostí k modernímu studiu vztahu růstu a mléčné užitkovosti.

Klíčová slova: jalovice; růst; mléčná užitkovost; ranost růstu; růstový hormon; genetický polymorfismus

Modern methods of dairy cattle husbandry are based on perfect herd management. Even though replacement heifer rearing has often been neglected, it should be paid due attention because the length of nonproductive period has important consequences for herd profitability. Age and live weight at first calving are the main criteria of heifer rearing evaluation. A number of studies, often with contradictory conclusions, have been published describing the relationships between growth, body weight, body size and subsequent milk production. The objective of this paper is to review the results of experiments and investigations, to synthesize them and to discover other possible ways of studying the relationship between growth and milk production.

A review of experiments

Growth, mainly in cattle, is a matter of time. Experiments aimed at growth as a production trait are lengthy and costly. Hence experiments lasting 10 to 15 years are not exceptional. Growth as a physiological trait has the same biological fundaments in all species of farm animals. Model animals with considerably shorter generation intervals are used to study this trait. But specificities of the single species, and growth-related production traits, should be investigated in the particular species of farm animals.

Field studies of farm animals are often conducted instead of complicated and costly experiments. A disadvantage of these studies is that only the rules of data collection are defined methodically but rearing conditions cannot be influenced in most cases. Nevertheless, results of field studies can be used to analyze relationships between production traits, between growth and milk production in this case. Any evaluation should consider the possible extent of result generalization or it should be stated that results are applicable in the given conditions.

Many experiments have indicated that the influence of growth intensity on milk production should be investigated in a prepubertal and postpubertal period separately.

Some studies demonstrate a negative relationship between growth rate and subsequent milk production. Heifers with accelerated growth in prepubertal period had lower milk production in the first lactation than heifers from standard rearing (Gardner *et al.*, 1977; Little and Kay, 1979). Important findings were reported by Sejrsen *et al.* (1982). They are based on the fact that the mammary gland growth is functionally conditioned by reproductive process and variations in hormone concentrations, but the basic structure of mammary gland is constituted at birth and its further growth is isometric to the whole body growth until the age of 2–3 months. The growth intensity of mammary gland increases in subsequent period as a result of parenchyma formation. The parenchyma content in heifers receiving feed *ad libitum* in the perpubertal period (actual weight gain 1 218 g/day) was lower by 23% than in the group of heifers on a diet amounting to 60% of *ad libitum* consumption (weight gain 613 g/day). This experiment included a study of blood plasma hormone concentrations (growth hormone, prolactin, insulin, glucocorticoids) (Sejrsen *et al.*, 1983). The negative influence of more intensive nutrition on mammary gland development in prepubertal period is explained by a lower plasma concentration of growth hormone.

Unlike the above findings, other experiments did not demonstrate any expected negative influence of accelerated growth on milk production (Gardner *et al.*, 1988; Stelwagen and Grieve, 1992). Van Amburgh *et al.* (1998) conducted an experiment with three planes of nutrition in prepubertal period. Taking into account the effects after the experimental period terminated, especially body weight after calving, the influence of growth intensity on subsequent milk production was not proved.

Discrepancies in conclusions of these experiments could result from different growth intensity of animals before they were included in experiments, different length of experimental period, growth intensity in subsequent period and from other methodical rules that are defined but are not comparable across the experiments in many cases.

The importance of growth intensity in relation to subsequent milk production changes in postpubertal period and at pregnancy. Fetus development and necessary body reserves (good body condition at calving) as well as proper growth of the animal are most important in this period. Higher body weight and good body condition at calving are related to lower requirements for energy needful for growth during the 1st lactation, higher capacity of body reserve mobilization and higher feed intake capacity.

As reported by Hoffman *et al.* (1996), accelerated growth in postpubertal period did not cause any significant differences in milk production over 305 days of lactation even though a tendency towards lower daily milk yield was observed in heifers under such a rearing system; differences in the yield and content of components at some stages of lactation were significant. Milk production in the first lactation correlates more closely with calving weight than with calving age or body weight gain during rearing. Hence the weight at first calving should be 82–90% of mature weight (Van Amburgh *et al.*, 1998).

Since there exist general correlations between growth rate, body weight at first calving and age at first calving, it is very difficult to determine separate effects of these variables on milk production. Rearing experiments can be divided into three groups (Table 1) (taken over from Mourits, 2000).

