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Amino Acid Composition in Fillets of Mirror Crossbreds Common Carp (*Cyprinus carpio*, Linnaeus 1758)

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Abstract

The aim of the study was to determine the amino acid composition in fillet proteins of newly bred mirror carp lines. In the experiments, the Hungarian mirror carp (M2) were used at the maternal position. These were crossed with male carp of other breeds (top crossing). They included the Hungarian mirror carp (M2) for the production of a pure line, the Hungarian mirror line (L15), the Israeli breed (DOR70) and the Northern mirror carp (M72). The scaly hybrid of the Ropsha (ROP) and the Tataj (TAT) carp was used as a control. In view of the genetic specification of the carp groups monitored, numerous differences ($P < 0.01$ and $P < 0.05$) in the composition of specific amino acids (EAA: Val, Leu, Lys, Arg, Met; NEAA: Asp, Glu, Tyr) and their total amounts (EAA_{sum}, $NEAA_{sum}$) were found between the scaly control (ROP × TAT) and the pure line M2. Higher amino acid values were found in control hybrids. Compositions of amino acids in fillet muscle tissue of experimental mirror carp (M2 × L15, M2 × DOR70) were practically identical. Compared to the controls (ROP × TAT), these carp groups contained less ($P < 0.01$) Leu, Lys, Arg and Glu. A composition of amino acids statistically comparable with the controls (ROP × TAT) was found only in the M2 × M72 hybrid with the exception of Glu, which was found in smaller quantities in this hybrid ($P < 0.01$). In terms of sex differences, the greatest amounts of amino acids were found in fillets of male ROP × TAT controls, the amino acid compositions in male and female mirror carp were practically the same. In this type of evaluation, i.e. regarding amino acid composition, the only carp comparable with the ROP × TAT control is the M2 × M72 hybrid.

Fish meat, carp, amino acid, chemical indicator, quality

In the Czech Republic, the common carp (*Cyprinus carpio,* Linnaeus 1758) of the family *Cyprinidae* is considered as economically the most important fresh-water fish species reared for commercial purposes. Typically extensive to semi-intensive in character, carp production is based on the farming of F1 generation fry obtained from controlled reproduction of sexually mature genetically specified generation carp. The breeds of mirror carp used in the Czech Republic for this purpose are of the original Hungarian line denominated as M2, or a hybrid between M2 and the Northern Mirror Carp breed referred to as M72 (Czech origin). In scaly carp, the most frequent generation fish is the Třeboňský scaly carp, Mariánsko-Lázeňský scaly carp (both breeds of Czech origin), or a hybrid between the Ropsha carp (ROP) of Russian origin and the Tataj carp (TAT) of Hungarian origin. Production of carp at smaller fish farms relies also on the fry from local carp populations that have been given names derived from the nearby villages or locations, and which are often not unambiguously genetically specified. Carp production utilizes natural foods supplemented with cereals and complementary feed mixes.

Carp breeding receives systematic attention with the objective to enhance useful characteristics and production efficiency (Linhart et al. 2002; Kocour et al. 2005a; Kocour et al. 2007). Production efficiency of different genetic groups of carp (breeds, lines, crossbreds) is regularly tested at both the level of production variables and slaughter value (Gela and Linhart 2000; Gela et al. 2003; Kocour et al. 2005b; Buchtová et

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al. 2006ab) and the level of chemical composition of edible parts and nutritional value (Buchtová et al. 2007ab; Buchtová et al. 2008).

Experimental studies evaluating common carp have recently been extended to include specific issues of food safety regarding the marketing of this most common freshwater fish (Ježek and Buchtová 2007). The factors considered include carp fillet shelf-life under various experimental packaging conditions (vacuum, modified atmosphere) and storage conditions with the objective to define physical and chemical indicators and their concrete numerical values that are decisive for shelf-life period determination.

In accordance with systematic research into the above issues in the Czech Republic, this paper presents the results of a study on amino acid composition of fillet proteins of the M2 breed and its mirror hybrids (M2 × L15, M2 × DOR70, M2 × M72) compared to the control hybrid ROP × TAT, which is commonly farmed for commercial purposes.

