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A novel porcine microsatellite panel for the identification of individuals and parentage control in the Czech Republic

L. Putnová, A. Knoll, V. Dvořák, J. Dvořák

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

ABSTRACT: For the identification of individuals and parentage control performed by pig breeders in the Czech Republic a novel porcine microsatellite panel amplified by means of multiplex polymerase chain reaction was designed. The efficiency of our set of ten microsatellites (panel A – *SW24*, *S0386*, *S0355*, *SW353*, *SW936*, *SW72*, *S0068*, *S0070*, *S0107* and *TNFB*) was compared in three breeds with the efficiency of that (panel B – *S0005*, *S0090*, *S0101*, *S0155*, *S0355*, *S0386*, *SW24*, *SW240*, *SW857* and *SW951*) described by Nechtelberger *et al.* (2001). The length polymorphisms of these microsatellites located on chromosomes 1–7, 10–15 and 17 were examined by multiplex PCR amplification followed by fragment analysis of the amplified products. The investigated population consisted of 120 pigs of three breeds (Large White, Landrace and Black Pied Prestice). The probabilities of paternity exclusion/one parental genotype unavailable/and parentage exclusion were for panel A 99.90%/98.09%/99.99% (Large White), 99.54%/94.61%/99.99% (Landrace), 99.94%/98.59%/99.99% (Black Pied Prestice) and for panel B 99.73%/96.31%/99.99% (Large White), 99.27%/93.17%/99.97% (Landrace), 99.89%/98.04%/99.99% (Black Pied Prestice), respectively. Research data certified the possibility of using this panel A of ten microsatellite markers for the individual identification and parentage control in the Czech Republic.

Keywords: microsatellites; pig; multiplex PCR; parentage control

Correct parentage of breeding stocks is a prerequisite for an efficient breeding programme in all farm animal species including pigs. In the Czech Republic the genotype determination and parentage control for elite breeding stock is performed pursuant to Act No. 154/2000. So far conventional blood markers (blood groups and protein polymorphisms) have been used for this purpose that are continually replaced by microsatellites in some countries.

Microsatellite markers also referred to as short tandem repeats (STR), short sequence repeats (SSR) or sequence tagged microsatellite sites (STMS) contain repetitive sequences composed of 2–6 nucleotides. The number of repeats can vary from one individual to another depending on the relationship and degree of genetic difference. The most common motif in the pig genome is $(CA)_n$ and its number is estimated to range between 65 000 and 100 000 copies (Winterø *et al.*, 1992). Information about porcine microsatellites can be found on the Internet (http://www.thearkdb.org/browser?species=pig).

Due to high polymorphic information content – PIC (Botstein *et al.*, 1980) and possibility of genotyping of all loci with the use of only one high-throughput technique microsatellites are very useful genetic markers not only for the construction of linkage maps (Rohrer *et al.*, 1996) suitable for mapping of economically important traits but also for parentage control. When com-

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pared with conventional blood markers, the use of several highly polymorphic and more numerous microsatellites enables to increase the exclusion probabilities and the proportion of correct parentage. Apart from that, blood as well as other tissues such as semen, muscle and hair root can be used for microsatellite typing. A possibility to co-amplify more than one microsatellite in one PCR reaction brings about significant cost savings. One of the disadvantages of microsatellites used for parentage control is their mutability (Ellegren *et al.*, 2000).

Due to (i) necessity to unify a panel of microsatellite markers tested by laboratories providing the service in the Czech Republic and (ii) non-existence of internationally recognized panel of microsatellite markers for this purpose it was necessary to design a panel for genotype determination and parentage control in the Czech Republic.

MATERIAL AND METHODS

Experimental animals

The efficiency of the method was evaluated in 120 pigs from various breeding farms encompassing Large White (LW, $n = 50$), Landrace (L, $n = 50$) and Czech Black Pied Prestice (BPP, $n = 20$) kept as gene reserve. Reference DNA ($n = 20$) samples provided by Dr. Meyer from Germany were used for the calibration of fragment size.

Genotype determination

Porcine genomic DNA was extracted from blood using QIAamp® Blood kit (Qiagen, Valencia, CA, USA).

Table 1. Microsatellite loci chosen for the analysis (panel A)

Locus	Fluorescent label[a]	Range (bp)	NM primers	Size (bp)	Sequence of primers (5'→ 3') (Authors of primers are cited in the text)
SW24	FAM	93–117	500	19	F: CTT TGG GTG GAG TGT GTG C
				18	R: ATC CAA ATG CTG CAA GCG
S0107	FAM	166–220	100	24	F: CAA GGA TGC CTG TAA CTG GTG CAG
				24	R: TCC TTA AGG CCT CGT AGG ATC TGT
S0068	FAM	225–257	100	22	F: AGT GGT CTC TCT CCC TCT TGC T
				22	R: CCT TCA ACC TTT GAG CAA GAA C
SW936	HEX	89–113	450	21	F: TCT GGA GCT AGC ATA AGT GCC
				20	R: GTG CAA GTA CAC ATG CAG GG
SW353	HEX	140–162	100	20	F: CAC CCC ATG CCT GAA TAC TG
				21	R: ATG TGA AGA CTC ATG CTT GGG
S0386	HEX	164–182	550	23	F: GAA CTC CTG GGT CTT ATT TTC TA
				29	R: GTC AAA AAT CTT TTT ATC TCC AAC AGT AT
S0355	HEX	241–269	600	26	F: TCT GGC TCC TAC ACT CCT TCT TGA TG
				26	R: GTT TGG GTG GGT GCT GAA AAA TAG GA
SW72	NED	97–113	200	18	F: ATC AGA ACA GTG CGC CGT
				20	R: TTT GAA AAT GGG GTG TTT CC
TNFB	NED	156–195	250	24	F: ATC GCA TCT GGT CAG CCA CCA AGA
				24	R: TTA GGA GGA TTT TGC AAC AAC CCA
S0070	NED	260–296	600	20	F: GGC GAG CAT TTC ATT CAC AG
				20	R: GAG CAA ACA GCA TCG TGA GC

[a] always performed at the 5' end of the forward primer; F = forward primer, R = reverse primer

Panel A: 10-plex PCR reactions were carried out in a GeneAmp™ PCR System 9700 cycler (Applied Biosystems, Foster City, CA) in a total volume of 12.5 µl, containing 336 µM of each dNTP, 1.2 × PCR buffer (containing 15 mM $MgCl_2$, 100 mM Tris-HCl, pH 8.3, 500 mM KCl, 0.01% gelatin), 1.8 U *Taq* polymerase (Ampli*Taq* Gold™, Applied Biosystems) and 20–100 ng DNA. The primers of selected MS markers were used in concentrations from 100 nM to 600 nM. The concentrations, labelling and primer sequences are in Table 1. The sequences of oligonucleotide primers flanking STR motifs and producing variably-sized DNA fragments depending on the number of repeats were described previously: *SW24*, *SW353*, *SW936*, *SW72* (Rohrer *et al.*, 1994); *S0068*, *S0070* (Fredholm *et al.*, 1993); *S0107* (Ellegren *et al.*, 1994); *TNFB* (Ellegren *et al.*, 1993); *S0386* (Riquet *et al.*, 1995); *S0355* (Robic *et al.*, 1994). Sequences of primers for *S0386* and *S0355* were modified by Nechtelberger *et al.* (2001). PCR conditions included an initial denaturation step of 10 min at 95°C, 30 cycles of 30 s at 95°C, 30 s at 58°C, 1 min at 72°C and a final extension of 60 min at 72°C. Each 1 µl of PCR product and 0.5 µl of an internal lane size standard were loaded in 11.5 µl of deionized formamide. The samples were then denatured at 95°C for 5 min and inserted into the ice. The polymorphism of microsatellite sequences was examined by the PCR method and capillary electrophoresis, based on laser scanning of fluorescence-marked DNA fragments. Genotyping was done on ABI PRISM 310™ Genetic Analyzer (Applied Biosystems) by fluorescent fragment analysis and evaluated by software GeneScan® 3.7 NT and Genotyper® 3.7 NT. The allele size was determined in bp by comparing the length with length standard GS ROX 500 (Applied Biosystems).

Panel B: 10-plex PCR reactions were prepared according to Nechtelberger *et al.* (2001) with small modifications. GS TAMRA 500 (Applied Biosystems) was used as a standard. The German reference DNA samples were applied for the calibration of fragment size.

Statistical evaluation

Theoretical heterozygosity (tH) and polymorphism information content (PIC) were calculated according to Green (1999). Exclusion probabilities (EP) and combined exclusion probabilities (CEPs) were calculated according to Jamieson and Taylor (1997).

RESULTS AND DISCUSSION

We constructed a novel multiplex amplification and typing panel for ten polymorphic microsatellites. The panel allows the co-amplification and three-colour detection of ten microsatellite markers (*SW24*, *S0386*, *S0355*, *SW353*, *SW936*, *SW72*, *S0068*, *S0070*, *S0107* and *TNFB*). The markers of this panel A are independently segregating and highly polymorphic. All markers have well-represented alleles. We designed primers agreeably to literature and EMBL/GeneBank sequences. Microsatellite loci chosen for the analysis and allelic ranges of each locus are presented in Table 1. Panel A was compared with the panel (marked as B) described by Nechtelberger *et al.* (2001) of the following microsatellites markers: *S0005*, *S0090*, *S0101*, *S0155*, *S0355*, *S0386*, *SW24*, *SW240*, *SW857* and *SW951*. They designed the panel to be suitable for use in both German and Austrian herd-book breeding.

Before the multiplex PCR was optimized, individual loci were analyzed and controlled in a single PCR reaction (Figure 1). The development of multiplex panel involved a rigorous experimental strategy that included careful selection of PCR primer sequences, along with optimization of PCR component concentrations, thermal cycling parameters and fluorescence detection conditions. This developmental approach provided a well-characterized DNA typing panel that is high performing (sensitive, specific and balanced), optimized to universal parameters (same reaction conditions), resilient to fluctuations in reaction conditions, simple to implement and use routinely. Figure 2 presents the electrophoretic separation of optimized 10-plex PCR panel. 120 unrelated animals of each important Czech breed (Large White, Landrace and Black Pied Prestice) were tested with the German 10-plex as well as with the Czech 10-plex battery.

All microsatellites show polymorphic variability across the study samples. Table 2 and 3 show the specific alleles for panel A and B identified in three Czech breeds. In animals of Large White a total of 63 alleles (panel A) and 57 alleles (panel B) were discovered. A total of 58 alleles (panel A) and 49 alleles (panel B) were obtained in Landrace. In ani-

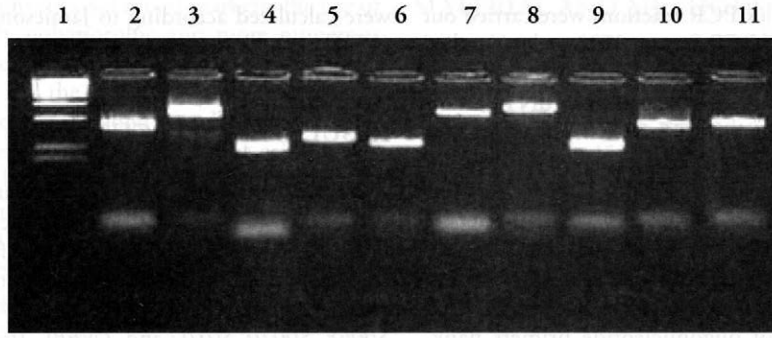

Figure 1. Electrophoretic pattern of ten polymorphic MS markers analyzed in a single PCR reaction

Fragments were separated on 4% MetaPhor® agarose gel stained with ethidium bromide. Lane 1: 100 bp ladder (1 000, 900, 800, 700, 600, 500, 400, 300, 200, 100, 80 bp); lane 2: PCR product of *S0107*; lane 3: PCR product of *S0068*; lane 4: PCR product of *SW936*; lane 5: PCR product of *SW353*; lane 6: PCR product of *SW24*; lane 7: PCR product of *S0355*; lane 8: PCR product of *S0070*; lane 9: PCR product of *SW72*; lane 10: PCR product of *TNFB*; lane 11: PCR product of *S0386*

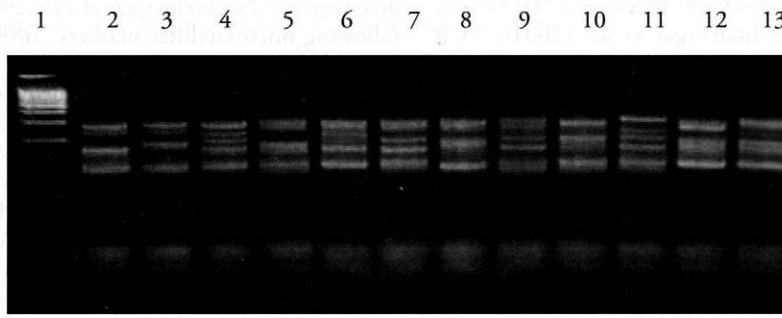

Figure 2. Electrophoretic pattern of microsatellite panel A

Fragments of 10-plex PCR were separated on 4% MetaPhor® agarose gel stained with ethidium bromide. Lane 1: 100 bp ladder (1 000, 900, 800, 700, 600, 500, 400, 300, 200, 100, 80 bp); lanes 2–13: PCR products of 12 different Large White pigs

mals of Black Pied Prestice 59 alleles (panel A) and 56 alleles (panel B) were established. The number of alleles at individual loci ranged from 3 (*S0386*, *S0355*, *SW72*) to 10 (*TNFB*) in panel A and from 2 (*SW951*) to 9 (*S0005*, *SW857*) in panel B. There exist alleles typical of a given breed. A higher number of alleles typical of the breed was observed in Large White pigs – 13/12 (panel A/panel B) alleles did not occur in Landrace and Black Pied Prestice. While 11/2 (panel A/panel B) alleles did not occur in animals of Large White and Black Pied Prestice and were specific to Landrace pigs. The number of alleles typical of Black Pied Prestice was 7/8 (panel A/panel B).

We described not only the number of detected MS alleles but also the real heterozygosity in Large White, Landrace and Black Pied Prestice (Table 4). The highest heterozygosity was observed for locus *TNFB* – over 80% in all three breeds. A similarly high heterozygosity, above average, was ascertained for loci *S0107*, *SW72*, *S0070*, *S0068*, *SW936* and *SW24*. The lowest value was observed for locus *SW353* in Black Pied Prestice (40%) and for locus *S0386* in Landrace (41%). Korwin-Kossakowska *et al.* (1998) also found the highest heterozygosity for locus *TNFB* in Polish Large White and Zlotnicka Pied pigs (87%). With regard to MS markers of panel B,

Table 2. Alleles identified in Large White, Landrace and Black Pied Prestice pigs (panel A)

Locus	Chr.	Large White	Landrace	Black Pied Prestice
SW24	17	95, **97**, 107, 109, 113, **117**	93, 95, 101, 107, 113	93, 95, **99**, 101, 107, 109, 113
S0107	4	166, 176, **178**, **188**, **190**, 194, 196, 198, 220	166, 194, 196, 198, 220	166, **174**, 176, 194, 196, 198, 220
S0068	13	225, 243, 247, 249, 251, 255, **257**	225, **227**, **233**, **237**, **239**, 243, 247, 249	225, 243, 247, 251, 255
SW936	15	**91**, 93, 107, 109	93, 105, 107, 109, **111**, **113**	**89**, 93, 101, 105, 107, 109
SW353	6	144, **146**, 148, 150, **162**	140, 144, 148, 150, **156**	140, 144, 148, 150
S0386	11	See Table 3	See Table 3	See Table 3
S0355	15	See Table 3	See Table 3	See Table 3
SW72	3	97, 99, **105**, 107, 109, 113	97, 107, 113	97, 99, 107, 109, 113
*TNFB**	7	156, 159, 162, **165**, 168, 174, 177, 180, 183, 195	156, 159, 162, 168, 174, 177, 180, 183, 195	156, 159, 168, 174, 180, 183
S0070	10	262, 266, 270, 272, 276, 280, 292	**260**, 262, 266, 270, **274**, 276, 280, 292, **296**	262, 266, 270, 272, 276, 280, 288, 292

bold = alleles found only in one breed; Chr. = chromosome; * = microsatellite sequence is located in intron of *TNFB* gene

Table 3. Alleles identified in Large White, Landrace and Black Pied Prestice pigs (panel B)

Locus	Chr.	Large White	Landrace	Black Pied Prestice
S0005	5	201, 215, 219, 227, 229, 231, 239, **241**, **243**	215, 219, 227, 229, 231, 233, 235, 239	201, 219, **225**, 229, 231, 233, 235, 239
S0090	12	239, 241, 243, **247**	237, 239, 241, 243	237, 239, 241, 243
S0101	7	195, 207, 209, 211, 213, **215**	195, 207, 209, 211	207, 209, 211, 213
S0155	1	**146**, 154, 156, 158, **172**	156, 158, 162	154, 156, 158, **160**, 162
S0355	15	241, 245, **247**, **253**, 255, 269	241, 245, 269	241, 245, 255, **257**, **259**, **263**
S0386	11	172, 174, 182	164, **168**, 172, 174, 182	164, 172, 174, **180**, 182
SW24	17	See Table 2	See Table 2	See Table 2
SW240	2	**90**, 92, 94, 106, 108, 110	92, 94, 104, 108, 110	92, 94, **96**, 104, 106, 108, 110
SW857	14	138, 142, 144, 146, 148, 150, 152, 154	**134**, 138, 142, 144, 146, 148, 150, 154, 156	138, 142, 146, 148, 150, 152, 154, 156
SW951	10	121, 123, **125**, 129	121, 123, 129	121, 123

bold = alleles found only in one breed; Chr. = chromosome

the highest heterozygosity was identified for MS *S0005* – over 70% in all three breeds. The lowest value was observed for MS *SW951* in Landrace (37%). The examined microsatellites are highly polymorphic – average value of real heterozygosity was for panel A 69.5% in LW, 63.9% in L, 79.3% in BPP and for panel B 65.1% in LW, 63.1% in L, 80.6% in BPP.