Table 1. Determination of the rearing experiments

	Type of experiment		
	I	II	III
Growth strategy	different	different	same
Body weight at first calving	same	different	different
Age at first calving	different	same	different

Previous studies were mostly conducted on heifers reared under different growth strategies while the same body weight at first calving taking place at different age was used - type I (Gardner *et al.*, 1977; Little and Kay, 1979; Hoffman *et al.*, 1996; Bettenay, 1985). Groups of heifers of the same age at first calving but different body weight and growth strategy were compared in other studies - type II (Little and Kay, 1979; Johnsson and Obst, 1984; Freetly and Cundiff, 1998). This type is more characteristic of beef cattle. Analyses of field studies are based in general on data on heifers with different body weight and age at first calving while the same growth strategy is used - type III (Heinrichs and Hargrove, 1987; Mäntysaari and Mäntysaari, 1997). Growth strategy is taken to mean a rearing system based on planes of nutrition: classical rearing system respecting the nutrient requirement standard (control group) and rearing system with intentionally growth accelerated or delayed growth (experimental groups). The same growth strategy in field studies means that it is not influenced intentionally even though there may occur differences in growth intensity caused by environmental conditions (e.g. herd, season, etc.) but not by the plane of nutrition.

A study of Finnish authors (Mäntysaari and Mäntysaari, 1997) aimed at the relationship between growth and milk production demonstrated that the results of field studies could be different from those expected on the basis of conclusions drawn from feeding trials. They determined by correlation analysis a positive (even though free, $r = 0.14$) correlation between milk production and weight gain before mating.

This review shows that relationships between growth and subsequent milk production are very complicated and very difficult to be generalized. What the experiments clearly indicate is that growth intensity (weight gain) is a very variable trait with low heritability and a relatively unreliable indicator for predictions of future productivity (Lee, 1997).

Heifer rearing optimization

Breeders want to know the definition of optimum animal size for evaluation or potential modification of their breeding programs. Criteria of optimum size are mostly based on live weight and some body measures because they are relatively easy to be determined. But recommended values should reflect much more complicated relationships, they should take into account body condition, reproductive performance, feed consumption per unit production, etc.

Table 2 shows average values of body weight and height at withers for heifers of Holstein breed on the basis of body size measurements in 5 723 heifers from 163 herds (Heinrichs and Hargrove, 1987), recommended optimum body size of Holstein heifers determined from published data (Hoffman, 1997) and recommended growth parameters that are a part of the Black-and-White Cattle Breeding Program in the Czech Republic (Bouška, 1996).

The basic rule of replacement heifer rearing optimization is a shortening of nonproductive period by earlier mating and lower age at first calving. Advantages of this approach are a decrease in feed costs, increase in production calculated per age, shortening of generation interval and total decrease in costs per animal. Considerations of these advantages should also take into account increased requirements for feeds and feed rations, decrease in milk production per lactation as well as a possible decrease in conception rate, shorter longevity (Sieber *et al.*, 1988; Lin *et al.*, 1988; Hoffman and Funk, 1992). Methods of dynamic programming were developed to cover these complicated biological relationships from economic aspects (Kirstensen, 1993 – cited by Mourits, 2000). Using a dynamic model simulating the behavior of a studied system (e.g. heifer rearing system) within a time period, Mourits (2000) stated that optimum average age and body weight

Table 2. Comparison of body sizes recommended by some authors (Heinrichs and Hargrove, 1987 – I, Hoffman, 1997 – II, Bouška, 1996 – III)

Age (mo)	Body size criterion						
	I		II			III	
	BW	HW	BW	HW	BL	BW	HH
0			42	75	82		
2	82.1	85.6	84	86	93		
4	122.8	93.4	130–135	97–98	104–105	140	105
6	168.6	101.1	177–186	104–105	114–116	195	110
8	209.0	107.2	223–237	109–111	123–126	240	115
10	255.9	112.7	270–288	114–116	132–135	285	120
12	302.5	117.9	316–339	118–120	140–143	325	125
15	368.4	122.7	386–416	124–126	150–154	380	130
18	419.8	127.2	456–492	129–132	158–162	430	134
21	477.5	130.7	525–569	134–137	165–168		
24	515.2	132.1	595–645	138–141	169–173	520	138
7d postpartum			536–581				
30d postpartum			500–541				
27						550	140
36						650	145

BW = body weight (kg)
HW = height at withers (cm)
HH = height at hips (cm)
BL = body length from the point of shoulder to ischium (cm)

at first calving were 22.6 months and 564 kg in the conditions of The Netherlands, which corresponded to values recommended in general (age < 24 months, 570 kg); neither did she find any differences in these values under the conditions of heifer rearing in Pennsylvania (USA). These values seem to be so well optimized for farming conditions that currently it is not necessary to verify or seek any other new solutions. But the economic aspects are interesting: calculation of profit/loss due to an increase/decrease in weight gain in prepubertal period, early/later mating or an increase/decrease in weight gain in postpubertal period and at pregnancy. It is reported in the above paper that an extra month of rearing will decrease the income of an average Dutch farmer by ca. 4.5% per year.