Materials and Methods

The performance test of mirror types of the common carp was started in 2003 by the fishfarming company Rybníkářství Tábor, when fish in the K_0 stage were stocked. The test was concluded at the end of the 2005 vegetation period, in which the fish reached harvest size. The fish were tested in ponds and, to guarantee the objectivity of results of performance, growth and survival, an internal control group with a different scaling phenotype was used (Linhart et al. 2002; Kocour et al. 2005ab, 2007). In the experiments, the Hungarian mirror carp (M2) were used at the maternal position. These were crossed with male carp of other breeds (top crossing). These breeds were the Hungarian mirror carp (M2) for pure breed production, Hungarian mirror line (L15), the Israeli breed (DOR70) and the Northern mirror carp (M72). The scaly hybrid of the Ropsha (ROP) and the Tataj (TAT) carp was used as a control. The fish were reared under standard conditions for pond fish farming in the CR with semi-intensive management. Fish had their natural diet available in the ponds (plankton, benthos) for growth over three vegetation seasons. Fish usually do not feed in the winter (November–February) period. In the first vegetation season, the fish were fed with supplementary feed mix KP1 three times a week, starting when they were 2 months old. In the second vegetation period, the supplementary feed mix was replaced with uncrushed wheat, which was also fed to the fish in the third vegetation period. The supplementary feed was fed 3 times weekly throughout the test. Daily feeding rate was calculated based on the water temperature, oxygen level and the occurrence of natural food according to the recommended directive for fish farmers (unpublished data). The rate of supplementary feeding on the total weight gain of fish during the whole rearing period was estimated approximately on the basis of applied feed and the feed conversion ratio (4 for grain and 3 for KP1) at 40%. During the test (before and after each vegetation period), data on growth (weight) and survival of the fish (% survival) were recorded.

The final evaluation of the test was made at the end of the 2005 vegetation period in three-year-old fish (K_3). From the pond with the highest mean fish weight, 40 carp from each of the 5 groups (i.e. the ROP × TAT control, M2 pure line, experimental hybrid M2 × L15, M2 × DOR70, M2 × M72) were chosen at random (a total of 200 fish). Fish carcasses were dressed according to Gela and Linhart (2000) at the University of South Bohemia, Research Institute of Fish Culture and Hydrobiology, Vodňany, Czech Republic.

The variables monitored included the fish live weight (FLW), the weight of the two skinned fillets of each of the fish (FW_{abs}), the gonad weight (GW) and the gonad-to-total weight ratio (FW_{rel}, GSI).

To study amino acid composition in fish meat, 5 male carp and 5 female carp fillets were chosen at random from each of the groups (a total of 50 fillets). The AAA was used to determine the composition (in %) of the amino acids found.

To prepare samples for amino analysis, 0.5 g from each mixed sample with a 0.0001 g accuracy (PRECISA 240 A, France) were used (homogenization: Moulinex ILLICO Y92, Ireland). The samples were prepared by acid hydrolysis (HCl = 6 mol·l^{-1}) for 24 h at 110 °C. The amino acid assay was performed on the AAA 400 automatic amino acid analyzer (INGOS a.s. Praha, CR). For their separation, sodium-citrate elution buffers in a chromatographic column with catex (OSTION LG ANB, CR) were used. After colour reaction with the ninhydrin, separated amino acids were detected in a flow photometer. AMIK software 3.0 (CR) was used to calculate retention times and areas of individual amino acid peaks, and to process data. Reagents necessary for the preparation of samples, buffers and AAA operation were supplied by the amino analyzer manufacturer. Solutions of standard amino acid mixtures also supplied by the AAA manufacturer were used as external amino acid standards.

The abundance of each of the amino acids was then calculated in grams per 1 kg fillet weight (g·kg^{-1}). For this calculation, laboratory determination of the net protein content in fillets was used. The net protein content was determined as the amount of organically bound nitrogen (recalculating coefficient $f_1 = 6.25$) after precipitation of the samples with hot tannin solution (Davídek et al. 1977) using the semiautomatic analyzer Kjeltec 2300 (FOSS Analytical AB, Sweden) and procedures recommended by the manufacturer (AN 300).

Basic statistical values (means, S.D. and S.E.) of the variables investigated were processed in Excel 97.

Table 1. Fish live weight (FLW), the weight of both fillets without skin (FW_{abs}), the gonad weight (GW) and the percentage of both fillets without skin per fish live weight (FW_{rel}) and gonadosomatic index (GSI) of the common carp (*Cyprinus carpio*, Linnaeus 1758)