Table 4. Number of alleles (NA) detected in Large White (LW), Landrace (L) and Black Pied Prestice (BPP) and their real heterozygosity (H)

Panel A	LW		L		BPP		Panel B	LW		L		BPP	
MS	NA	H	NA	H	NA	H	MS	NA	H	NA	H	NA	H
SW24	6	0.72	5	0.74	7	0.90	*S0005*	9	0.83	8	0.77	8	0.88
S0107	9	0.86	5	0.72	7	0.85	*S0090*	4	0.56	4	0.69	4	0.93
S0068	7	0.70	8	0.62	5	0.75	*S0101*	6	0.70	4	0.73	4	0.65
SW936	4	0.70	6	0.58	6	0.80	*S0155*	5	0.63	3	0.68	5	0.92
SW353	5	0.50	5	0.69	4	0.40	*S0355*	6	0.71	3	0.43	6	0.79
S0386	3	0.48	5	0.41	5	0.84	*S0386*	3	0.48	5	0.41	5	0.84
S0355	6	0.71	3	0.43	6	0.79	*SW24*	6	0.72	5	0.74	7	0.90
SW72	6	0.70	3	0.70	5	0.90	*SW240*	6	0.55	5	0.67	7	0.80
TNFB	10	0.84	9	0.88	6	0.90	*SW857*	8	0.67	9	0.82	8	0.85
S0070	7	0.74	9	0.62	8	0.80	*SW951*	4	0.66	3	0.37	2	0.50

MS = microsatellite

Table 5. Average theoretical heterozygosity (tH), average polymorphism information content (PIC), combined exclusion probability of CEP1: paternity exclusion, CEP2: one parental genotype unavailable, CEP3: parentage exclusion

Breed	Panel A			Panel B		
	LW	L	BPP	LW	L	BPP
tH	0.6985	0.6221	0.7171	0.6716	0.5832	0.6893
PIC	0.6578	0.5769	0.6824	0.6199	0.5376	0.6415
CEP1	0.9990	0.9954	0.9994	0.9973	0.9927	0.9989
CEP2	0.9809	0.9461	0.9859	0.9631	0.9317	0.9804
CEP3	0.9999	0.9999	0.9999	0.9999	0.9997	0.9999

Average theoretical heterozygosity, average polymorphism information content (PIC) and combined exclusion probability are in Table 5. The PIC of the microsatellite *SW951* was the lowest (less than 0.60) in all breeds. In our material the highest polymorphism information contents (PIC > 0.70) were present at the following loci and breeds: *TNFB*, *S0107*, *S0070*, *SW857*, *S0005* and *S0355* in Large White; *TNFB*, *SW353*, *S0005* and *SW857* in Landrace; *TNFB*, *S0107*, *S0070*, *SW24*, *SW936*, *S0005*, *SW240* and *SW857* in Black Pied Prestice. Nechtelberger *et al.* (2000) also found the microsatellites *SW857*, *S0005* and *S0355* with the highest PIC index in Austrian Large White.

The probabilities of paternity exclusion/one parental genotype unavailable/and parentage exclusion were for panel A in LW 99.90%/98.09%/99.99%, in L 99.54%/94.61%/99.99%, in BPP 99.94%/98.59%/99.99%; for panel B in LW 99.73%/96.31%/99.99%, in L 99.27%/93.17%/99.97% and in BPP 99.89%/98.04%/99.99%, respectively. The results make these loci suitable for use in the pig parentage control analysis. The assay provides high CEPs in all tested breeds and produces easily interpretable results. This multiplex panel for pig parentage control could be adapted for other pig populations than the Czech ones. This study further shows that microsatellites are very useful in the study of genetic variations.

In Austria Nechtelberger *et al.* (2001) described the paternity exclusion/one parental genotype unavailable/and parentage exclusion in Landrace 99.18%/92.14%/99.97%, in Large White 99.76%/96.42%/99.99% and in Peitrain 99.74%/96.33%/99.99% (for a panel marked in this study as B). These values are comparable with our results.

To calculate exclusion probabilities randomly mating populations of animals and no mutations at included microsatellite loci were postulated. However, practically there exist kinship relations on breeding farms (full-sibs, half-sibs) that decrease real exclusion probabilities in a particular herd (Jamieson 1994; Garcia *et al.*, 2002). Microsatellite DNA sequences mutate at higher rates than the rest of DNA. The same is true of potential mutations in analysed microsatellites. The mutation rate of particular microsatellite locus is usually unknown and can vary across repeat types, base composition of repeat and other potential factors (Balloux and Lugon-Moulin, 2002). Direct observations, by pedigree analysis, of mutations at human microsatellite loci have revealed estimates of mean mutation rates of 3×10^{-3}–6×10^{-4}. Taking together practical exclusion probabilities of the microsatellite panel used in herds with certain degree of inbreeding is lower than the exclusion probabilities calculated.

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REFERENCES

Balloux F., Lugon-Moulin N. (2002): The estimation of population differentiation with microsatellite markers. Molec. Ecol., *11*, 155–165.

Botstein D., White R.L., Skolnick M., Davis R.M. (1980): Construction of a genetic linkage map in man using restriction fragment length polymorphisms. Am. J. Hum. Genet., *32*, 314–331.

Ellegren H. (2000): Microsatellite mutations in the germline: implications for evolutionary inference. Trends Genet., *16*, 551–558.

Ellegren H., Johansson M., Chowdhary B., Marklund S., Ruyter D., Marklund L., Bräuner-Nielsen P., Edfors-Lilja I., Gustavsson I., Juneja R.K., Andersson L. (1993): Assignment of 20 microsatellite markers to the porcine linkage map. Genomics, *16*, 431–439.

Ellegren H., Chowdhary B., Johansson M., Andersson L. (1994): Integration the porcine physical and linkage map using cosmid-derived markers. Anim. Genet., *25*, 155–164.

Fredholm M., Winterø A.K., Christensen K., Kristensen B., Nielsen P.B., Davies W., Archibald A. (1993): Characterization of 24 porcine (dG-dT)n – (dC-dA)n microsatellites: Genotyping of unrelated animals from four breeds and linkage studies. Mamm. Genome, *4*, 187–192.

Garcia D., Carleos C., Parra D., Canon J. (2002): Sib-parentage testing using molecular markers when parents are unknown. Anim. Genet., *33*, 364–371.

Green E.C. (1999): In: Genome analysis: a laboratory manual: mapping genomes. Cold Spring Harbor Lab., USA, *4*, 37–38.

Jamieson A. (1994): The effectiveness of using co-dominant polymorphic allelic series for (1) checking pedigrees and (2) distinguishing full-sib pair members. Anim. Genet., *25*, Suppl. 1, 37–44.

Jamieson A., Taylor St.C.S. (1997): Comparisons of three probability formulae for parentage exclusion. Anim. Genet., *28*, 397–400.

Korwin-Kossakowska A., Pierzchała M., Cymerowska-Prokopczyk I. (1998): The Polish "Pig Genome Mapping" project. X. Polymorphism of selected microsatellite DNA sequences in the Zlotnicka Spotted and Polish Large White pigs and their F1 and F2 crosses. Anim. Sci. Papers Reports, *17*, 35–47.

Nechtelberger D., Kaltwasser C., Stur I., Meyer J.-N., Brem G., Müller M., Müller S. (2000): DNA microstellite analysis in Austrian pigs for parentage control. In: Conference Abstract Book of the 27th International Conference on Animal Genetics, Minneapolis, USA, 22.–26.7.2000, Poster No. D064 (http://www.isag.org.uk/conference2000.htm).

Nechtelberger D., Kaltwasser C., Stur I., Meyer J.-N., Brem G., Müller M., Müller S. (2001): DNA microsatellite analysis for parentage control in Austrian pigs. Anim. Biotech., *12*, 141–144.

Riquet J., Milan D., Woloszyn N., Schmitz A., Pitel F., Frelat G.,Gellin J. (1995): A linkage map with microsatellites isolated from swine flow-sorted chromosome 11. Mamm. Genome, *6*, 623–628.

Robic A., Dalens M., Woloszyn N., Milan D., Riquet J., Gellin J. (1994): Isolation of 28 new porcine mic-

rosatellites revealing polymorphism. Mamm. Genome, *5*, 580–583.

Rohrer G.A., Alexander L.J., Keele J.W., Smith T.P., Beattie C.W. (1994): A microsatellite linkage map of the porcine genome. Genetics, *136*, 231–245.

Rohrer G.A., Alexander L.J., Hu Z., Smith T.P., Keele J.W., Beattie C.W. (1996): A comprehensive map of the porcine genome. Genome Res., *6*, 371–391.

Winterø A.K., Fredholm M., Thomsen P.D. (1992): Variable (dG-dT)n (dC-dA)n sequences in the porcine genome. Genomics, *12*, 281–288.

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ABSTRAKT

Nový panel mikrosatelitů pro identifikaci jedinců a ověřování původu prasat v České republice

Pro identifikaci jedinců a ověřování původu prasat v České republice jsme navrhli nový panel mikrosatelitů, který je možno amplifikovat pomocí jedné polymerázové řetězové reakce. Provedli jsme srovnání účinnosti tohoto panelu (panel A – *SW24*, *S0386*, *S0355*, *SW353*, *SW936*, *SW72*, *S0068*, *S0070*, *S0107* a *TNFB*) s panelem (panel B – *S0005*, *S0090*, *S0101*, *S0155*, *S0355*, *S0386*, *SW24*, *SW240*, *SW857* a *SW951*) popsaným autory Nechtelberger *et al.* (2001). Délkový polymorfismus těchto mikrosatelitů lokalizovaných na chromozomech 1–7, 10–15 a 17 byl testován prostřednictvím multiplexové PCR reakce a fragmentační analýzy amplifikovaných fragmentů. Populace testovaných prasat byla složena ze 120 zvířat tří plemen (bílé ušlechtilé, landrase a přeštické černostrakaté). Pravděpodobnost vyloučení nesprávného rodiče při znalosti genotypu potomka i obou rodičů/pravděpodobnost vyloučení nesprávného rodiče při neznalosti genotypu jednoho z rodičů/pravděpodobnost vyloučení obou rodičů při znalosti genotypu potomka i obou rodičů byla dle uvedeného pořadí pro panel A 99,90 %/98,09 %/99,99 % (bílé ušlechtilé), 99,54 %/94,61 %/99,99 % (landrase), 99,94 %/98,59 %/99,99 % (přeštické černostrakaté) a pro panel B 99,73 %/96,31 %/99,99 % (bílé ušlechtilé), 99,27 %/93,17 %/99,97 % (landrase), 99,89 %/98,04 %/99,99 % (přeštické černostrakaté). Zjištěné výsledky potvrdily možnost využití panelu A tvořeného deseti mikrosatelitními markery k individuální identifikaci a ověřování původu prasat v České republice.

Klíčová slova: mikrosatelity; prase; multiplex PCR; ověření původu

Corresponding Author

Mgr. Lenka Putnová, PhD., Mendelova zemědělská a lesnická univerzita, Ústav genetiky, Zemědělská 1, 613 00 Brno, Česká republika
Tel. +420 545 133 181, e-mail: putnova@mendelu.cz

Effect of age on digestibility of fatty acids in chickens

J. Zelenka, E. Fajmonová, D. Kladroba

Faculty of Agronomy, Mendel University of Agriculture and Forestry, Brno, Czech Republic

ABSTRACT: Effect of age on apparent digestibility of fatty acids was investigated from the 2nd to the 42nd day of age using Ross chickens receiving a commercial feed mixture *ad libitum*. Digestibility of all fatty acids rapidly decreased from Day 2 to Day 4. This drop was followed by an increase till Day 8. The observed changes can be explained on the basis of excretion of endogenous nutrients originating primarily from the yolk sac. In the period of Days 9 to 42, coefficients of all saturated and monounsaturated fatty acids (with the exception of C20 : 1 n-9) significantly ($P < 0.001$) decreased with age. Changes in digestibility of linoleic, α-linolenic, arachidonic, and docosahexaenoic acid were very small ($P > 0.05$). Digestibility of eicosapentaenoic acid increased highly significantly; the daily increase was 1.09 per cent. Mean values of polyunsaturated fatty acid digestibility were higher ($P < 0.001$) than those of saturated and monounsaturated fatty acids.

Keywords: chickens; age; digestibility; fatty acids

Apparent digestibility of fat is not stable in the course of fattening and the changes are especially pronounced in the several first days of chick life (Zelenka *et al.*, 2000). The objective of this experiment was to determine changes in the digestibility of dietary fatty acids (FA) during the fattening period of chickens.

In the course of hatching, some remnant yolk material is expelled through the yolk stalk into the small intestine during the process of retraction of the yolk sac into the peritoneal cavity (Klasing, 1998). A part of the yolk sac content was also found in the caeca in a study of Zelenka and Jílek (1970). The yolk that reaches the proximal small intestine by antiperistaltic movements is hydrolysed and absorbed whereas the yolk remaining in the ileum and caecum is not utilised by the hatching bird and is excreted. This can explain the low apparent digestibility values for fatty acids in very young birds (Noy and Sklan, 1998). A significant amount of the yolk sac fat is stored in the liver (Zelenka and Jílek, 1970). A part of these lipids can be excreted by means of bile into the intestine and can also influence apparent digestibility values.

Fat composition will influence overall fat utilisation because different components can be digested with varying efficiency. Unsaturated fatty acids have a higher overall digestibility than those that are saturated (Wiseman, 1997). It is generally recognised that following digestion, micelle formation is an important prerequisite for absorption into the portal system. Micelles are complexes of bile salts, fatty acids, some monoglycerides and perhaps glycerol. The conjugation of bile salts with fatty acids is an essential prerequisite for transportation to and absorption through the microvilli of the small intestine. Polar unsaturated fatty acids and monoglycerides readily form this important association. However, micelles themselves have the ability to solubilise non-polar compounds such as saturated fatty acids. Therefore fat absorption depends on an adequate supply of bile salts and an appropriate balance of unsaturates and saturates. Higher content of unsaturated fatty acids in feed improves digestibility of saturated fatty acids (Leeson and Summers, 1997).

Leeson and Summers (1997) observed that young birds were able to digest saturated fatty acids to a lesser extent and stated that the real cause of this fact was not well understood, although it could be related to lower production of bile salts, less efficient re-circulation of bile salts or lower production

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of fatty acid binding protein. In their experiment with feed mixtures containing higher levels of tallow palmitic acid digestibility increased from 50 to 85% over 14–56 days of age. Tyleček *et al.* (1963) studied fat digestibility coefficients in chickens in ten subsequent seven-day periods starting from the 9th day of age. The effect of age on fat digestibility was not demonstrated ($P > 0.05$), similarly like in an experiment performed by Zelenka (1973), who determined apparent digestibility at 24 intervals within 2 and 10 weeks of age. In another experiment, Zelenka (1984) evaluated digestibility of nutrients of a commercial feed mixture in three-day balance periods from Day 12 to Day 56 and found out that fat digestibility slightly decreased with increasing age ($P < 0.05$). Negm (1966) compared coefficients of digestibility of a feed mixture estimated in chickens at 2, 4, and 6 weeks of age. The digestibility of ether extract at 4 and 6 weeks was significantly higher than at 2 weeks of age. Wiseman (1997) also recorded increased values of fat digestibility in older chicks.

MATERIAL AND METHODS

Using Ross 208 chickens, the effect of age on apparent digestibility of fatty acids was investigated in 27 sequential balance periods from Day 2 to Day 21 of age in one-day periods and from Day 22 to Day 42 in three-day periods. 25 males and 25 females were followed till Day 21; thereafter, their numbers were reduced to 8 males and 8 females kept in balance cages.

Chickens received a diet of the following composition (in g/kg) *ad libitum*: maize meal (350), wheat meal (132), soybean meal (315), heat treated soybeans (40), fish meal (50), meat-and-bone meal (70), ground limestone (7), mono- and dicalcium phosphate (15), sodium chloride (1.5), supplementary premix (9.5) and chromic oxide (10). Contents of nutrients under study in 1 kg dry matter of feed mixture are presented in Table 3.

The values of apparent digestibility of fat and fatty acids were estimated using the chromic oxide indicator method. The content of chromic oxide in feed and freeze-dried excreta was determined iodometrically (Mandel *et al.*, 1960) and that of crude fat gravimetrically after extraction with diethyl ether under the reflux for 6 hours. Ether extract was used for fatty acid determination by the gas chromatography. The method is described in detail in the paper of Fajmonová *et al.* (2003). When estimating fat digestibility, urinary fat was not taken into consideration (Mehring *et al.*, 1961).

Fatty acid patterns were also determined in lyophilised samples prepared from 10 yolk sacs of newly hatched chickens and compared with percentages of individual fatty acids in feed.

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

RESULTS AND DISCUSSION

Mean values of apparent digestibility coefficients determined in male and female chicks till the Day 8 are presented in Table 1. Digestibility of all FA rapidly decreased from Day 2 to Day 4. This drop of saturated (SFA), monounsaturated (MUFA), polyunsaturated n-6 (PUFA n-6) and PUFA n-3 was followed by an increase till Day 8 (Table 1). Based on the observations by Noy and Sklan (1999), who reported that the intestinal absorption of labelled exogenous fatty acids slightly increased till Day 4, as well as on the results published by Zelenka and Jílek (1970), who found a lower concentration of chromic oxide in dry matter of digesta than in dry matter of feed mixture from Day 3 to Day 7, it was possible to explain the observed changes on the basis of excretion of endogenous nutrients originating primarily from the yolk sac. In the yolk sac, the proportions of MUFA and SFA in the total content of FA were higher by one half and one third, respectively, than in the diet. On the other hand, the proportion of PUFA was lower than in the feed mixture (Table 2). Proportionally to this finding, the most marked decrease in digestibility in the first stage of life was observed in MUFA while that in SFA was lower and that in PUFA was relatively very small (Figure 1).

In the period of Days 9 to 42, the sex differences in digestibility of ether extract and all fatty acids were insignificant ($P > 0.05$). Considering both sexes as one set, the mean values of digestibility and its dependence on age expressed by linear regression are presented in Table 3. When using the second or third degree parabola equations, deviations from linearity were not significant ($P > 0.05$).