Use of heifer growth ability for breeding

Growth ability is not a selection trait in dairy cattle, but it is important for herd economics. Only negative selection is used in the category of heifers during their rearing when animals lagging behind in their growth are culled from the herd. Genetic variability in the shape of growth curves and breeding for early maturity should be used to alter growth. Jenkins *et al.* (1991) state that genetic variability within a breed is sufficiently high to alter the shape of growth curve, even higher than that between breeds.

Most studies aimed at early growth were conducted in beef cattle where growth is the basic production trait (Webster *et al.*, 1982; Marshall *et al.*, 1984; De Nise and Brinks, 1985; Meyer, 1995). Parameters of growth curves – maturation rate (parameter k of growth function) or degree of maturity (u_t) were used as the characteristics of early growth. Fitzhugh (1976) defined maturation rate as a function of maximum growth rate to mature weight ratio, degree of maturity as the proportion of weight y achieved at age t in mature weight A ($u_t = y/A$). Both parameters are in close correlation. The correlation between maturation rate and mature weight is negative (Marshall *et al.*, 1984; Jenkins *et al.*, 1991). Animals with earlier growth tend to have smaller body size at maturity. A disadvantage of the two parameters of early maturity is that they cannot be determined sooner than at maturity, so they are hardly usable for selection. Therefore Knížetová (1997) suggested two ways of replacing the asymptotic (mature) weight:

a) to use the parent values if known, making use of higher heritability; Meyer (1995) reported for average mature weight the coefficient of heritability $h^2 = 0.47 – 0.73$, Kaps *et al.* (1999) $h^2 = 0.44 – 0.53$, or
b) to use the conversion of highly correlated body measure in which growth is terminated considerably earlier than in body weight (similarly like in Meyer, 1995).

The choice of a criterion that would correlate with early maturity parameters and would be a trait easy to determine at early age (e.g. relative weight gain) could be another way of using early maturity for breeding. Statistical analyses are necessary for this purpose in order to choose a suitable selection criterion.

New approaches to the problem

Genetics of the last decade has contributed new knowledge to farm animal breeding that is used for identification of so called candidate genes for quantitative trait loci (QTL). The goal is to find a genetic marker that would be in linkage with QTL and could be used for selection (marker assisted selection – MAS). Such gene variants of encoding or noncoding (intra- and inter-gene) domains are sought that would have demonstrable positive effects on production traits.

The growth hormone gene is supposed to be such a marker for its polymorphic characteristics and versatile effects of its product in the organism. Many studies have proved that the growth hormone gene is linked up with commercially important quantitative traits in different animal species. Winkelman and Hodgetts (1992) discovered a relationship between gene variants of growth hormone and body weight and growth intensity in mice after weaning, Knorr *et al.* (1997) described its significant relationship to some performance traits in pigs. Kuhnlein *et al.* (1997) reported correlated presence of one of the alleles of growth hormone gene in poultry (White Leghorns) during selection for egg production and resistance to Marek's disease.

Relationships between gene polymorphism of growth hormone and traits of meat (Schlee *et al.*, 1994; Chrenek *et al.*, 1998) and milk (Sneyers *et al.*, 1994; Lee *et al.*, 1996, Sabour *et al.*, 1997; Vukasinovic *et al.*, 1999) production were evaluated in cattle. But the results are not unambiguous enough to be generalized and to designate any of the genotypes of growth hormone as a marker. Detailed analyses are necessary for this purpose.

Conclusion

This review presents some common aspects of different methods and the purpose of study aimed at a relationship between growth and milk production. For producers it is important what growth parameters of heifers should be achieved in view of their future high productivity and profitable heifer rearing. For breeders it is necessary to meet requirements of breeding programs, to maintain breeding type (body weight and size of animals) and to seek new criteria (e.g. early maturity) for improvement of the herd and whole population. For science it means to seek ways of disclosing new links in such a complicated organism as the farm animal is.

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