Digestibility of ether extract was highly significantly ($P < 0.001$) lower than that of the sum of determined FA. Apparent digestibility of fat

Table 1. Apparent digestibility of fatty acids and ether extract in chickens from 2 to 8 days of age

Fatty acids	Age of chickens in days						
	2	3	4	5	6	7	8
C14 : 0	0.962	0.971	0.960	0.964	0.963	0.962	0.965
C16 : 0	0.963	0.956	0.927	0.938	0.939	0.941	0.950
C16 : 1	0.964	0.966	0.938	0.945	0.943	0.957	0.958
C18 : 0	0.956	0.964	0.936	0.944	0.945	0.948	0.958
C18 : 1 n-9	0.965	0.952	0.906	0.910	0.913	0.923	0.939
C18 : 2 n-6	0.983	0.980	0.966	0.968	0.969	0.969	0.976
C18 : 3 n-3	0.989	0.989	0.983	0.984	0.984	0.985	0.989
C20 : 1 n-9	0.979	0.977	0.962	0.966	0.967	0.964	0.971
C20 : 4 n-6	0.903	0.967	0.934	0.940	0.924	0.930	0.962
C20 : 5 n-3	0.902	0.909	0.878	0.903	0.893	0.884	0.887
C22 : 5 n-3	0.887	0.890	0.857	0.881	0.853	0.857	0.862
C22 : 6 n-3	0.986	0.978	0.950	0.952	0.954	0.961	0.960
Σ SFA	0.961	0.958	0.930	0.940	0.941	0.944	0.952
Σ MUFA	0.966	0.953	0.908	0.912	0.915	0.925	0.940
Σ PUFA	0.983	0.980	0.966	0.967	0.968	0.969	0.975
Σ (n-6)	0.983	0.980	0.966	0.968	0.969	0.969	0.976
Σ (n-3)	0.976	0.975	0.959	0.963	0.961	0.964	0.966
Σ fatty acids	0.971	0.965	0.936	0.940	0.942	0.947	0.957
Ether extract	0.931	0.946	0.901	0.904	0.929	0.925	0.953

SFA = saturated fatty acids
MUFA = monounsaturated fatty acids
PUFA = polyunsaturated fatty acids

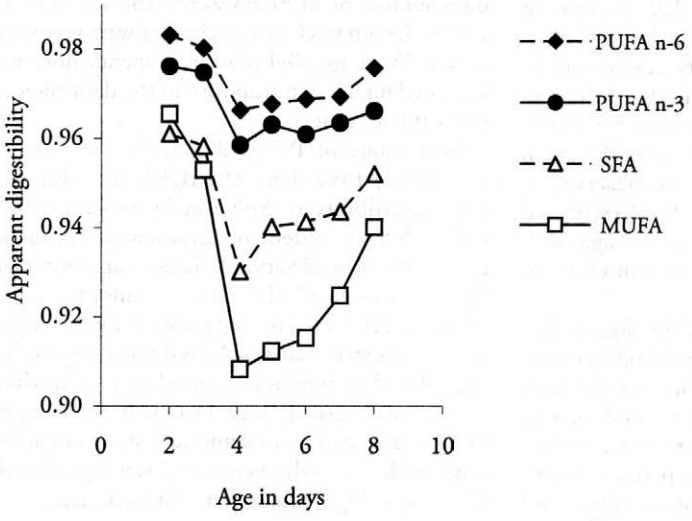

Figure 1. Digestibility of SFA, MUFA, PUFA n-3 and PUFA n-6

Table 2. Fatty acid pattern of the yolk sac and of the diet

Fatty acids	Yolk sac	Diet	Yolk sac/Diet
C14 : 0	0.42	0.93	0.45
C16 : 0	24.35	17.55	1.39
C16 : 1	3.78	1.38	2.75
C18 : 0	7.34	5.72	1.28
C18 : 1 n-9	47.60	32.29	1.47
C18 : 2 n-6	14.58	37.52	0.39
C18 : 3 n-3	0.60	1.87	0.32
C20 : 1 n-9	0.26	0.66	0.39
C20 : 4 n-6	0.64	0.07	9.59
C20 : 5 n-3	0.07	0.73	0.10
C22 : 5 n-3	0.03	0.26	0.11
C22 : 6 n-3	0.32	1.02	0.31
Σ SFA	32.10	24.20	1.33
Σ MUFA	51.64	34.32	1.50
Σ PUFA	16.25	41.48	0.39
Σ (n-6)	15.23	37.60	0.41
Σ (n-3)	1.02	3.88	0.26
Σ (n-3)/Σ (n-6)	0.07	0.10	0.65

linearly decreased; these changes were not large but they were highly significant ($P < 0.001$). The daily decrease was 0.11 per cent. In our earlier experiment (Zelenka, 1984), the daily decrease in fat digestibility was even lower (daily by 0.05%; $P < 0.05$) while in experiments conducted by Tyleček *et al.* (1963) and Zelenka (1973) the age-linked changes were not significant ($P > 0.05$). In experiments of Negm (1966) and Wiseman (1997) a higher fat digestibility was observed in older chicks. However, Negm (1966) estimated coefficients of digestibility only at the age of 2, 4 and 6 weeks and Wiseman (1997) in chickens aged 1.5 and 7.5 weeks.

Coefficients of all SFA and MUFA digestibility (with the exception of C20 : 1 n-9) significantly ($P < 0.001$) decreased with age. When feeding diets with a low content of fat (4%) data published by Leeson and Summers (1997) were not corroborated. These authors performed experiments with a diet containing a high amount of tallow and observed that palmitic acid digestibility significantly increased from the 2nd to the 8th week of age. With the exception of eicosapentaenoic acid, digestibilities of all PUFA were stabilised from the 2nd to the 6th week of age, changes were very small ($P > 0.05$). Digestibility of eicosapentaenoic acid increased highly significantly and the daily increase was 1.09 per cent.

Mean value of PUFA digestibility was higher ($P < 0.001$) than these of MUFA and SFA. The high digestibility of SFA can be explained by a high (75.8%) content of unsaturated FA in the total content of dietary FA. Leeson and Summers (1997) considered the ratio of unsaturated to saturated FA 3 to 1 to be optimum for fat digestibility. This means that SFA need not always be less digestible than monounsaturated oleic acid whose proportion is usually high in fats of plant origin. Linoleic acid and α-linolenic acid are essential FA. Digestibility of α-linolenic acid was significantly ($P < 0.001$) higher than that of linoleic acid.

Table 3. Dependence of fatty acid and ether extract digestibility on the age of chickens

Y	Content in DM of feed mixture (g/kg)	Apparent digestibility				
		mean ± standard error of the mean	$Y = a + bX$			
			a	b	r	P
C14 : 0	0.28	0.942 ± 0.0018	0.959	–0.00084	0.715	<0.001
C16 : 0	5.37	0.913 ± 0.0028	0.941	–0.00136	0.729	<0.001
C16 : 1	0.42	0.953 ± 0.0015	0.965	–0.00056	0.561	<0.001
C18 : 0	1.75	0.917 ± 0.0036	0.952	–0.00164	0.677	<0.001
C18 : 1 n-9	9.88	0.907 ± 0.0033	0.936	–0.00137	0.622	<0.001
C18 : 2 n-6	11.48	0.938 ± 0.0045	0.947	–0.00041	0.134	>0.05
C18 : 3 n-3	0.57	0.964 ± 0.0037	0.968	–0.00022	0.089	>0.05
C20 : 1 n-9	0.20	0.939 ± 0.0042	0.951	–0.00055	0.199	>0.05
C20 : 4 n-6	0.02	0.919 ± 0.0198	0.992	–0.00347	0.262	>0.05
C20 : 5 n-3	0.22	0.816 ± 0.0274	0.588	0.01087	0.594	<0.001
C22 : 5 n-3	0.08	0.793 ± 0.0085	0.784	0.00045	0.080	>0.05
C22 : 6 n-3	0.31	0.959 ± 0.0019	0.957	0.00011	0.088	>0.05
Σ SFA	7.41	0.915 ± 0.0029	0.944	–0.00140	0.727	<0.001
Σ MUFA	10.50	0.910 ± 0.0032	0.937	–0.00132	0.618	<0.001
Σ PUFA	12.69	0.938 ± 0.0044	0.945	–0.00033	0.113	>0.05
Σ (n-6)	11.51	0.938 ± 0.0045	0.947	–0.00041	0.136	>0.05
Σ (n-3)	1.19	0.942 ± 0.0035	0.931	0.00052	0.224	>0.05
Σ fatty acids	30.60	0.922 ± 0.0032	0.941	–0.00090	0.417	<0.01
Ether extract	39.50	0.883 ± 0.0031	0.906	–0.00112	0.533	<0.001

SFA = saturated fatty acids
MUFA = monounsaturated fatty acids
PUFA = polyunsaturated fatty acids
DM = dry matter
X = age in days ($9 \leq X \leq 42$)
a, b = parameters of equation
Y = apparent digestibility
r = correlation coefficients
P = significance of regression coefficient b
n = 40

REFERENCES

Fajmonová E., Zelenka J., Komprda T., Kladroba D., Šarmanová I. (2003): Effect of sex, growth intensity and heat treatment on fatty acid composition of common carp *(Cyprinus carpio)* fillets. Czech J. Anim. Sci., *48*, 85–92.

Klasing K.C. (1998): Comparative Avian Nutrition. 1st ed. University Press, Cambridge. 350 pp.

Leeson S., Summers, J.D. (1997): Commercial Poultry Nutrition. 2nd ed. University Books, Guelph, Canada. 356 pp.

Mandel L., Turynek V., Trávníček J. (1960): An iodometric method of determination of chromic oxide, used as an indicator in digestibility trials (in Czech). Živoč. Výr., *5*, 645–652.

Mehring A.L., Jr., Nesbitt L.L., Johnson D. Jr., Titus H.W. (1961): The effect of urinary fat on estimates of digestibility of fat in the diet of chickens. Poultry Sci., *40*, 826–827.

Negm H.M. (1966): Die Verdaulichkeit des Hühnerfutters und ihre Beeinflussung durch Tiermaterial und Futterform. Institut für Tierzucht, Landesgeflügelanstalt der Landwirtschaftlichen Hochschule, Stuttgart-Hohenheim. 77 pp.

Noy Y., Sklan D. (1998): Yolk utilization in hatching birds. In: Proc. the 10th European Poultry Conference, Jerusalem, 435–438.

Noy Y., Sklan D. (1999): Energy utilization in newly hatched chicks. Poultry Sci., *78*, 1750–1756.

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

Tyleček J., Špaček F., Čechovský J., Zelenka, J. (1963): Změny koeficientů stravitelnosti živin v průběhu růstu kuřat. Živoč. Výr., *8*, 727–736.

Wiseman J. (1997): The influence of dietary factors on fat and fatty acid digestibility and utilisation. In: Proceedings of the 11th European Symposium on Poultry Nutrition, World's Poultry Science Association, Faaborg, Denmark, 34–45.

Zelenka J. (1973): Digestibility of organic nutrients and energy of the feed mixture at various ages of fattened chickens. Acta Univ. Agric. (Brno), Fac. Agron., *21*, 125–131.

Zelenka J. (1984): Vliv pohlaví a věku vykrmovaných kuřat na stravitelnost organických živin krmných směsí. Živoč. Výr., *29*, 367–372.

Zelenka J., Jílek F. (1970): Contribution to studies on the yolk sac role in the nutrition of chickens. Acta Univ. Agric. (Brno), Fac. Agron., *18*, 439–448.

Zelenka J., Fajmonová E., Blažková E. (2000): Apparent digestibility of fat and nitrogen retention in young chicks. Czech J. Anim. Sci., *45*, 457–462.

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ABSTRAKT

Vliv věku kuřat na stravitelnost mastných kyselin

V pokuse s kuřaty hybridní kombinace Ross krmenými *ad libitum* kompletní krmnou směsí byly od 2. do 42. dne života zjišťovány koeficienty bilanční stravitelnosti mastných kyselin. Stravitelnost všech mastných kyselin se od 2. do 4. dne rychle snižovala. Pokles byl následován vzestupem do věku 8 dní. Změny lze vysvětlit vylučováním endogenních živin primárně pocházejících ze žloutkového vaku. Od 9. do 42. dne života se koeficienty všech nasycených a mononenasycených mastných kyselin (s výjimkou C20:1 n-9) průkazně ($P < 0,001$) snižovaly. Změny ve stravitelnosti kyseliny linolové, α-linolenové, arachidonové a dokosahexaenové byly velmi malé ($P > 0,05$). Stravitelnost kyseliny eikosapentaenové se vysoce průkazně ($P < 0,001$) zvyšovala, denně o 1,09 %. Průměrná stravitelnost polynenasycených mastných kyselin byla vyšší ($P < 0,001$) než stravitelnost nasycených a mononenasycených mastných kyselin.

Klíčová slova: kuřata; věk; stravitelnost; mastné kyseliny

Corresponding Author

Prof. Ing. Jiří Zelenka, CSc., Mendelova zemědělská a lesnická univerzita v Brně, Zemědělská 1, 613 00 Brno, Česká republika
Tel. +420 545 133 159, fax +420 545 133 199, e-mail: zelenka@mendelu.cz

Effect of dietary linseed and sunflower oil on cholesterol and fatty acid contents in rainbow trout (*Oncorhynchus mykiss*) fillets

J. Zelenka, E. Fajmonová, T. Komprda, D. Kladroba, I. Šarmanová

Faculty of Agronomy, Mendel University of Agriculture and Forestry, Brno, Czech Republic

ABSTRACT: Rainbow trouts *(Oncorhynchus mykiss)* were fed a diet containing 2.5 or 5% linseed (L) or sunflower (S) oil (L2.5, L5, S2.5, S5), or a mixture (5%) of both oils (LS5). Control group (0) received a commercial feed mixture. After 75 days of feeding 16 individuals from each of the six groups were selected to estimate the content of nutrients in flayed fillets. There were no significant differences ($P > 0.05$) in body gains and contents of dry matter, fat, crude protein, cholesterol, saturated and monounsaturated fatty acids, arachidonic, eicosapentaenoic and docosahexaenoic acid, respectively, in meat of fish fed the different diets. Meat of controls contained less polyunsaturated fatty acids (PUFA) than meat of fish fed the feed mixtures L5, S5 and LS5 ($P < 0.05$–0.01). When only L was used, trout meat contained less linoleic acid and more α-linolenic acid ($P < 0.01$) than after feeding a diet containing S. Fish receiving S showed significantly higher levels of n-6 PUFA in their meat than all other groups. The content of n-3 PUFA was significantly ($P < 0.05$–0.01) higher in the group receiving L than in that fed S alone. In the group L5, the n-3/n-6 PUFA ratio in meat was significantly ($P < 0.01$) higher than in all other groups.

Keywords: rainbow trout; fatty acids; cholesterol; linseed oil; sunflower oil

Nutritionally modified foods are referred to as functional or designer foods (American Dietetic Association, 1995). The design of foods to take advantage of the preventive and therapeutic properties of nutrients represents a critical step in the successful restructuring of food supply for the improvement of consumer's health.

The natural abundance of n-3 polyunsaturated fatty acids (PUFA) in the lipids of fish has led to an increased consumer's awareness of fish as a "healthy food". However, storage triacylglycerols usually contain lower proportions of PUFA than do the structural phospholipids, and the extent to which PUFAs are incorporated into triacylglycerols depends on the dietary supply. Thus, the extent to which the meat of farmed fish contains high levels of PUFAs will be governed by the dietary fatty acid (FA) composition (Jobling, 2001; Caballero *et al.*, 2002).

Under the conditions of a shortage of fish oil as a source of energy in feed mixtures for salmonids there is a possibility to replace it with fats of plant origin. However, it is very important to decide correctly which type of oil will be used.

Muscles of fish fed the sunflower oil diet had a double concentration of oleic acid (C18 : 1 n-9; OA) in comparison with fish fed the herring oil diet in an experiment by Skonberg *et al.* (1994). Leucocytes from the rainbow trout fed sunflower oil diets showed a 2.1-fold increase in total n-6 PUFA and a 2.3-fold decrease in n-3 PUFA, compared with the original basal levels (Ashton *et al.*, 1994).

Regarding the fact that the intake of linoleic acid (18 : 2 n-6; LA) relative to α-linolenic acid (18 : 3 n-3; ALA) in Western human diets is very high, dietary linseed oil can prove to be a key feed ingredient in the establishment of rainbow trout

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meat as a food useful for decreasing the risk of cardiovascular diseases in humans. Linseed oil is acceptable from the viewpoint of human nutrition based on the innate ability of salmonids to convert dietary ALA to eicosapentaenoic acid (20 : 5 n-3; EPA) and docosahexaenoic acid (22 : 6 n-3; DHA). In rainbow trout fed the diet with labelled ALA after receiving diets free of fat, 70% of the radioactivity was present in DHA six days later (Owen *et al.*, 1975).

The objective of the present experiment was to quantify the effect of sunflower oil rich in n-6 PUFA and linseed oil with high proportion of n-3 PUFA on the content of FA in the meat of rainbow trout.

MATERIAL AND METHODS

The experiment involved 930 one-year-old rainbow trouts (*Oncorhynchus mykiss*) with average body weight of 257 g. The fish were divided into 6 groups of 155 animals each. Through-flow concrete troughs containing 5 m^3 of water were supplied with well oxygenated water (2.2–2.3 l/s; oxygen concentration ranged from 9.3 to 9.9 mg/l). The feeding experiment, lasting altogether 75 days, started on April 12 and finished on June 26, 2002. Water temperature in the morning hours ranged from 8 to 9°C till May 20; thereafter the water temperature was 11–12°C.

The fish of control group (0) were fed Extruded Trout Grower TroCo SUPREME-16 EX (produced by Coppens International bv, The Netherlands). This extruded feed 4.5 mm in size was sprayed with either 2.5 or 5% of oils for the other groups of fish. Groups L2.5 and L5 received linseed oil (L; pressed from the cultivar Atalante), groups S2.5 and S5 were fed sunflower oil (S) and LS5 group received 2.5% L and 2.5% S (Table 1). In L and S, the percentage of LA from all determined FA was 13.7 and 61.3 and that of ALA 63.0 and 0.1, respectively. The supplement of oils widened the energy/protein ratio of diets and changed their fatty acid patterns (Table 1 and 2). The energy/protein ratio was 39.7 kJ of digestible energy/1 gram of crude protein in the control diet (i.e. exactly the amount required by the National Research Council standards; 1993), and 41.7 and 43.5–43.6 in the diets containing 2.5 and 5% of vegetable oil, respectively. Fish were hand fed twice a day and the daily ration ranged (in dependence on water temperature) from 0.7 to 1% of live body weight (LBW; Table 3). LBW and feed consumption were estimated in 7 to 15-day intervals (Table 3).

After 75 days of fattening, 16 trouts were selected from each group in such a way that the differences in their LBW were as low as possible. Selected animals were individually weighed, killed and filleted. Fillets were flayed, ground in a Moulinex blender and frozen for further analyses.

Total nitrogen was determined according to Kjehldahl using Kjeltec 2300 (Tecator, Sweden). Crude protein content was calculated using the factor 6.0 pertinent to meat (N × 6). Total lipids were determined gravimetrically after extraction by the modified method of Hara and Radin (1978) using hexane : 2-propanol (HIP) mixture. The method is described in detail in a previous paper (Fajmonová *et al.*, 2003). HIP extract was used for cholesterol and fatty acids determinations.

Arneth and Al-Ahmad's (1995) procedure was modified for cholesterol determination. The solid residue after HIP extraction was dissolved in 30 ml HIP1 (hexane p.a., 99.0%, Merck, Germany; 2-propanol, p.a., 99.7%, Dorapis, Czech Republic; 3 : 2, v/v) and 1 ml of the sample was mixed with 10 ml of sodium methoxide (3.2 g NaOH dissolved in 48 ml CH_3OH), 32 ml of diethyl ether and 0.012 g of phenolphthalein in a separation funnel. The mixture was left to stand at room temperature for 30 minutes and neutralized with methanolic HCl (150 ml of conc. HCl and 675 ml of methanol). The sample was shaken with 30 ml of hexane (96%, p.a. ACS, Merck, Darmstadt, Germany), the separated hexane layer was passed through anhydrous Na_2SO_4 and evaporated to dryness. The solid residue was dissolved in 2 ml of acetonitrile : 2-propanol (8 : 2, v/v) mixture and analysed by HPLC on Eclipse XDB-C18 column (150 × 2.1 mm, 5 µm particle size; Agilent Technologies, Folsom, CA, USA). Gradient pump LCP 4100 was equipped with LCO 101 column oven, LCD 2083 UV detector and LCI injector (Ecom, Czech Republic). A mobile phase was acetonitrile : 2-propanol (95 : 5, v/v – acetonitrile 99.8%, Merck, Germany; 2-propanol 99.7%, Dorapis, Czech Republic). The flow rate of mobile phase was 0.5 ml/min, injection volume 20 µl. Cholesterol was detected at 210 nm.

Fatty acid determination is also described in detail in the paper of Fajmonová *et al.* (2003).

Fatty acid content was expressed as a percent of the sum of all determined fatty acids on the one

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

Components	Diet					
	L5	S5	LS5	0	L2.5	S2.5
TroCo SUPREME-16 EX	950	950	950	1000	975	975
Linseed oil	50		25		25	
Sunflower oil		50	25			25
Nutrient composition						
Dry matter	916.3	911.5	909.7	909.5	912.9	912.8
DE (MJ/kg)	18.6	18.4	18.4	17.7	18.2	18.2
Crude protein (N*6.25)	426.7	423.8	421.9	445.7	436.2	436.1
Crude fat	189.2	183.7	181.9	145.7	168.5	168.7
Fatty acids						
C14 : 0	5.74	5.38	5.24	5.62	5.69	5.77
C16 : 0	22.30	21.21	20.37	19.99	20.89	21.15
C16 : 1	6.55	6.17	6.08	6.49	6.44	6.62
C18 : 0	6.36	6.62	6.03	4.90	5.53	5.93
C18 : 1 n-9	29.02	33.76	29.48	23.16	25.49	28.81
C18 : 2 n-6	29.18	49.58	36.93	24.48	25.68	36.36
C18 : 3 n-6	0.10	0.09	0.09	0.09	0.10	0.10
C18 : 3 n-3	33.33	3.59	16.92	3.76	20.27	3.36
C20 : 1 n-9	3.69	3.53	3.40	3.61	3.60	3.72
C20 : 4 n-6	0.84	0.79	0.78	0.85	0.81	0.85
C20 : 5 n-3	10.82	10.44	10.17	10.72	10.14	11.04
C22 : 4 n-6	0.07	0.07	0.06	0.08	0.03	0.07
C22 : 5 n-6	0.24	0.23	0.23	0.24	0.22	0.25
C22 : 5 n-3	2.56	2.47	2.39	2.52	2.44	2.60
C22 : 6 n-3	11.37	10.57	10.52	11.31	10.28	11.50
Σ FA	162.2	154.5	148.7	117.8	137.6	138.1
Σ SFA	34.4	33.2	31.6	30.5	32.1	32.8
Σ MUFA	39.3	43.5	39.0	33.3	35.5	39.1
Σ PUFA	88.5	77.8	78.1	54.0	70.0	66.1
Σ (n-6)	30.4	50.8	38.1	25.7	26.8	37.6
Σ (n-3)	58.1	27.1	40.0	28.3	43.1	28.5
Σ (n-3)/Σ (n-6)	1.91	0.53	1.05	1.10	1.61	0.76

DE = digestible energy
FA = fatty acids
SFA = saturated fatty acids
MUFA = monounsaturated fatty acids
PUFA = polyunsaturated fatty acids

Table 2. Fatty acid pattern of oils and diets

Fatty acids	Linseed oil	Sunflower oil	Diet					
			L5	S5	LS5	0	L2.5	S2.5
C14 : 0	0.04	0.07	3.54	3.48	3.53	4.77	4.13	4.18
C16 : 0	5.48	5.91	13.75	13.73	13.70	16.97	15.18	15.32
C16 : 1	0.08	0.08	4.04	3.99	4.09	5.51	4.68	4.79
C18 : 0	3.43	4.59	3.92	4.29	4.05	4.16	4.02	4.29
C18 : 1 n-9	13.88	26.81	17.90	21.85	19.83	19.66	18.53	20.86
C18 : 2 n-6	13.68	61.34	17.99	32.09	24.83	20.78	18.66	26.32
C18 : 3 n-6	0.01	0.01	0.06	0.06	0.06	0.08	0.07	0.07
C18 : 3 n-3	62.97	0.10	20.55	2.32	11.38	3.19	14.73	2.44
C20 : 1 n-9	0.18	0.15	2.28	2.29	2.29	3.07	2.62	2.69
C20 : 4 n-6	0.01	0.00	0.52	0.51	0.53	0.72	0.59	0.62
C20 : 5 n-3	0.13	0.71	6.67	6.76	6.84	9.10	7.37	7.99
C22 : 4 n-6	0.00	0.00	0.04	0.04	0.04	0.07	0.02	0.05
C22 : 5 n-6	0.00	0.00	0.15	0.15	0.15	0.21	0.16	0.18
C22 : 5 n-3	0.09	0.20	1.58	1.60	1.61	2.14	1.77	1.88
C22 : 6 n-3	0.03	0.03	7.01	6.84	7.08	9.60	7.47	8.33
Σ SFA	8.95	10.57	21.22	21.50	21.28	25.90	23.33	23.78
Σ MUFA	14.14	27.04	24.21	28.13	26.20	28.23	25.82	28.34
Σ PUFA	76.91	62.39	54.57	50.37	52.52	45.87	50.85	47.87
Σ (n-6)	13.70	61.35	18.77	32.86	25.62	21.85	19.51	27.24
Σ (n-3)	63.21	1.04	35.80	17.52	26.91	24.02	31.34	20.64
Σ (n-3)/Σ (n-6)	4.62	0.02	1.91	0.53	1.05	1.10	1.61	0.76

SFA = saturated fatty acids
MUFA = monounsaturated fatty acids
PUFA = polyunsaturated fatty acids

hand, and on the other hand in g/kg of meat using the recovery of internal standard and the known total lipid content.

The analysis of variance of determined values was performed according to Snedecor and Cochran (1967) and regression analysis using the UNISTAT package (version 5.1, Unistat Ltd., London, England).

RESULTS AND DISCUSSION

One fish from the control group and one fish from the experimental group L5 died during the experiment. Ambient water was so muddy during rains occurring between the 25th and 38th day of experiment that it was not possible to feed the fish for 5 days, so that the live body gains of all fish were very low.

As far as the diet formulation is concerned, Takeuchi and Watanabe (1977) determined n-3 PUFA requirement as 20% of lipids as ALA or 10% of lipids as EPA and DHA. This minimum requirement was exceeded in all diets used in our experiment.

Initial and final LBWs and their dependence on the length of fattening period (0–75 days) were expressed by linear regression equations (Table 4). Average daily gains from the beginning of the experiment are presented in Figure 1. Average daily

Table 3. Water temperature and daily ration

Date	Days	Average water temperature (°C)	Daily ration as per cent of live weight
April 12–22	10	8	0.7
April 22–29	7	8	0.8
April 29–May 6	7	8	0.8
May 6–20	14	9	0.8
May 20–June 4	15	12	1.0
June 4–13	9	11	1.0
June 13–26	13	11	1.0

Table 4. Live weight of fish

Diet	Live weight (g)		$Y = a + bX$			Weight of fish selected for analyses	Carcass yield
	initial	final	a	b	r		
L5	259	433	261	2.16**	0.988	423 ± 3.6	84.2 ± 0.41
S5	257	431	254	2.16**	0.985	423 ± 3.6	84.6 ± 0.48
LS5	254	422	253	2.13**	0.989	422 ± 4.3	85.2 ± 0.49
0	257	422	256	2.12**	0.991	422 ± 2.3	84.9 ± 0.48
L2.5	257	437	256	2.27**	0.989	422 ± 3.7	85.6 ± 0.56
S2.5	258	439	258	2.29**	0.992	420 ± 5.6	85.4 ± 0.29

X = day of experiment
Y = live weight in g
a, b = parameters of equation
r = correlation coefficients
Significance of linear regression $^{**}P < 0.01$

gains of fish in groups S2.5, L2.5 and L5 were higher than those of controls during the whole experiment. However, the coefficients of the linear term did not differ significantly ($P > 0.05$).

Feed conversion ratio (FCR) gradually increased during the experiment (Figure 2). Within 75 days of feeding period, FCR values in groups L5, S5, LS5, L2.5 and S2.5 were lower by 8.9; 8.6; 5.8; 5.7 and 7.2%, respectively, than in controls.

Average weight and carcass yield of fish selected for chemical analyses ranged from 420 to 423 g and from 84.2 to 85.6 per cent of LBW, respectively (Table 4).

The fatty acid pattern in fish meat is presented in Table 5. The ratio of saturated fatty acids (SFA) in meat reflected their percentages in feed mixtures. SFA content in the meat of fish of all experimental groups was lower ($P < 0.01$) than in controls.

The percentage of monounsaturated fatty acids (MUFA) in the meat of control fish was higher in comparison with groups receiving 5% of oil in the diet ($P < 0.01$) and with the group fed the feed mixture with 2.5% L ($P < 0.05$), but did not differ from the S2.5 group ($P > 0.05$). We were not able to confirm the data of Skonberg *et al.* (1994), who found that the contents of OA doubled in muscle lipids after the addition of S into the diet. In our experiment, the OA ratio remained unchanged in spite of the fact that feed mixtures with S contained significantly more OA than the control diets. On the other hand, a significant effect of S on the increased retention of n-6 PUFA and decreased n-3 PUFA ratio, mentioned by Ashton *et al.* (1994), was also demonstrated in our experiment.

When S alone was added into the diet, the ratio of n-3 PUFA was significantly ($P < 0.001$) lower

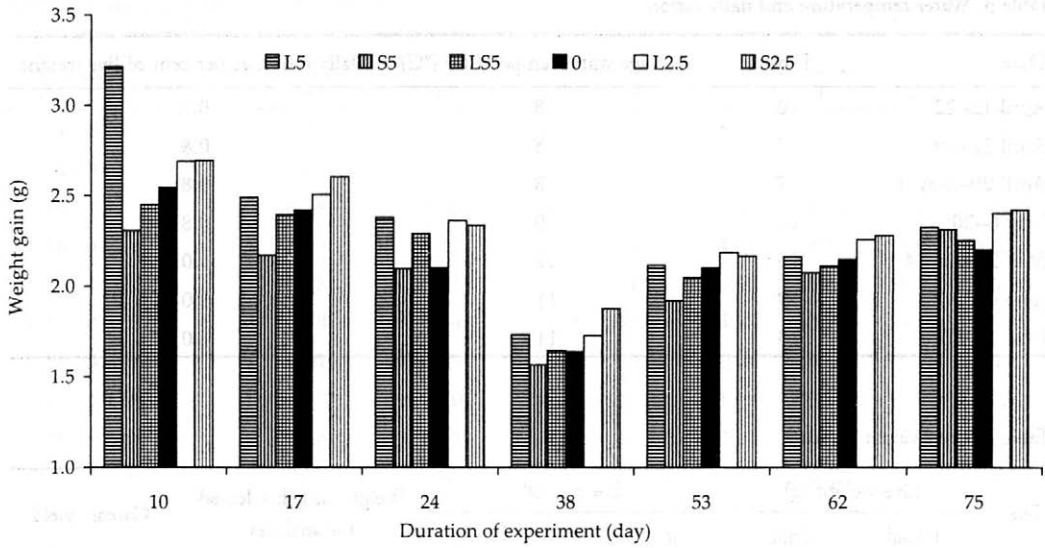

Figure 1. Average daily gains from the beginning of the experiment

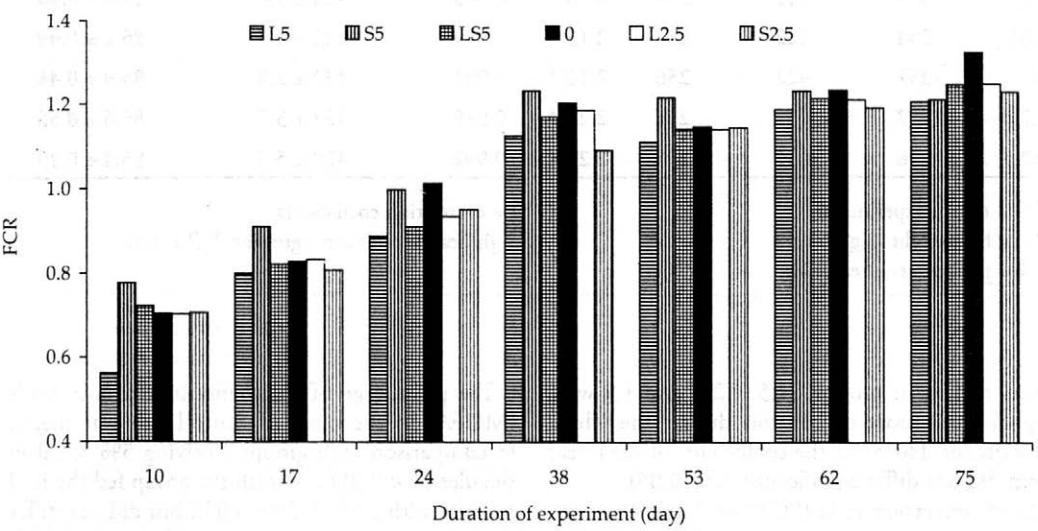

Figure 2. Feed Conversion Ratio from the beginning of the experiment

than in the control and L groups. In the L2.5 group the n-3 PUFA ratio was lower ($P < 0.001$) than in L5, but significantly higher ($P < 0.05$) than in LS5 and control groups.

On the other hand, when L alone was supplemented into the diet, the ratio of LA and n-6 PUFA in meat, respectively, was much lower ($P < 0.001$) than in the S groups and practically the same as in controls.

The supplementation of oils showed an effect on the n-3/n-6 PUFA ratio. Its value was equal to 1.0 in the S5 group, no significant change was observed in the S2.5 group, while it was significantly higher ($P < 0.05$) in LS5. L2.5 group did not differ in the above trait from controls. The highest n-3/n-6 PUFA ratio ($P < 0.01$) was found in the L5 group. This ratio was wider in all our experimental groups as compared to the results of Johansson *et al.*

Table 5. Fatty acid pattern in meat[1]

Fatty acids	Fish receiving the diet					
	L5	S5	LS5	0	L2.5	S2.5
C14 : 0	3.09^{a}	3.06^{a}	3.03^{a}	3.59^{c}	3.33^{b}	3.32^{b}
C16 : 0	15.93^{a}	15.92^{a}	15.76^{a}	17.61^{c}	16.70^{b}	16.68^{b}
C16 : 1	4.80^{ab}	4.49^{a}	4.57^{a}	5.89^{d}	5.40^{c}	5.14^{bc}
C18 : 0	3.84^{a}	4.05^{b}	3.91^{ab}	3.91^{ab}	3.79^{a}	3.98^{ab}
C18 : 1 n-9	20.38^{a}	21.74^{b}	21.42^{b}	21.77^{b}	21.32^{ab}	21.95^{b}
C18 : 2 n-6	15.83^{a}	23.01^{c}	20.35^{b}	15.57^{a}	16.16^{a}	20.32^{b}
C18 : 3 n-6	0.23^{a}	0.35^{c}	0.33^{bc}	0.26^{ab}	0.27^{ab}	0.33^{bc}
C18 : 3 n-3	11.42^{c}	2.79^{a}	7.17^{b}	2.98^{a}	7.71^{b}	2.27^{a}
C20 : 1 n-9	2.43^{b}	2.24^{a}	2.18^{a}	2.88^{d}	2.68^{c}	2.47^{b}
C20 : 4 n-6	0.62^{a}	0.69^{bc}	0.66^{ab}	0.73^{c}	0.65^{ab}	0.73^{c}
C20 : 5 n-3	5.06^{ab}	4.88^{a}	4.89^{a}	5.89^{c}	5.51^{bc}	5.34^{ab}
C22 : 4 n-6	0.03^{a}	0.04^{b}	0.04^{b}	0.04^{b}	0.03^{a}	0.04^{b}
C22 : 5 n-6	0.17^{a}	0.20^{bc}	0.19^{ab}	0.21^{cd}	0.18^{a}	0.21^{cd}
C22 : 5 n-3	1.84^{a}	1.84^{a}	1.83^{a}	2.22^{c}	1.98^{ab}	2.02^{b}
C22 : 6 n-3	14.32^{a}	14.69^{a}	13.65^{a}	16.44^{b}	14.30^{a}	15.20^{ab}
Σ SFA	22.87^{a}	23.03^{ab}	22.70^{a}	25.11^{d}	23.82^{bc}	23.98^{c}
Σ MUFA	27.61^{a}	28.48^{ab}	28.18^{ab}	30.54^{c}	29.39^{bc}	29.56^{bc}
Σ PUFA	49.52^{c}	48.49^{bc}	49.12^{c}	44.35^{a}	46.79^{b}	46.47^{ab}
Σ (n-6)	16.88^{a}	24.29^{c}	21.65^{b}	17.01^{a}	17.49^{a}	21.91^{b}
Σ (n-3)	32.64^{c}	24.20^{a}	27.45^{b}	27.30^{b}	29.28^{b}	24.48^{a}
Σ (n-3)/ Σ (n-6)	1.93^{d}	1.00^{a}	1.27^{b}	1.61^{c}	1.67^{c}	1.12^{ab}

[1]per cent of total determined fatty acids; n = 16

^{abcde} = means with different superscripts in the lines differ highly significantly ($P < 0.01$)

SFA = saturated fatty acids

MUFA = monounsaturated fatty acids

PUFA = polyunsaturated fatty acids

(2000), who found n-3/n-6 PUFA ratios ranging from 0.20 to 0.21 in older rainbow trouts fed altered ration levels.

Meat composition of the fish is presented in Table 6. As far as dry matter, fat and crude protein contents are concerned, there were no significant ($P > 0.05$) differences between the groups fed the different diets. Salmonids are usually considered to be medium-fat fish, with muscle lipid contents ranging from 2 to 7% (Jobling, 2001). The values of fillet lipid content ranged within relatively narrow limits (3.6–3.9%) in our experiment, in spite of the fact that the differences in fat content in individual diets were relatively high and remained unchanged even after a widening of the energy/protein ratio in the diet from 39.7 to 43.6.

There were no significant differences in average values of cholesterol content (0.562–0.594 g/kg) in our experiment. Immediately after the feeding period finished, Bieniarz *et al.* (2000) found the values in meat of rainbow trout that ranged within similar limits (0.634 ± 0.051 g/kg). These contents are comparable with the values found in white poultry meat. Cholesterol content in breast meat of male turkeys

Table 6. Composition of meat (g/kg)

Nutrients	Fish receiving the diet					
	L5	S5	LS5	0	L2.5	S2.5
Dry matter	240.6^{a}	240.9^{a}	241.5^{a}	239.2^{a}	243.0^{a}	242.9^{a}
Crude protein (N*6)	177.5^{a}	179.0^{a}	177.2^{a}	180.5^{a}	178.8^{a}	178.9^{a}
HIP extract	38.2^{a}	38.0^{a}	39.2^{a}	35.9^{a}	38.2^{a}	38.3^{a}
Cholesterol	0.571^{a}	0.571^{a}	0.587^{a}	0.562^{a}	0.594^{a}	0.584^{a}
Fatty acids						
C14 : 0	1.070^{a}	1.063^{a}	1.101^{a}	1.201^{a}	1.169^{a}	1.169^{a}
C16 : 0	5.497^{a}	5.498^{a}	5.736^{a}	5.838^{a}	5.845^{a}	5.873^{a}
C16 : 1	1.661^{a}	1.568^{a}	1.676^{a}	1.987^{a}	1.900^{a}	1.832^{a}
C18 : 0	1.326^{a}	1.394^{a}	1.425^{a}	1.289^{a}	1.329^{a}	1.404^{a}
C18 : 1 n-9	7.048^{a}	7.560^{a}	7.805^{a}	7.273^{a}	7.488^{a}	7.795^{a}
C18 : 2 n-6	5.449^{a}	8.004^{b}	7.320^{b}	5.112^{a}	5.656^{a}	7.155^{b}
C18 : 3 n-6	0.077^{a}	0.124^{c}	0.120^{c}	0.085^{ab}	0.094^{abc}	0.112^{bc}
C18 : 3 n-3	4.014^{c}	0.966^{a}	2.575^{b}	0.949^{a}	2.695^{b}	0.798^{a}
C20 : 1 n-9	0.835^{a}	0.774^{a}	0.794^{a}	0.956^{a}	0.937^{a}	0.864^{a}
C20 : 4 n-6	0.212^{a}	0.236^{a}	0.239^{a}	0.238^{a}	0.226^{a}	0.253^{a}
C20 : 5 n-3	1.743^{a}	1.682^{a}	1.761^{a}	1.931^{a}	1.917^{a}	1.841^{a}
C22 : 4 n-6	0.012^{a}	0.015^{ab}	0.016^{b}	0.014^{ab}	0.012^{a}	0.015^{ab}
C22 : 5 n-6	0.058^{a}	0.068^{ab}	0.067^{ab}	0.069^{ab}	0.063^{ab}	0.074^{b}
C22 : 5 n-3	0.634^{a}	0.632^{a}	0.663^{a}	0.730^{a}	0.693^{a}	0.703^{a}
C22 : 6 n-3	4.866^{a}	4.982^{a}	4.896^{a}	5.250^{a}	4.975^{a}	5.219^{a}
Σ FA	34.503^{a}	34.568^{a}	36.195^{a}	32.921^{a}	34.999^{a}	35.109^{a}
Σ SFA	7.893^{a}	7.956^{a}	8.262^{a}	8.327^{a}	8.343^{a}	8.446^{a}
Σ MUFA	9.544^{a}	9.901^{a}	10.275^{a}	10.216^{a}	10.325^{a}	10.492^{a}
Σ PUFA	17.066^{ab}	16.710^{ab}	17.657^{b}	14.377^{a}	16.331^{ab}	16.171^{ab}
Σ (n-6)	5.808^{a}	8.447^{b}	7.793^{b}	5.579^{a}	6.126^{a}	7.702^{b}
Σ (n-3)	11.258^{c}	8.263^{a}	9.855^{bc}	8.786^{abd}	10.194^{cd}	8.444^{ab}
Σ (n-3)/Σ (n-6)	1.94^{d}	0.98^{a}	1.26^{b}	1.57^{c}	1.66^{c}	1.10^{ab}

^{abcde} = means with different superscripts in the lines differ highly significantly ($P < 0.01$)
FA = fatty acids
SFA = saturated fatty acids
HIP = hexane/2-propanol
MUFA = monounsaturated fatty acids
PUFA = polyunsaturated fatty acids

slaughtered at the age of 20 weeks was 0.582 g/kg in the experiment of Komprda *et al.* (2001).

PUFA content in storage fat is usually much lower than in functional fat (Jobling, 2001). In our experiment, the content of FA was 3.3–3.6% and the PUFA ratio in total FA ranged from 44 to 50% (Table 5). Similar results were obtained by Kinsella *et al.* (1978), who found 52% of PUFA at

the level of 2.2% of total FA. On the other hand, Johansson *et al.* (2000) observed only 25–29% of PUFA in much fattier rainbow trouts with 5–11% of fat in their fillet.

When fatty acids were expressed as concentrations in the fish meat (Table 6), meat of control samples contained significantly less PUFA in comparison with fish fed L5 and S5 ($P < 0.05$). As compared to controls, the supply of LS5 resulted in an increase in PUFA content by 23% ($P < 0.01$). Fish receiving S diets showed higher ($P < 0.01$) levels of n-6 PUFA than all other groups. The content of n-3 PUFA in the L5 group was higher than in the LS5 group ($P < 0.05$) and in groups fed diets without L ($P < 0.001$). The value of this trait was higher ($P < 0.01$) in the L 2.5 group than in groups receiving the diet with S. As far as the contents of SFA and MUFA are concerned, there were no significant differences between the individual groups of fish ($P > 0.05$).

When L alone was added to the diet, the content of LA in meat was significantly ($P < 0.01$) lower than in S groups. An increase in the content of ALA was proportional to the content of L in the diet and was highly significant ($P < 0.001$) both in L2.5 and L5 groups. There were no significant differences ($P > 0.05$) in the levels of arachidonic acid, EPA and DHA in meat of fish fed the different diets.

Fish can desaturate and elongate ALA to their C20 and C22 derivatives EPA and DHA which are physiologically more important than this parent fatty acid (Henderson, 1996). Therefore they can show a positive effect on the cholesterol content in meat (Leskanich and Noble, 1997). However, we found no significant differences ($P > 0.05$) in contents of EPA, DHA and cholesterol, respectively, in the meat of fish fed the different diets in our experiment, in spite of the fact that the content of ALA in feed mixtures with L was high.

REFERENCES

Arneth W., Al-Ahmad H. (1995): Cholesterol Bestimmung in Muskel- und Fettgewebe sowie in Immerein mittels HPLC. Fleischwirtschaft, *75*, 185–187.

American Dietetic Association (1995): Position of the American Dietetic Association. Phytochemicals and functional foods. J. Amer. Diet. Assoc., *95*, 493–496.

Ashton I., Clements K., Barrow S.E., Secombes C.J., Rowley A.F. (1994): Effects of dietary fatty acids on eicosanoid-generating capacity, fatty acid composition and chemotactic activity of rainbow trout (*Oncorhynchus mykiss*) leucocytes. Biochim. Biophys. Acta, *6*, 253–262.

Bieniarz K., Koldras M., Kaminski J., Mejza T. (2000): Fatty acids and cholesterol in some freshwater fish species in Poland. Folia Univ. Agric. Stetin, *27*, 21–44.

Caballero M.J., Obach A., Rosenlund G., Montero D., Gisvold M., Izquierdo M.S. (2002): Impact of different dietary lipid sources on growth, lipid digestibility, tissue fatty acid composition and histology of rainbow trout, *Oncorhynchus mykiss*. Aquaculture, *214*, 253–271.

Fajmonová E., Zelenka J., Komprda T., Kladroba D., Šarmanová I. (2003): Effect of sex, growth intensity and heat treatment on fatty acid composition of common carp *(Cyprinus carpio)* fillets. Czech J. Anim. Sci., *48*, 85–92.

Hara A., Radin M.S. (1978): Lipid extraction of tissues with a low-toxicity solvent. Anal. Biochem., *90*, 420–426.

Henderson R.J. (1996): Fatty acid metabolism in freshwater fish with particular reference to polyunsaturated fatty acids. Arch. Tierernähr., *49*, 5–22.

Jobling M. (2001): Nutrient partitioning and the influence of feed composition on body composition. In: Houlihan D., Boujard T., Jobling M. (eds.): Food Intake in Fish. Blackwell Science Ltd, Oxford. 414 pp.

Johansson L., Kiessling A., Kiessling K.H., Berglund L. (2000): Effects of altered ration levels on sensory characteristics, lipid content and fatty acid composition of rainbow trout (*Oncorhynchus mykiss*). Food Quality Prefer., *11*, 247–254.

Kinsella J.E., Shimp J.L., Mai J. (1978): The proximate and lipid composition of several species of freshwater fishes. N.Y. Fd Life Sci., *69*, 1–20.

Komprda T., Zelenka J., Jarošová A., Fialová M., Blažková E., Fajmonová E. (2001): Cholesterol and fatty acid content in breast and thigh meat of turkeys growing with different intensity. Arch. Geflügelkd., *65*, 258–264.

Leskanich C.O., Noble R.C. (1997): Manipulation of the n-3 polyunsaturated fatty acid composition of avian eggs and meat. World Poultry Sci. J., *53*, 155–183.

National Research Council (1993): Nutrient Requirements of Fish. National Academy Press, Washington, D.C. 115 pp.

Owen J.M., Adron J.W., Middleton C., Cowey C.B. (1975): Elongation and desaturation of dietary fatty acids in turbot, *Scophtalmus maximus* L., and rainbow trout, *Salmo gairdnerii* Rich. Lipids, *10*, 528–531.

Skonberg D.I., Rasco B.A., Dong F.M. (1994): Fatty acid composition of salmonid muscle changes in

response to a high oleic acid diet. J. Nutr., *124*, 1628–1638.

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

Takeuchi T., Watanabe T. (1977): Dietary levels of methyl laurate and essential fatty acid requirement of rainbow trout. Bull. Jpn. Soc. Sci. Fish, *43*, 893–898.

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ABSTRAKT

Vliv lněného a slunečnicového oleje na zastoupení cholesterolu a mastných kyselin v mase pstruha duhového (*Oncorhynchus mykiss*)

Pstruzi duhoví byli vykrmováni směsí obsahující 2,5 nebo 5 % lněného (L) nebo slunečnicového (S) oleje (L2.5, L5, S2.5, S5), nebo 5 % směsi obou olejů (LS5). Skupina kontrolní (0) dostávala průmyslově vyráběnou krmnou směs. Po 75 dnech výkrmu bylo ze šesti skupin vybráno po 16 rybách a ve filé bez kůže byl stanoven obsah živin. V přírůstcích a obsahu sušiny, tuku, bílkovin, cholesterolu, nasycených i mononenasycených mastných kyselin, kyseliny arachidonové, eikosapentaenové a dokosahexaenové v mase různě krmených ryb nebylo průkazných rozdílů ($P > 0,05$). Svalovina kontrolních ryb obsahovala méně polynenasycených mastných kyselin (PUFA) než maso ryb krmených L5, S5 a LS5 ($P < 0,05–0,01$). Při zařazení samotného L svalovina obsahovala méně kyseliny linolové a více kyseliny α-linolenové ($P < 0,01$) než při zkrmování směsi obsahující S. Ryby, které dostávaly S měly ve svalovině vysoce průkazně více n-6 PUFA než ryby v ostatních skupinách. Obsah n-3 PUFA byl při zkrmování L průkazně ($P < 0,05–0,01$) vyšší než při krmení samotným S. Ve skupině L5 byl poměr n-3/n-6 PUFA v mase podstatně ($P < 0,01$) příznivější pro spotřebitele než ve všech ostatních skupinách.

Klíčová slova: pstruh duhový; mastné kyseliny; cholesterol; lněný olej; slunečnicový olej

Corresponding Author

Prof. Ing. Jiří Zelenka, CSc., Mendelova zemědělská a lesnická univerzita v Brně, Zemědělská 1, 613 00 Brno, Česká republika
Tel. +420 545 133 159, fax +420 545 133 199, e-mail: zelenka@mendelu.cz

The effect of slaughter weight and growth rate on meat performance of Holstein steers

G. Chládek, I. Ingr

Faculty of Agronomy, Mendel University of Agriculture and Forestry, Brno, Czech Republic

ABSTRACT: A group of 62 Holstein bullocks was castrated using a non-invasive Burdizzo tongs method at 4 months of age. They were fed a diet based on crushed cereals and fattened up to 400 kg–500 kg of live weight. The data were analysed for the effect of a lower (L up to 430 kg) and higher (H above 431 kg) slaughter weight, and the effect of a lower (S up to 1.050 kg) and higher (T above 1.051 kg) daily weight gain on some parameters of meat performance. Mean values of the parameters were: slaughter weight 431.2 kg, age at slaughter 418.9 days, daily weight gain 1.071 kg, net weight gain 0.558 kg, duration of fattening 295.5 days, dressing percentage 51.4%, carcass weight 221.6 kg, weight of the right side of carcass 110.0 kg, weight and proportion of kidney fat 4.9 kg and 2.2%. Weight and proportions of some parts of the right side of carcass were as follows: forequarter 49.9 kg and 45.3%, hindquarter 60.1 kg and 54.7%, rib roast 4.6 kg and 4.2%, neck 4.5 kg and 4.2%, shoulder 6.9 kg and 6.3%, rump 20.7 kg and 18.8%, short loin 3.7 kg and 3.4%, sirloin 1.42 kg and 1.29%, shins 5.7 kg and 5.2%, fat trim 3.9 kg and 3.5%, meat trim 13.6 kg a 12.4%. In H group (a higher slaughter weight by +42.2 kg), the following parameters were different from L group: age at slaughter (+18.5 days), duration of fattening (+17.5 days), dressing percentage (–1.7%), carcass weight (+14.3 kg), weight of the right side of carcass (+6.4 kg), weight and proportion of forequarter (+3.8 kg and +0.9%), hindquarter (+2.6 kg and –0.9%), rib roast (+1.2 kg and +0.9%), neck (+1.0 kg and +0.6%), shoulder (+1.1 kg and +0.6%), rump (+1.1 kg) and shins (+0.5 kg). In T group (a higher daily weight gain by +0.237 kg/head and day), the following parameters were significantly different from S group: age at slaughter (–52.9 days), duration of fattening (–56.8 days), net weight gain (+0.119 kg/head and day), weight and proportion of kidney fat (+1.0 kg and +0.5%), weight and proportion of shoulder (–0.5 kg and –0.6%) and proportion of rump (–1.2 kg).

Keywords: Holstein breed; steers; Burdizzo; meat efficiency; carcass value; fattening

As in other countries, the male part of the Holstein population is used for beef production in the Czech Republic. Numerous Czech authors studied problems of fattening of Holstein (previously called Black and White) bulls, e.g. Urban *et al.* (1976, 1981), Franc *et al.* (1993), Teslík *et al.* (1998) and Bartoň *et al.* (1996). Their results were accurately summed up in the paper of the latter who concluded that improvement of milk performance of cows had negative consequences for meat performance of male animals, such as deterioration of muscle tissue (and consequently lower proportion of valuable parts), higher proportion of bones and, partly, higher fat deposition.

Ptáček and Suchánek (1985) recommend that the final live weight of bulls in intensive fattening systems should not exceed 500 kg. Chládek *et al.* (1998) studied meat performance of Holstein bulls fattened in this way. Apart from the effect of housing system the authors analysed the effect of lower (210 kg–229 kg) and higher (230 kg–249 kg) carcass weight, and the effect of lower (up to 999 g) and higher (above 1 000 g) daily weight gain. In the group with higher carcass weight (+22 kg) the authors found highly significantly higher slaughter weight (+28 kg), age at slaughter (+12 days), dressing percentage (+1.2%), weight of hindquarter (+4.5 kg), forequarter (+4.9 kg), rump

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(+2.7 kg) and neck (+1.4 kg). Significantly higher was net weight gain (+51 g), short loin (+0.3 kg), shoulder (+0.6 kg) and meat trim in forequarter (+1.6 kg). More intensive growth was accompanied by a highly significantly higher daily weight gain (+191 g) and net weight gain (+114 g) and lower age at slaughter (–57 days) and significantly higher dressing percentage (+0.7%).

Despite of some positive qualities of meat of castrated animals, fattening of steers for beef is not very common in the Czech Republic and Central Europe, mainly due to culinary traditions. Thus there are few studies dealing with this issue. For example Braun and Lízal (1970) compared feedlot performance of bulls and steers kept in two types of housing system. Age of bulls at slaughter was 537.7 days and 564.0 days and age of steers was 559.8 days and 565.2 days. Live weight of bulls at slaughter was 402.0 kg and 386.9 kg and of steers 369.3 kg and 360.5 kg. Weight of kidney fat in bulls was 2.9 kg and 2.0 kg and in steers 4.6 kg and 3.8 kg. Dressing percentage in bulls was 55.6% and 56.76% and in steers 57.75% and 56.20%.

One of the latest papers is a study of Chládek and Ingr (2003), who analysed feedlot performance data of Holstein steers fattened up to 300 kg–400 kg. The data were analysed for the effect of lower (up to 359 kg) and higher (above 360 kg) slaughter weight, and the effect of lower (up to 1.0 kg) and higher (above 1.001 kg) daily weight gain on their meat performance. In the group with higher slaughter weight (+29.6 kg) the values of the following parameters were higher: age at slaughter (+53.3 days), duration of fattening (+56.2 days), carcass weight (+15.8 kg), weight of the right side of carcass (+7.8 kg), forequarter (+3.8 kg), hindquarter (3.9 kg), rump (+1.3 kg) and short loin (+0.3 kg). Animals with higher growth rate (higher daily weight gain by +0.263 kg per head and day) showed significantly different age at slaughter (–83 days), duration of fattening (–67.6 days), net weight gain (+0.140 kg/head and day), weight of hindquarter (+0.6 kg), weight and proportion of kidney fat (+1.3 kg and +0.7%), weight and proportion of rib roast (+0.8 kg and +0.8%), weight and proportion of short loin (+0.3 kg and +0.2%), weight of neck (+0.5 kg) and shin (+0.6 kg). The authors concluded that the meat performance parameters of steers corresponded with majority of literature resources concerning bulls fattened in similar conditions.

Steers in the experiment of Shahim *et al.* (1993) were slaughtered at 415 days of age at live weight 421 kg while the weight of the right side of carcass was 119.2 kg. The authors observed that the differences between bulls and steers in carcass composition were more pronounced with higher live weight; steers grew fat earlier and faster. Growth rate was observed in a study of Bruckmaier *et al.* (1997). The authors presented daily weight gain 0.88 kg and 1.00 kg and slaughter weight 330 kg and 450 kg. In a different group of steers they found dressing percentage 50.6%.

MATERIAL AND METHODS

The aim of this study was to quantify the effect of live weight and growth rate on some parameters of meat performance in Holstein steers fattened up to 400 kg–500 kg of live weight.

An experimental group of 62 Holstein bullocks, castrated at 4 months of age using a non-invasive Burdizzo tongs method was investigated. The effect of slaughter weight (up to 430 kg and above 431 kg) and growth rate (daily weight gain up to 1 050 kg and above 1.051 kg) on some parameters of meat performance was analysed.

The diet consisted of ad lib amount of crushed cereals (barley and wheat), limited amount of protein concentrate (containing an adequate amount of minerals and vitamins) and limited amount of alfalfa hay. The daily ration was calculated in order to achieve predicted daily weight gain 1.3 kg as recommended by Sommer *et al.* (1994).

The steers were evenly slaughtered at the live weight between 400 kg and 500 kg. The following beef production parameters were evaluated on the day of slaughter: live weight and age, duration of fattening period, daily weight gain and net weight gain, carcass weight and dressing percentage. Then the weight and proportion (Figure 1) of right side of carcass, fore- and hindquarter, kidney fat, rib roast, neck, shoulder, rump, short loin, sirloin, fore- and hind shin, fat trim and meat trim were recorded.

The data were analysed for mean value ($\bar{x}$), standard deviation ($s_{\bar{x}}$) and coefficient of variation ($V\%$). GLM method was applied to determine the observed effects.

RESULTS

Data describing the effect of slaughter weight and growth rate on some parameters of feedlot perform-

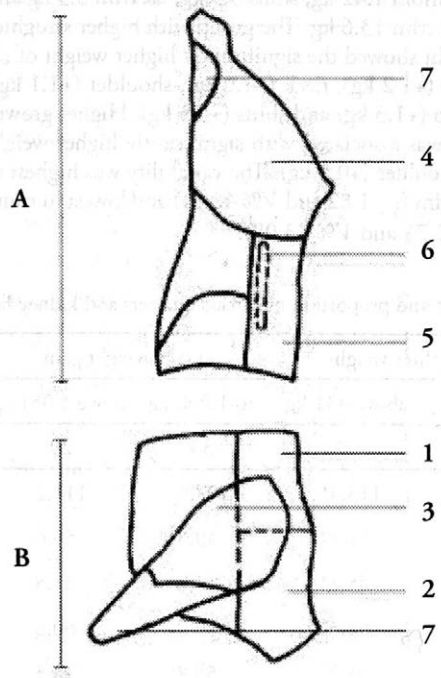

Figure 1. Chart of carcass divortion

A = Hindquarter; B = Forequater

1 = rib roast; 2 = neck; 3 = shoulder; 4 = rump; 5 = short loin; 6 = sirloin; 7 = shins

ance are presented in Table 1. Mean live weight at slaughter was 431.2 kg and carcass weight 221.6 kg, which resulted in dressing percentage 51.4%. Age at slaughter was 418.9 days and duration of fattening 295.5 days. Daily weight gain was 1.071 kg and daily net weight gain 0.558 kg. The group with higher slaughter weight (+42.2 kg) showed a significantly higher age at slaughter (+18.5 days), duration of fattening (+17.5 days) and carcass weight (+14.3 kg) and significantly lower dressing percentage (–1.70%). Higher growth rate (+0.237 kg daily weight gain) was accompanied by a significantly lower age at slaughter (–52.9 days) and duration of fattening (–56.8 days) while daily net weight gain (+0.119 kg) was significantly higher. The highest variability was found in duration of fattening ($s_{\bar{x}}$ 50.9 and *V%* 17.24) and the lowest in dressing percentage ($s_{\bar{x}}$ 1.86 and *V%* 3.61).

The effect of slaughter weight and growth rate on the weight and proportion of carcass quarters and kidney fat is presented in Table 2. The mean weight of the right side was 110.0 kg. The weight and proportion of forequarter were 49.9 kg and 45.3%, of hindquarter 60.1 kg and 54.7% and of kidney fat 4.9 kg and 2.2%. The group with higher slaughter weight showed the significantly higher weight of right side (+6.4 kg), forequarter (+3.8 kg) and hindquarter (+2.6 kg). While the proportion of forequarter in H group was higher (+0.9%), the proportion of hindquarter was lower (–0.9%). Higher growth rate was associated with

Table 1. The effect of slaughter weight and growth rate on some parameters of feedlot performance of bullocks

Parameter	$\bar{x}$	$s_{\bar{x}}$	*V%*	Slaughter weight		Daily weight gain	
				to 430 kg	above 431 kg	to 1 050 kg	above 1 051 kg
Number	62			33	29	33	29
Slaughter weight (kg)	431.2	25.37	5.88	411.2	453.4	424.2	439.3
Age at slaughter (day)	418.9	46.82	11.18	410.2*	428.7*	443.6*	390.7*
Daily weight gain (kg)	1.071	0.1656	5.46	1.033	1.115	0.965	1.202
Duration of fattening (day)	295.5	50.9	17.24	287.3*	304.8*	322.1*	265.3*
Carcass weight (kg)	221.6	12.63	5.7	214.9*	229.2*	219.3	224.2
Net gain (kg)	0.558	0.0892	16.00	0.550	0.566	0.502*	0.621*
Dressing percentage	51.4	1.86	3.61	52.2*	50.5*	51.7	51.1

*$P < 0.05$

significantly higher weight and proportion of kidney fat (+1.0 kg and +0.5%). The highest variability was found in the weight of kidney fat ($s_{\bar{x}}$ 1.72 and *V%* 34.80) and the lowest in the proportion of hindquarter ($s_{\bar{x}}$ 1.38 and *V%* 2.53).

The effect of slaughter weight and growth rate on the weight of some carcass parts is shown in Table 3. The mean weight of rib roast was 4.6 kg, neck 4.5 kg, shoulder 6.9 kg, rump 20.7 kg, short loin 3.7 kg, sirloin 1.42 kg, shins 5.7 kg, fat trim 3.9 kg and meat trim 13.6 kg. The group with higher slaughter weight showed the significantly higher weight of rib roast (+1.2 kg), neck (+1.0 kg), shoulder (+1.1 kg), rump (+1.3 kg) and shins (+0.5 kg). Higher growth rate was associated with significantly higher weight of shoulder (+0.5 kg). The variability was highest in fat trim ($s_{\bar{x}}$ 1.82 and *V%* 46.45) and lowest in rump ($s_{\bar{x}}$ 2.71 and *V%* 13.08).

Table 2. The effect of slaughter weight and growth rate on weight and proportion of carcass quarters and kidney fat

Parameter	$\bar{x}$	$s_{\bar{x}}$	*V%*	Slaughter weight		Daily weight gain	
				to 430 kg	above 431 kg	to 1.050 kg	above 1.051 kg
Number	62			33	29	33	29
Right side weight (kg)	110.0	6.59	5.99	107.0*	113.4*	108.9	111.2
Forequarter weight (kg)	49.9	3.47	6.97	48.1*	51.9*	49.3	50.6
Forequarter proportion (%)	45.3	1.38	3.06	44.9*	45.8*	45.2	45.5
Hindquarter weight (kg)	60.1	14.05	6.23	58.9*	61.5*	59.7	60.6
Hindquarter proportion (%)	54.7	1.38	2.53	55.1*	54.2*	54.8	54.5
Kidney fat weight (kg)	4.9	1.72	34.8	4.6	5.3	4.5*	5.5*
Kidney fat proportion (%)	2.2	0.773	34.43	2.1	2.3	2.0*	2.5*

*$P < 0.05$

Table 3. The effect of slaughter weight and growth rate on weight of some parts of carcass

Parameter	$\bar{x}$	$s_{\bar{x}}$	V%	Slaughter weight		Daily weight gain	
				to 430 kg	above 431 kg	to 1.050 kg	above 1.051 kg
Number	62			33	29	33	29
Rib roast (kg)	4.6	1.11	23.89	4.1*	5.3*	4.7	4.5
Neck (kg)	4.5	1.15	25.19	4.1*	5.1*	4.7	4.5
Shoulder (kg)	6.9	1.24	17.93	6.4*	7.5*	7.2*	6.7*
Rump (kg)	20.7	2.71	13.08	20.2*	21.3*	21.1	20.3
Short loin (kg)	3.7	0.54	14.63	3.6	3.8	3.6	3.8
Sirloin (kg)	1.42	0.28	20.00	1.36	1.48	1.41	1.43
Shins (kg)	5.7	0.96	16.66	5.5*	6.0*	5.8	5.6
Fat trim (kg)	3.9	1.82	46.45	3.9	3.9	4.2	3.6
Meat trim (kg)	13.6	5.02	36.97	14.2	12.9	12.9	14.2

*$P < 0.05$

Table 4. The effect of slaughter weight and growth rate on proportion of some parts of carcass

Parameter	$\bar{x}$	$s_{\bar{x}}$	V%	Slaughter weight		Daily weight gain	
				to 430 kg	above 431 kg	to 1.050 kg	above 1.051 kg
Number	62			33	29	33	29
Rib roast (%)	4.2	0.95	22.43	3.8*	4.7*	4.3	4.1
Neck (%)	4.2	0.98	23.76	3.8*	4.4*	4.3	4.1
Shoulder (%)	6.3	1.03	16.31	6.0*	6.6*	6.6*	6.0*
Rump (%)	18.8	2.37	12.60	18.9	18.7	19.4	18.2*
Short loin (%)	3.4	0.42	12.33	3.4	3.4	3.4	3.4
Sirloin (%)	1.29	0.241	18.66	1.27	1.31	1.29	1.29
Shins (%)	5.2	0.88	16.81	5.1	5.3	5.3	5.1
Fat trim (%)	3.5	1.58	44.18	3.6	3.4	3.8	3.2
Meat trim (%)	12.4	4.63	37.40	12.8	12.0	11.9	12.9

*$P < 0.05$

The effect of slaughter weight and growth rate on the proportion of some carcass parts is shown in Table 4. The mean percentage of rib roast was 4.2%, neck 4.2%, shoulder 6.3%, rump 18.8%, short loin 3.4%, sirloin 1.29%, shins 5.2%, fat trim 3.5% and meat trim 12.4%. Higher slaughter weight was associated with a higher proportion of rib roast (+0.9%), neck (+0.6%) and shoulder (+0.6%). Higher growth rate was accompanied by a lower proportion of shoulder (–0.6%) and rump (–1.2%). The variability was highest in fat trim ($s_{\bar{x}}$ 1.58 and *V%* 44.18) and lowest in short loin ($s_{\bar{x}}$ 0.42 and *V%* 12.33).

DISCUSSION

The weight of kidney fat was comparable to the values found by Braun and Lízal (1970) despite of the fact that the authors used a thoroughly different, i.e. extensive method of fattening; the evidence is a considerably higher age of steers when they reached comparable live weights. A considerable difference was found in dressing percentage; their values were higher (at least by 5.7%). This could probably be explained by adding the weight of kidney and kidney fat to the carcass weight, the method that was used at that time. The method of determination of the weight of animals before slaughter could also affect the results.

Almost identical dressing percentage (51.8%) was found by Chládek a Ingr (2003) in Holstein steers fattened in similar conditions up to lower live weight (300–400 kg). Chládek *et al.* (1998) also found similar dressing percentage (52.0%) in intact Holstein bulls fattened and slaughtered in comparable conditions.

Dressing percentage was in agreement with the results of those authors who analysed data on steers fattened to similar live weight. Their values were both lower (50.6%) e.g. Bruckmaier *et al.* (1997) and higher (52.6%) e.g. Keane (1994).

Unlike Shahim *et al.* (1993), we did not prove earlier and more pronounced fat deposition in steers. The amount and percentage of kidney fat were similar to that (5.03 kg and 2.28%) found by Chládek and Ingr (2001) in Holstein bulls fattened in similar conditions. The weight of kidney fat was also comparable to that found by Antal (1977) 3.4 kg or by Nosál and Čubon (1994) 4.59 kg, despite of the fact that their experimental animals were bulls.

The weight and proportion of fat trim were also similar to the values found by Chládek and Ingr (2001) in Holstein bulls (3.64 kg and 3.3%). Nosál and Pavlič (1988) found even slightly higher values in bulls (5.36 kg and 6.69 kg). The weight and proportion of kidney fat were not affected by the growth rate of steers in this study (unlike steers fattened up to 300–400 kg in the study of Chládek

and Ingr, 2003). However, a certain tendency towards higher fat deposition in steers with higher slaughter weight was indicated by lower dressing percentage. On the contrary, Chládek *et al.* (1998) found that higher slaughter weight of Holstein bulls was associated with higher dressing percentage.

As for the carcass composition, the weight of hindquarter was similar to the value found by Chládek *et al.* (1998) in Holstein bulls but the weight of forequarter was considerably lower (while the total carcass weight was by 6 kg lower in our study). Consequently, the weights of the observed parts of hindquarter (rump, short loin and sirloin) were similar while the weights of parts comprising forequarter (rib roast, neck and shoulder) were lower than the values of Chládek *et al.* (1998). Meat trim and variability of the observed parameters were also comparable.

The percentage of some carcass parts could be compared to the results of Chládek and Ingr (2003). We found a higher proportion of neck, comparable proportion of rib roast and meat trim, somewhat lower proportion of shoulder, short loin, sirloin and fat trim and considerably lower proportion of rump. Unlike Chládek and Ingr (2003) we found higher slaughter weight accompanied by the higher weight and proportion of rib roast, neck and shoulder. But in our study the higher growth rate was not associated with higher proportion of rib roast and short loin but with lower proportion of shoulder and rump.

In spite of the tendency towards lower dressing percentage in animals with higher slaughter weight, the applied system of steer fattening appeared to be an effective way of beef production by Holstein male animals. Higher slaughter weight resulted in higher weight and proportion of some parts of hindquarter. Higher growth rate was associated with higher weight and proportion of kidney fat but also with a lower proportion of some carcass parts. Furthermore, our values of meat performance parameters of steers corresponded with the majority of literature resources concerning the fattening of bulls in similar systems.

REFERENCES

Antal J. (1977): Výroba hovädzieho mäsa so zníženym obsahom tuku. Živoč. Výr., *23*, 1–9.

Bartoň L., Teslík V., Urban F., Řehák D. (1996): Jatečná hodnota býků českého strakatého a černostrakatého skotu při výkrmu do hmotnosti 620 kg. Živoč. Výr., *41*, 467–472.

Braun B., Lízal F. (1970): Výkrm býků a volů vysokými dávkami kukuřičných oklasků, melasy a močoviny. Živoč. Výr., *15*, 639–648.

Bruckmaier R.M., Lehmann E., Hugi D., Hammon H.M., Blum J.W. (1997): Ultrasonic measurement of longissimus dorsi muscle and backfat, associated with metabolic and endocrine traits, during fattening of intact and castrated male cattle. Livest. Prod. Sci., *53*, 123–134.

Chládek G., Ingr I. (2001): Meat quality and beef production parameters in Holstein bulls fattened to 305–400 kg of live weight. Acta Univ. Agric. et Silvic. Mendel. Brun, *49*, 125–133.

Chládek G., Ingr I. (2003): Meat performance of Holstein steers fattened up to 305–400 kg of live weight. Acta Univ. Agric. et Silvic. Mendel. Brun., *51*, 129–134.

Chládek G., Soutor J., Ingr I., Krása A. (1998): Meat efficiency of bullocks of the black pied breed finished to a lower slaughter weight. Czech J. Anim. Sci., *43*, 537–540.

Franc Č., Teslík J., Urban F., Bouška J., Řehák D., Živocká J. (1993): Nutriční, technologické a senzorické vlastnosti masa býků plemen české strakaté, černostrakaté a bezrohé herefordské. Živoč. Výr., *38*, 73–83.

Keane M.G. (1994): Productivity and carcass composition of Friesian, Meuse-Rhine-Issel (MRI) × Friesian and Belgian Blue × Friesian steers. Anim. Prod., *59*, 197–208.

Nosáľ V., Pavlič M. (1988): Jatočná hodnota býčkov s vysokým dedičným podielom čiernostrakatého nížinného plemena vykrmovaných do nižšej porážkovej hmotnosti. Živoč. Výr., *33*, 809–820.

Nosáľ V., Čuboň J. (1994): Produkcia mladého hovädzieho mäsa pri využití úžitkového kríženia s mäsovými plemenami. Živoč. Výr., *39*, 467–474.

Ptáček J., Suchánek B. (1985): Masná užitkovost býků pěti genotypů při výkrmu do rozdílných hmotností. Živoč. Výr., *30*, 689–698.

Shahim K.A., Berg R.T., Price M.A. (1993): The effect of breed type and castration on tissue growth patterns and carcass composition in cattle. Livest. Prod. Sci., *35*, 251–264.

Sommer A. *et al.* (1994): Potřeba živin a tabulky výživné hodnoty krmiv pro přežvýkavce. ČAZV, komise výživy hospodářských zvířat. 1. Vyd. Pohořelice, ČZS VÚVZ. 198 pp.

Teslík V., Bartoň L., Urban F. (1996): Jatečný a technologický rozbor jatečných půlek býků českého strakatého a černostrakatého skotu při ukončení výkrmu v živé hmotnosti 575 kg. Živoč. Výr., *41*, 175–181.

Urban F., Dvořáček M., Volek J. (1976): Výsledky výzkumu masné užitkovosti při křížení s černostrakatým nížinným skotem. Živoč. Výr., *21*, 103–110.

Urban F., Dvořáček M., Burda J. (1981): Křížení českého strakatého skotu s býky černostrakatého nížinného plemene – masná užitkovost býků a jalovic. Živoč. Výr., *26*, 15–22.

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ABSTRAKT

Vliv porážkové hmotnosti a intenzity růstu na masnou užitkovost holštýnských volků

Cílem sledovaní bylo kvantifikovat vliv živé hmotnosti a intenzity růstu na vybrané ukazatele masné užitkovosti volků holštýnského plemene (n = 62), vykrmených do živé hmotnosti 400 kg až 500 kg. Krmná dávka byla založena na příjmu mačkaných obilovin (ječmen a pšenice) *ad libitum*, limitovaném množství bílkovinného koncentrátu (obsahujícím též potřebné vitaminy a minerální látky) a limitovaném množství vojtěškového sena. Živinové složení krmné dávky bylo optimalizováno na denní přírůstek živé hmotnosti 1,3 kg podle doporučení autora Sommer *et al.* (1994). Zvířata byla vykastrována ve věku čtyř měsíců nekrvavou metodou Burdizzo kleštěmi. U souboru byl analyzován jednak vliv nižší (L do 430 kg) a vyšší (H nad 431 kg) živé hmotnosti při porážce, jednak nižšího (S do 1,050 kg) a vyššího (T nad 1,051 kg) denního přírůstku živé hmotnosti na vybrané ukazatele masné užitkovosti. Byly zjištěny tyto průměrné hodnoty vybraných ukazatelů: živá hmotnost a věk při porážce 431,2 kg a 418,9 dnů, denní přírůstek živé hmotnosti a netto přírůstek 1,071 kg a 0,558 kg, délka výkrmu a jatečná výtěžnost 295,5 dne a 51,4 %, hmotnost jatečně upraveného těla a jeho pravé poloviny 221,6 kg a 110,0 kg, hmotnost a podíl ledvinového loje 4,9 kg a 2,2 %. Hmotnost a podíl vybraných částí pravých polovin byl: přední čtvrť 49,9 kg a 45,3 %, zadní čtvrť 60,1 kg a 54,7 %, vysoký roštěnec 4,6 kg a 4,2 %, krk 4,5 kg a 4,2 %, plec 6,9 kg a 6,3 %, kýta 20,7 kg a 18,8 %, nízký roštěnec 3,7 kg a 3,4 %, svíčková 1,42 kg a 1,29 %, kližky 5,7 kg a 5,2 %, lojový ořez 3,9 kg a 3,5 %, masitý ořez 13,6 kg a 12,4 %. U **H** skupiny (vyšší živá hmotnost při porážce o +42,2 kg) byly ze všech sledovaných ukazatelů průkazně rozdílné pouze: věk při porážce (+18,5 dne), délka výkrmu (+17,5 dne), výtěžnost (–1,7 %), hmotnost jatečně upraveného těla (+14,3 kg) a dále hmotnosti, resp. podíly u pravé poloviny (+6,4 kg), přední čtvrtě (+3,8 kg, resp. +0,9 %), zadní čtvrtě (+2,6 kg, resp. –0,9 %), vysokého roštěnce (+1,2 kg, resp. +0,9 %), krku (+ 1,0 kg, resp. +0,6 %), plece (+1,1 kg, resp. +0,6 %), kýty (+1,1 kg) a kližek (+0,5 kg), ve srovnání s **L** skupinou. U **T** skupiny (vyšší denní přírůstek o +0,237 kg/kus a den) byly ze všech sledovaných ukazatelů průkazně rozdílné pouze: věk při porážce (–52,9 dne), délka výkrmu (–56,8 dne), netto přírůstek (+0,119 kg/kus a den), hmotnost a podíl ledvinového loje (+1,0 kg a +0,5 %), hmotnost a podíl plece (–0,5 kg a –0,6 %) a podíl kýty (–1,2 kg) ve srovnání s **S** skupinou. Na základě zjištěných výsledků a jejich porovnání s literárními údaji je možné konstatovat, že přes tendenci k nižší jatečné výtěžnosti při vyšší porážkové hmotnosti představuje analyzovaný způsob výkrmu holštýnských volků velmi dobrou možnost uplatnění samčí části této populace skotu. Při vyšší porážkové hmotnosti lze očekávat vyšší hmotnost a podíl zejména těch částí jatečně upraveného těla, které patří do přední čtvrtě. Vyšší intenzita růstu je doprovázena vyšším množstvím i podílem ledvinového loje a může přinést nižší podíl některých částí jatečně upraveného těla. Je možné dále konstatovat, že v práci uvedené parametry masné užitkovosti volků jsou srovnatelné s většinou literárních údajů, které se týkají obdobně vykrmených býčků.

Klíčová slova: holštýnské plemeno; volci; Burdizzo; masná užitkovost; jatečná hodnota; výkrm

Corresponding Author

Doc. Ing. Gustav Chládek, CSc., Mendelova zemědělská a lesnická univerzita, Ústav chovu hospodářských zvířat, Zemědělská 1, 613 00 Brno, Česká republika
Tel. +420 545 133 211, fax +420 545 133 213, e-mail: chladek@mendelu.cz

Comparison of differences in muscle depth and possibilities to predict some parameters of carcass value in bulls by an ultrasonographic method

N.E. Blanco Roa, J. Huba, P. Polák, L. Hetényi, D. Peškovičová, I. Bahelka

Research Institute of Animal Production, Nitra, Slovak Republic

ABSTRACT: We analysed the relations between the depth of muscles detected sonographically in live bulls and their carcass value determined *post mortem*. Animals of two breeds, Slovak Pied and Holstein, were used in our experiment, 27 and 33 bulls, respectively. We found out statistically significant ($P < 0.05$) to highly significant ($P < 0.01$) differences in muscle depth by comparing individual sonographic measures between the breeds. The differences were always significant to the disadvantage of Holstein bulls. The highest values of correlation coefficients were found in the Slovak Pied breed between the depth of *musculus gluteus superficialis* on thigh and weight of warm carcass, weight of cold carcass and weight of 1st class meat: $r = 0.57$, 0.58 and 0.55 ($P < 0.01$), respectively. In our analyses of Holstein breed the correlation between the depth of *musculus longissimus dorsi* on the last lumbar vertebra and parameters of carcass value was $r = 0.75$, 0.75 and 0.73 ($P < 0.01$), respectively. Sonographic measures on shoulder, behind the shoulder and on the last dorsal vertebra showed medium to insignificant values of correlation coefficients at the correlation with the parameters of carcass value. We found high values of the coefficients of determination R^2 in linear regression models in which the live weight before slaughter was an independent variable for the parameter warm carcass weight $R^2 = 0.95$ and 0.87 for Holstein and Slovak Pied breeds, respectively. In linear models into which the live weight before slaughter was not incorporated, the coefficients of determination $R^2 = 0.68$ and 0.39 were in the same order. We can state on the basis of the obtained results that this method can be convenient for the prediction of some parameters of carcass value in cattle.

Keywords: sonography; depth of muscles; carcass value; prediction; cattle

Carcass is the final product of cattle fattening. Objective assessment or estimation of carcass value in animals is important for the optimisation of nutrition and selection of animals as well as for realization. Therefore it is important to improve the forms of carcass value estimation used in cattle today.

Detailed dissection is a very precise system of carcass value assessment *post mortem*, however, it has some disadvantages. It is time-consuming, staff-demanding, there are higher losses of money when such meat is sold and it necessitates to kill the animals. It means there is no optimum system at disposal to assess the carcass value of cattle, and it is a sufficient impulse to look for new more effective classification methods to assess or estimate the carcass value in animals.

A possible solution of this problem is looked for in the instrumentation. In some decades many authors were engaged in the utilization of ultrasonography as a possible means for estimation of carcass value in animals. At the beginning Temple *et al.* (1956), Tulloh *et al.* (1973), Wallace *et al.* (1977), and at present Bugiwati *et al.* (1999), Hassen *et al.* (2001), Blanco Roa *et al.* (2001), Melo *et al.* (2001) and others. All of them analysed the relation between the depth of various muscles, back fat depth or mld area measured by sonography with quantitative and qualitative parameters of carcass value in various animal species.

The aim of this study was to assess the differences in depth of muscles sonographically and to analyse statistically their mutual relationship to the carcass value of bulls of two breeds.

MATERIAL AND METHODS

We used bulls of two breeds – Holstein (H) – 33 animals and Slovak Pied (S) – 27 animals in our experiment. The animals came from different herds and regions of Slovakia. They were purchased at the age of approximately 20 days and they were raised in a calf-house of the farm at the Research Institute for Animal Production. They were fed milk replacer during the period of milk nutrition at the dose 10 l per day, lucerne hay and concentrate feed mixture *ad libitum* till weaning. Then they were housed in a four-row fattening tie stall. The diet was composed of lucerne hay, maize silage and concentrate mixture until the end of fattening at the age of 440 ± 5 days. We measured the depth of muscles sonographically with the apparatus Aloka SSD-500, probe UST-5044 – (3.5 Mhz/172 mm) at this age. The animals were killed at the average age of 455 days.

The measurements with sonograph and data collection were performed at a special stand in a stable with four rows. The sedative xylazinum at 2% concentration was administered at a dose 0.25 ml per 100 kg l.w. approximately 20 minutes before the measurement. The hairs in the area of measurement were shaved and lubricated with oil. The depth of muscle was measured at five points: the probe was placed cranio-caudally in the middle of the shoulder and the *musculus infraspinatus* was measured, by placing the probe dorso-ventrally behind the shoulder between the 6th and 7th dorsal vertebra, on the last rib between 12th and 13th dorsal vertebra and between 5th and 6th lumbar vertebra the *musculus longissimus* dorsi was measured. We measured the *musculus gluteus superficialis* on thigh in a similar way. In all cases we measured the depth of muscle only, i.e. without subcutaneous fat and skin. Measuring or sonography of the muscle is based on the fact that the reflected sound is projected on the screen of the monitor as a digital picture with precisely marked dividing line of tissues, i.e. bones, muscle and fat layer. This picture is frozen and by means of buttons it is possible to measure the depth of muscle or fat layer. The calibration of sonograph by means of a sound amplifier is very important to reach a bright picture. We measured four times at each place, and we calculated the average value. Body measures and live weight of each bull were determined immediately after the sonographic measurement.

The animals were killed in an experimental slaughterhouse at the Research Institute for Animal Production, Nitra. The weight of warm carcass was determined there. The weight of cold carcass was determined one day after the slaughter. Detailed dissection of the right carcass side was done. We studied the following parameters of carcass value: meat weight in the carcass side, weight of 1st class meat (meat from shoulder, rib, loin and round), weight of total fat and bones in the carcass side. Basic variation and statistical characteristics were calculated for the selected data. All analysed parameters between breeds were tested by Scheffe's test on two significance levels 95 and 99%. Other statistical analyses were calculated in the statistical package SAS/STAT 6.12 using the procedure REG, STEPWISE. Coefficients of linear correlations were calculated between individual sonographic measures and selected parameters of carcass value. Then we calculated two alternatives of linear regressive models using the weight before slaughter, and using the sonographic measures of muscle depth only.

Universal form of the model:

$$Y_i = B_o + B_1X_1 + B_2X_2 + e_i$$

where: B_o = absolute member

B_1 = partial linear regression coefficient of dependence of studied parameters on live weight

B_2 = partial linear regression coefficient of dependence of studied parameters on sonographic measures

e_i = random errors

Live weight before slaughter as an independent variable was not included in the models without live weight.

RESULTS AND DISCUSSION

The arithmetical means of fattening parameters and carcass value in bulls of both breeds were not balanced very much in spite of the fact they were slaughtered approximately at the same age. Bulls of the Slovak Pied breed achieved the highest average live weight 536 kg with 57.38% dressing percentage. Bulls of the Holstein breed had the lowest live weight 420.66 kg with 52.41% dressing percentage. More marked differences were observed in the weight of 1st class meat in the Slovak Pied and Holstein breeds, 59.17 kg and 39.39 kg, respectively, as there is a higher proportion of fat and bones and a lower proportion of muscular substance in

the Holstein breed (Chrenek *et al.*, 1996; Nosáľ *et al.*, 1999; Kica *et al.*, 2000). We compared the studied parameters of fattening and carcass value between the Slovak Pied and Holstein breeds and we found statistically highly significant differences ($P < 0.01$) (Table 1).

It follows from the sonographically measured depths of muscles that there were differences between the breeds at each of the measured places. The maximum depth of *musculus infraspinatus* (on the shoulder) was detected in bulls of the Slovak Pied breed 50.75 mm compared with 40.85 mm in the Holstein breed. The sonographic measure on shoulder was carried out reliably in both breeds, its accuracy consists in the fact that the depth of muscle layer is quite thin and so very good to scan (Bugiwati *et al.*, 1999). The maximum depth was found on *m.l.d.* measured behind the shoulder in the Slovak Pied bulls (91.61 mm), followed by the bulls of Holstein breed (69.81 mm). The highest *m.l.d.* depth found on the last dorsal vertebra and last lumbar vertebra was in bulls of Slovak Pied breed (64.66 mm and 62.36 mm, resp.). It proves that the largest rib eye is in the Slovak Pied breed out of the analysed breeds. The sonographically measured depth of *musculus gluteus superficialis* (on thigh) was as follows: Slovak Pied breed 105.20 mm and Holstein breed 77.72 mm. We compared the sonographic measures of the depth of muscles from shoulder, behind the shoulder, from the last dorsal vertebra, from the last lumbar vertebra and from the thigh, and we found statistically highly significant differences ($P < 0.01$) between the Slovak Pied and Holstein breeds (Table 2). The accuracy of the values of sonographically measured depth of muscles depends on many factors, e.g. on the apparatus used, operator's skill, place of measurement, etc. All these factors can affect the size of statistical signifi-

Table 1. Basic parameters of meat efficiency, carcass value and differences between breeds

Parameter	S		H		Significance of differences between groups
	$n = 27$		$n = 33$		
	$\bar{x}$	s	$\bar{x}$	s	
Live weight before slaughter (kg)	536.31	45.63	420.66	42.99	S : H^{++}
Dressing percentage (%)	57.38	1.56	52.41	1.46	S : H^{++}
Warm carcass weight (kg)	308.33	23.88	220.41	23.56	S : H^{++}
Cold carcass weight (kg)	303.44	23.57	216.22	23.57	S : H^{++}
Weight of 1st class meat (kg)	59.17	5.36	39.39	4.38	S : H^{++}
Fat proportion in carcass side (kg)	8.83	1.47	8.21	1.38	

S = Slovak Pied breed, H = Holstein breed
$^{++}P < 0.01$

Table 2. Sonographically measured depths of the layers of muscles

Parameter	S		H		Significance of differences of sonographic measures between breeds
	$\bar{x}$	s	$\bar{x}$	s	
	$n = 27$		$n = 33$		
On shoulder (mm)	50.75	4.70	40.85	4.49	S : H^{++}
Behind shoulder (mm)	91.61	8.22	69.81	6.24	S : H^{++}
On last dorsal vertebra (mm)	64.66	5.85	50.24	4.23	S : H^{++}
On last lumbar vertebra (mm)	62.36	4.86	44.29	2.81	S : H^{++}
On thigh (mm)	105.2	6.04	77.72	7.37	S : H^{++}

S = Slovak Pied breed, H = Holstein breed
$^{++}P < 0.01$

cance of differences (Demo *et al.*, 1993; Hamlin *et al.*, 1995). In spite of this, the results of our measurements prove that the existing differences between the breeds in muscularity, i.e. meatiness of animals, can be determined quite accurately by this technique.

The highest coefficients of linear correlation were found in the Holstein breed, namely between the warm carcass weight and *m.l.d.* depth on the last lumbar vertebra ($r = 0.75$), between the weight of cold carcass weight and *m.l.d.* depth on the last lumbar vertebra ($r = 0.75$), and between the weight of 1st class meat and *m.l.d.* depth on the last lumbar vertebra ($r = 0.73$) ($P < 0.01$). As the difference between the warm and cold carcass weight amounts to 1 to 2 kg only, it is logical that the correlation coefficients are the same. They are expressed identically (Walder *et al.*, 1992; Demo *et al.*, 1993; Hamlin *et al.*, 1995; Sloniewski *et al.*, 1997). In the Holstein breed we also found statistically highly significant correlations ($P < 0.01$) between the *m.l.d.* depth on shoulder, behind the shoulder, and on the last dorsal vertebra and all studied parameters of carcass value, as well as in the case of *musculus gluteus superficialis*, i.e. on thigh (Table 3). We can summarize that the places behind the shoulder (top of shoulder), *m.l.d.* and thigh (rump) where we found strong correlations are generally recognised as parts of carcass with great effect on the carcass value (Martin *et al.*, 1993) irrespective of differences between the breeds that affected our results within breeds to a certain extent by a different number of observations.

The coefficients of determination in linear models without using the live weight before slaughter were markedly lower ($R^2 = 0.33$ to 0.68), see Table 4, than in linear models in which the live weight before slaughter was used ($R^2 = 0.72$ to 0.95), see Table 5. In linear models using the sonographic measurements and live weight of bulls we found out that the stepwise procedure used not even one sonographic measure to estimate the 1st class meat weight parameter as the live weight before slaughter had absolutely the greatest influence on this parameter.

There are papers reporting that the live weight before slaughter is a sufficient trait for the prediction of carcass value mainly in combination with other measurements, e.g. with the weight of kidney tallow (Martin *et al.*, 1993). However, in such case the estimation would be done *post mortem*, which is of lower importance for breeding purposes than *in vivo* estimation. Walder *et al.* (1992) stated that the inclusion of sonographic measures of muscle depths in the prediction models using live weight before slaughter improves the prediction accuracy by 1 to 2% whereas Sloniewski *et al.* (1997) mentioned up to 5%. The regression coefficients we calculated in models without and with the live weight before slaughter have sufficient prediction ability for the warm carcass weight and cold carcass weight in both breeds. We found insufficient prediction ability with weight of 1st class meat in some models.

Table 3. Coefficients of linear correlation between parameters of carcass value and depths of muscles measured sonographically

Depth of muscle measured sonographically	Breed	Warm carcass weight	Cold carcass weight	Weight of 1st class meat
On shoulder	S	0.24	0.24	0.27
	H	0.68^{++}	0.68^{++}	0.62^{++}
Behind shoulder	S	0.37	0.37	0.40^{+}
	H	0.50^{++}	0.49^{++}	0.42^{+}
On last dorsal vertebra	S	0.41^{+}	0.42^{+}	0.46^{+}
	H	0.63^{++}	0.63^{++}	0.56^{++}
On last lumbar vertebra	S	0.30	0.30	0.33
	H	0.75^{++}	0.75^{++}	0.73^{++}
On thigh	S	0.57^{++}	0.58^{++}	0.55^{++}
	H	0.64^{++}	0.63^{++}	0.61^{++}

S = Slovak Pied breed, H = Holstein breed

$^{+}P < 0.05$; $^{++}P < 0.01$

Table 4. Linear regression model using the sonographical measures of muscle depths

Slaughter parameter	Breed	Absolute member	Live weight before slaughter	Depth of muscle					R^2
				on shoulder	behind shoulder	on last dorsal vertebra	on last lumbar vertebra	on thigh	
Warm carcass weight	S	67.81	–	–	–	–	–	2.28	0.33
	H	58.48	–	2.47	–	–	2.75	–	0.68
Cold carcass weight	S	65.14	–	–	–	–	–	2.26	0.34
	H	59.72	–	2.38	–	–	2.78	–	0.67
Weight of 1st class meat	S	0.35	–	–	–	–	0.28	0.39	0.39
	H	8.14	–	–	0.38	–	0.51	–	0.60

S = Slovak Pied breed, H = Holstein breed

Table 5. Linear model using live weight before slaughter and sonographic measures of muscle depth

Slaughter parameter	Breed	Absolute member	Live weight before slaughter	Depth of muscle					R^2
				on shoulder	behind shoulder	on last dorsal vertebra	on last lumbar vertebra	on thigh	
Warm carcass weight	S	6.08	0.55	–	–	–	–	–	0.87
	H	23.20	0.50	–	0.38	–	–	–	0.95
Cold carcass weight	S	6.82	0.56	–	–	–	–	–	0.72
	H	32.39	0.50	–	–	–	–	0.42	0.96
Weight of 1st class meat	S	2.66	0.12	–	–	–	–	–	0.73
	H	2.89	0.09	–	–	–	–	–	0.75

S = Slovak Pied breed, H = Holstein breed

We can summarize that *m.l.d.* depth and depth of *gluteus superficialis* muscle on thigh are characteristics that are sufficient for the prediction of carcass value parameters. In spite of it we recommend to continue the research and to repeat similar experiments with a higher number of animals of various breeds.

REFERENCES

Bugiwati A.R., Harada H.D., Fukuhara R. (1999): Effects of genetic and environmental factors on ultrasonic estimates of carcass traits of Japanese Brown cows. Asian-Australian J. Anim. Sci., *12*, 506–510.

Blanco Roa N.E., Huba J., Hetényi L., Demo P., Sloniewski K., Polák P. (2001): Využitie sonografie pre stanovenie hrúbky svalov na rôznych častiach tela výkrmových býkov rôznych plemien. J. Farm Anim. Sci., *34*, 215–221.

Chrenek J. (1996): Exteriérový profil býkov plemena slovenského strakatého, holštajnizovaného čiernostrakatého a ich kríženco v. J. Farm Anim. Sci., *29*, 15–22.

Demo P., Krška P., Poltársky J., Borecký. (1993): The use of an echocamera for *in vivo* prediction of some carcass characteristics in pig (in Slovak). Živoč. Výr., *38*, 645–654.

Hamlin K.E., Green R.D., Perkins T.L., Cundiff L.V., Miller M.F. (1995): Real – time ultrasonic measurement of fat thickness and longissimus muscle area: Description of age and weight effects. J. Anim. Sci., *73*, 1713–1724.

Hassen A., Wilson D.E., Amin V.R., Rouse G.H., Hays C.L. (2001): Predicting percentage of intramuscular fat using two types of real – time ultrasound equipment. J. Anim. Sci., *79*, 11–18.

Kica J., Huba J., Polák P., Sakowski T. (2000): Comparison of meat yield in young bulls of Slovak Pied breed, Braunvieh, Pinzgau and its crosses with Piemotese. Czech J. Anim. Sci., *45*, 405–412.

Martin T.G., Alenda R., Cabrero M. (1993): Predicción de la composición de la canal en razas de ganado vacuno Rubia Gallega y Asturiana. II. Por simples medidas en la canal. Investig. Agrar., *8*, 65–73.

Melo L., Castillo J.L., Miquel M.C., Erias A.J., Porteyro I., Mirande S. (2001): Mediciones con ultrasonidos de espesor de grasa abdominal en pollos parrilleros para estimación de su peso y proporción. Investig. Agrar., *16*, 127–134.

Nosáľ V., Zaujec K., Mojto J., Pavlič M., Huba J. (1999): Jatočná kvalita teliat rôznych úžitkových typov z pohľadu klasifikačného systému EUROP. J. Farm. Anim. Sci., *32*, 139–144.

Sloniewski K. (1997): Ocena wartości buhajów ras miasnych na podstavie rodzeństwa uzyskanego metoda MOET. IGIHZ PAN, Jasterzebiec.

Temple R.S., Stonaker H.H., Howry D., Posakony G., Hazeleus M. H. (1956): Ultrasonic and conductivity methods for estimating fat thickness in live cattle. Proc. West. Sect. Am. Soc. Anim. Prod., *7*, 477.

Tulloh N.M., Truscott T.G., Lang C.P. (1973): An evaluation of the scanogram for predicting of carcass composition of live cattle. A report submitted to Australian meat boart.

Walder D.N., Dikeman M.E., Schales R.R., Olson W.G., Houghton P.L., Unruh J.A., Corah L.R. (1992): Validation of real – time ultrasound technology for predicting fat thicknesses, longissimus muscle areas and composition of Brangus bulls from 4 months to 2 years of age. J. Anim. Sci., *70*, 3044–3054.

Wallace M.A., Stouffer J.R., Weatervelt R.G. (1977): Relationships of ultrasonic and carcass measurements with retaily yiel in beef cattle. Livest. Prod. Sci., *4*, 153–164.

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ABSTRAKT

Porovnanie rozdielov v hrúbke svalov a možnosti predikcie niektorých ukazovateľov jatočnej hodnoty býkov ultrasonografickou metódou

V práci analyzujeme vzťahy medzi hrúbkami svalov, zistené sonograficky na živých býkoch a ich jatočnou hodnotou zistenou *post mortem*. V našom experimente sme použili zvieratá dvoch plemien, slovenské strakaté a holštajnské v počte 27 a 33 býkov. Porovnaním jednotlivých sonografických mier medzi plemenami sme zistili štatisticky významné ($P < 0,05$) až vysoko významné ($P < 0,01$) rozdiely v hrúbke svalov. Rozdiely boli vždy významné v neprospech holštajnského plemena. Najvyššie hodnoty korelačných koeficientov sme zistili medzi hrúbkou *musculus gluteus superficialis* na stehne a hmotnosťou jatočného tela v teplom, hmotnosťou jatočného tela vychladeného a hmotnosťou mäsa 1. triedy $r = 057$; 0,58 a 0,55 ($P < 0,01$) respektive, pri plemene slovenské strakaté. Medzi hrúbkou *musculus longissimus dorsi* na poslednom bedrovom stavci a nami analyzovanými ukazovateľmi jatočnej hodnoty bol $r = 0,75$; 0,75 a 0,73 ($P < 0,01$) respektive, pre plemeno holštajnské. Sonografické miery na lopatke, za lopatkou a na poslednom hrudnom stavci pri korelácii s ukazovateľmi jatočnej hodnoty preukazovali u obidvoch plemien stredné až nepreukazné hodnoty korelačných koeficientov. Vysoké hodnoty koeficientov determinácie R^2, sme zistili v lineárnych regresných modeloch kde bola zaradená živá hmotnosť pred zabitím, ako nezávislá premena, $R^2 = 0,95$ a 0,87 pre holštajnské a slovenské strakaté plemeno respektive. V lineárnych modeloch, kde živá hmotnosť pred zabitím nebola zaradená koeficienty determinácie boli $R^2 = 0,68$ a 0,39 v tom istom poradí. Na základe zistených výsledkov konštatujeme, že metóda môže byť vhodná na predikciu jatočnej hodnoty dobytka.

Kľúčové slová: sonografia; hrúbka svalov; jatočná hodnota; predikcia; hovädzí dobytok

Corresponding Author

Ing. Noel Ernesto Blanco Roa, Výskumný ústav živočíšnej výroby, Hlohovská 2, 949 92 Nitra, Slovak Republic
Tel. +421 37 654 63 28–360, e-mail: blanco@vuzv.sk

Evaluation of temperament in cows of different age and bulls of different colour variety

J. Tőzsér[1], K. Maros[1], A. Szentléleki[1], R. Zándoki[1], E. Nikodémusz[1], F. Balázs[2], A. Bailo[1], L. Alföldi[1]

[1]Faculty of Agricultural and Environmental Sciences, Szent István University, Gödöllő, Hungary
[2]Angus Beef Cattle Breeding and Trading Ltd., Adony, Hungary

ABSTRACT: Temperament was compared in 30 primiparous (age 2.44 years, body weight 550 kg) and 37 multiparous (age 4.76 years, body weight 626 kg) Holstein-Friesian cows as well as in 28 black (age 266 days, body weight 351 kg) and 23 red (age 260 days, body weight 342 kg) variety of Angus bull calves. Temperament was measured by the Scale Test and the Flight Speed Test. The mean temperament scores revealed that temperament was better in multiparous cows (2.20 for primiparous vs. 1.78 for multiparous) and in red bull calves (1.43 for red vs. 2.56 for black bulls). Flight speed scores showed a significant negative correlation with temperament scores between cows ($r = -0.32$, $P < 0.01$) and bull calves ($r = -0.35$, $P < 0.05$) indicating that the animals behaving calmer on the weight scale left the scale at a slower rate. Additional experiments are required to identify a standardised scoring system for temperament of cattle adoptable in selection work.

Keywords: temperament; beef calves; dairy cows; age; coat colour

In the last decades an increasing attention has been focused on the improvement of animal welfare in the European Union and throughout the world. A practical approach can be to improve the temperament of farm animals, e.g. through selection of breeding stock for good temperament.

Temperament of cattle was assessed in several tests reviewed by Burrow (1997). Considering the lack of Hungarian data, this study was aimed to gain experience with the use of temperament tests by comparing primiparous and multiparous Holstein-Friesian cows and two colour varieties of Angus bull calves for this trait.

The term temperament (under farm situations) is defined as the animal's behavioural response to handling by humans (Burrow, 1997). Temperament of cattle was measured in non-restrained tests including e.g. the Flight Speed Test (Burrow *et al.*, 1988) as well as in restrained tests such as the Scale Test (Sato, 1981; Kabuga and Appiah, 1992).

Temperament of livestock species can vary by age, sex, management, maternal influence, genetic factors and breed (Burrow, 1997). The relation of coat colour with temperament was reported by Keeler as early as in 1947, more recently Hemmer (1990) reviewed the connections between coat colour and behaviour. Several papers demonstrated different temperament between cattle breeds and between sexes using different temperament tests and scoring systems (Stricklin *et al.*, 1980; Fordyce *et al.*, 1985; Burrow *et al.*, 1988; Morris *et al.*, 1994; Voisenet *et al.*, 1997; Buchenauer, 1999).

Temperament is an inherent characteristic. The published estimates for heritability of temperament range from 0.27 to 0.48 in cattle (Stricklin *et al.*, 1980; Oikawa *et al.*, 1989). The average, unweighted heritability of tests summarised by Burrow (1997) in the non-restrained and restrained category was 0.36 and 0.23, respectively.

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The relationships between measures of temperament and other traits (growth, milk production, fertility, carcass and meat quality, resistance to parasites and other stressors) were discussed by Burrow (1997).

MATERIAL AND METHODS

The experiments were carried out in a dairy herd of Holstein-Friesian cows and in a herd of Angus bull calves in 2001. In total 30 primiparous and 37 multiparous cows as well as 28 black and 23 red variety of bull calves were examined (Table 1).

Temperament was evaluated in two successive tests as it was suggested by Trillat *et al.* (2000). In the Scale Test animals were confined in a weight scale for 30 s meanwhile behaviours were assessed in a 5-score system: 1) calm, no movement, 2) calm with occasional movements, 3) calm with some more movements but without shaking the scale, 4) abrupt episodic movements without shaking the scale, 5) permanent episodic movements and shaking the scale. With the Flight Speed Test, the time for an animal to cover a set distance of 1.7 m after leaving the weight scale was recorded in tenths of a second. The tests were assisted by video-recording and stop-watching.

Data were statistically processed by program SPSS 10 (2-sample *t*-test, Mann-Whitney test, Spearman correlation).

RESULTS

Percentage distributions of individuals by the 1–5 temperament scores and the corresponding flight speed scores are presented in Figures 1 and 2.

The mean temperament score was 1.78 for multiparous and 2.2 for primiparous Holstein-Friesian cows since 78% and 63% of cows were awarded score 1 and 2, respectively. The mean temperament score was 1.43 for red and 2.57 for black Angus bull calves, since 92% and 50% of calves received score 1 and 2, respectively, further 7% of black ones received score 5. The evaluation of temperament scores applying Mann-Whitney test (Table 2) revealed significant between-group differences between cows (392.5, $P < 0.05$) as well as bull calves (140.0, $P < 0.001$).

The mean flight speed scores showed no significant between-group differences between cows (2.56–2.75 s) and bull calves (2.86–3.06 s) although the flight speed decreased inconsistently throughout temperament score 1–5. The weak but significant negative rank correlation of tempera-

Table 1. Presentation of experimental groups by age and body weight

Parameter	Holstein-Friesian cows		Angus bull calves	
	primipara	multipara	black	red
	(n = 30)	(n = 37)	(n = 28)	(n = 23)
Age (year or day)	2.44 ± 0.32	4.76 ± 2.07	266 ± 15.48	260 ± 11.73
Body weight (kg)	550 ± 60	626 ± 55	351 ± 30	342 ± 31

Table 2. Evaluation of temperament applying Mann-Whitney test

Group	n	Mean of ranks	Sum of ranks	Result of test
Holstein-Friesian				
primipara	30	39.42	1 182.5	392.5
multipara	37	29.61	1 095.5	$P < 0.05$
Angus bull calves				
black	28	32.50	910.0	140.0
red	23	18.09	416.0	$P < 0.001$

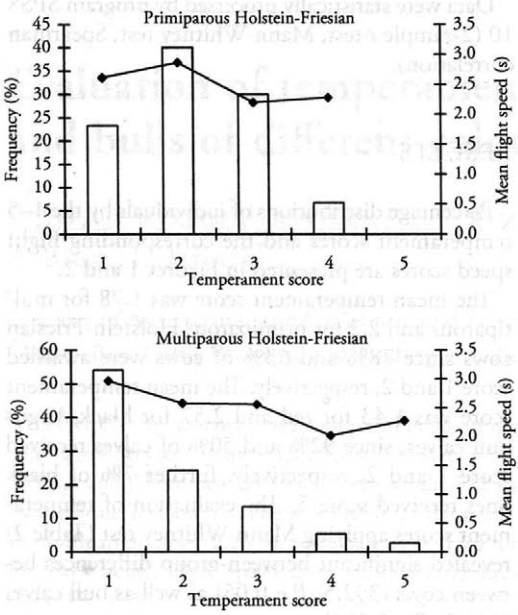

Figure 1. Percentage distributions of primiparous and multiparous Holstein-Friesian cows by 1–5 temperament scores and the corresponding flight speed scores

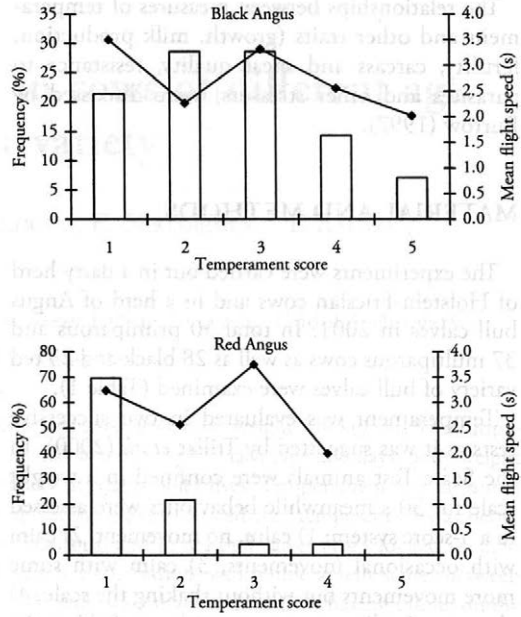

Figure 2. Percentage distributions of black and red Angus calves by 1–5 temperament scores and the corresponding flight speed scores

Table 3. Correlation of temperament scores with flight speed scores

Group	n	r_{rang}	
Holstein-Friesian cows	67	–0.32	$P < 0.01$
Angus bull calves	51	–0.35	$P < 0.05$

ment scores with flight speed scores found between cows ($n = 67$, $r = -0.32$, $P < 0.01$) and bull calves ($n = 51$, $r = -0.35$, $P < 0.05$) indicated that the animals behaving calmer on the weight scale left the scale at a slower rate. Rank correlation of temperament scores with age was also weak but significant in the cows ($r = -0.25$, $P < 0.05$).

DISCUSSION

Measuring temperament by the closely related Scale Test and Flight Speed Test enabled us to reveal differences in temperament of cattle by age and coat colour.

Most studies conclude that temperament of animals improves with increasing age or experience (Burrow, 1997). Sato (1981) found that cattle became "relatively mild" with age although the ranking of individuals' temperament scores did not change fundamentally throughout life. Roy and Nagpaul (1984) reported that temperament score improved from the third to sixth lactation. In our sample, temperament of multiparous cows (aged 4.76 years) improved by score 0.42 compared to primiparous cows (aged 2.44 years), and rank correlation of temperament scores with age ($r = -0.25$, $P < 0.05$) indicated that age had a low but significant effect on temperament. The flight speed scores improved only little (0.19 s) with age.

The coat colour of a mammal is related to the basic level of its activity, its reaction intensity and its environmental appreciation (Hemmer, 1990).

In our sample, red Angus bull calves proved calmer than black ones in respect of temperament score (lower by 1.14) and flight speed score (longer by 0.2 s), in spite of similar age (266–261 days) and body weight (351–342 kg) records. Stockmen also found easier to handle red than black bull calves

on the farm. Consequently, this difference in temperament seemed to relate with difference in coat colour. Experiments on horses also demonstrated that chestnuts reacted more distinctly than the bays and that dark-coloured sheep and goats were more motile than white ones (Hemmer, 1990).

Probably, coat colour and behaviour are connected via a common biochemical synthesis pathway of the pigments determining colour – the melanins – and the catecholamide group of neurotransmitters forming the basis of the information-processing system (Hemmer, 1990).

CONCLUSION

The use of the closely related Scale Test and Flight Speed Test can be a useful tool for demonstrating differences in temperament of cattle. Both tests are inexpensive, quick and easy to implement on the farm. Additional experiments are required to identify a standardised scoring system for temperament of cattle adoptable in selection work.

REFERENCES

Bucherauer D. (1999): Genetics of behaviour in cattle. In: Fries R., Ruvinsky A. (eds.): The Genetics of Cattle. CAB International, Wallingford, UK.

Burrow H.M. (1997): Measurement of temperament and their relationship with performance traits of beef cattle. Anim. Breed. Abstr., *65*, 478–495.

Burrow H.M., Seifert G.W., Corbet N.J. (1988): A new technique for measuring temperament in cattle. Proc. Aust. Soc. Anim. Prod., *17*, 154–157.

Fordyce G., Goddard M.E., Tyler R., Williams G., Toleman M.A. (1985): Temperament and bruising of *Bos indicus* cross cattle. Aust. J. Exp. Agric., *25*, 283–288.

Hemmer H. (1990): Domestication. The decline of environmental appreciation. Cambridge University Press.

Kabuga J.D., Appiah P. (1992): A note on the ease of handling and flight distance of *Bos indicus*, *Bos taurus* and their crossbreds. Anim. Prod., *54*, 309–311.

Keeler C.E. (1947): Coat colour, physique and temperament. J. Hered., *38*, 271–279.

Morris S.T., Parker W.J., Grant D.A. (1994): Herbage intake, liveweight gain, and grazing behaviour of Friesian, Piedmontese × Friesian, and Belgian Blue × Friesian bulls. NZ J. Agric. Res., *36*, 231–236.

Oikawa T., Fudo T., Kaneji K. (1989): Estimate of genetic parameters for temperament and body measurements of beef cattle. Jpn. J. Zoot. Sci., *60*, 894–896.

Roy P.K., Nagpaul P.K. (1984): Influence of genetic and non-genetic factors on temperament score and other traits of dairy management. Indian J. Anim. Sci., *54*, 566–568.

Sato S. (1981): Factors associated with temperament of beef cattle. Jpn. J. Zoot. Sci., *52*, 595–605.

Stricklin W.R., Heisler C.E., Wilson L.L. (1980): Heritability of temperament in beef cattle. J. Anim. Sci., *5* (Suppl. 1), 109–110.

Trillat G., Boissy A., Boivin X., Monin G., Sapa J., Mormende P., Le Neindre P. (2000): Relations entre le bien-entre des bovines et les caracteristiques de la viande (Rapport definitif-Juin). INRA, Theix, France. 1–33.

Voisenet B.D., Grandin T., Tatum J.D., O'Connor S.F., Struthers J.J. (1997): Feedlot cattle with calm temperaments have higher daily gains than cattle excitable temperaments. J. Anim. Sci., *75*, 892–896.

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ABSTRAKT

Hodnocení temperamentu u dojnic různého věku a býčků různé barevné variety

Porovnávali jsme temperament u 30 prvotelek (věk 2,44 roku, tělesná hmotnost 550 kg) a 37 dojnic na druhé a další laktaci (věk 4,76 roku, tělesná hmotnost 626 kg) holštýnsko-fríského plemene a u 28 býčků plemene angus černé variety (věk 266 dní, tělesná hmotnost 351 kg) a 23 býčků plemene angus červené variety (věk 260 dní, tělesná hmotnost 342 kg). Temperament jsme měřili pomocí váhového testu a testu rychlosti odchodu. Průměrné bodové hodnocení temperamentu ukázalo, že temperamentnější byly dojnice na druhé a další laktaci (2,20 u prvotelek oproti 1,78 u starších dojnic) a býčci červené variety plemene angus (1,43 u červených oproti 2,56 černých býčků).

Hodnocení rychlosti odchodu naznačilo významnou zápornou korelaci s bodovým hodnocením temperamentu mezi dojnicemi ($r = -0,32$, $P < 0,01$) a býčky ($r = -0,35$, $P < 0,05$). Zvířata, která se chovala na váze klidněji, opouštěla ji pomalejším tempem. Bude třeba uskutečnit další pokusy, aby bylo možné stanovit standardizovaný bodovací systém pro hodnocení temperamentu a uvažovat o jeho využití v selekci zvířat.

Klíčová slova: temperament; telata masného skotu; holštýnsko-fríský skot; věk dojnic; zbarvení skotu

Corresponding Author

Dr. János Tőzsér, Szent István University, Páter Károly 1, H-2100 Gödöllö, Hungary
Tel. +36 28 522 000(1944), fax +36 28 522 000(1643), e-mail: tozser@fau.gau.hu

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