Index			Control group ROP x TAT n = 41	Experimental group 1 M2 n = 40	Experimental group 2 M2 x L15 n = 40	Experimental group 3 M2 x DOR70 n = 40	Experimental group 4 M2 x M72 n = 39
			Male Female n = 17 n = 24 Mean ± S.D.*	Male Female n = 16 n = 24 Mean ± S.D.*	Male Female n = 24 n = 16 Mean ± S.D.*	Male Female n = 19 n = 21 Mean ± S.D.*	Male Female n = 16 n = 23 Mean ± S.D.*
FLW	g		2030 ± 176.0^{b}	1699 ± 167.4^{a}	1709 ± 197.2^{a}	1790 ± 150.9^{a}	1772 ± 221.3^{a}
FW_{abs}	g		676 ± 77.3^{b}	525 ± 70.6^{a}	519 ± 78.1^{a}	528.3 ± 71.4^{a}	533 ± 99.0^{a}
FW_{rel}	%		32.7 ± 0.5^{b}	31.0 ± 0.4^{a}	30.6 ± 0.4^{a}	29.5 ± 0.4^{a}	29.9 ± 0.4^{a}
$GW_{♂}$	g		56.8 ± 24.5^{a}	57.4 ± 24.8^{a}	67.6 ± 25.3^{a}	63.2 ± 19.8^{a}	71.9 ± 22.6^{a}
$GW_{♀}$	g		20.0 ± 25.1^{a}	13.2 ± 5.1^{a}	21.4 ± 27.8^{a}	18.0 ± 19.8^{a}	19.5 ± 8.4^{a}
FLW		male	2003 ± 183.5^{b}	1677 ± 207.3^{a}	1670 ± 191.2^{a}	1777 ± 135.6^{a}	1747 ± 205.7^{a}
g		female	2048 ± 172.0^{b}	1713 ± 137.7^{a}	1771 ± 202.6^{a}	1802 ± 166.1^{a}	1789 ± 234.5^{a}
FW_{abs}		male	650 ± 76.4^{b}	504 ± 87.6^{a}	509 ± 80.1^{a}	523 ± 60.5^{a}	505 ± 64.9^{a}
g		female	694 ± 73.9^{b}	540 ± 53.9^{a}	540 ± 69.9^{a}	533 ± 81.1^{a}	552 ± 114,5^{a}
FW_{rel}		male	32.0 ± 0.7^{b}	30.2 ± 0.7^{ab}	30.7 ± 0.5^{ab}	29.5 ± 0.6^{a}	29.1 ± 0.7^{a}
%		female	33.4 ± 0.6^{b}	31.7 ± 0.5^{ab}	30.6 ± 0.7^{a}	29.5 ± 0.6^{a}	30.6 ± 0.5^{a}
GSI		male	2.7 ± 0.35^{a}	3.5 ± 0.32^{ab}	4.1 ± 0.27^{b}	3.5 ± 0.29^{ab}	4.1 ± 0.31^{b}
		female	0.9 ± 0.18^{a}	0.8 ± 0.16^{a}	1.2 ± 0.19^{a}	1.0 ± 0.17^{a}	1.1 ± 0.16^{a}

*Mean ± S.E. for value of FW_{rel} (%) and GSI

Groups with different alphabetic superscript (a, b) within each row differ significantly at P<0.05. ROP – Ropsha Scaly Carp, TAT - Tataj Scaly Carp, M2 – Hungarian Mirror Carp, L15 – Hungarian Strain Carp, DOR70 – Israeli Mirror Carp, M72 – Northern Mirror Carp

Significance was evaluated using the multifactorial analysis of variance ANOVA (for indicators FLW, FW_{abs} and GW) and ANCOVA (for indicator FW_{rel} and GSI) Statistica 7.0 (StatSoft CR, s.r.o., Praha, Czech Republic).

Results

The live weight (g), fillet weight without skin, gonad weight and ratios of those values to the total weight in the carp groups studied including sex dependence (female carp vs. male carp) are given in Table 1. The highest ($P < 0.05$) values of the indicators monitored (FLW: 2030 ± 176.0 g, FW_{abs}: 676 ± 77.3 g, FW_{rel}: 32.7 ± 0.5 %) were found in the scaly control group ROP × TAT. Values of the same ones (i.e. FLW, FW_{abs}, FW_{rel}) ascertained in experimental mirror carp groups (M2, M2 × L15, M2 × DOR70, M2 × M72) were generally lower and mutually comparable.

FLW and FW_{abs} values were higher in female carp than in their male counterparts. Inside groups (ROP × TAT, M2, M2 × L15, M2 × DOR70, M2 × M72), sex-based differences (female carp v. male carp) in these values were not significant.

Table 2. Amino acid composition (in g·kg^{-1} wet tissue) in skinned fillet of the common carp (*Cyprinus carpio*, Linnaeus 1758)

Index	Control group ROP x TAT n = 10 Mean ± S.D.	Experimental group 1 M2 n = 10 Mean ± S.D.	Experimental group 2 M2 x L15 n = 10 Mean ± S.D.	Experimental group 3 M2 x DOR70 n = 10 Mean ± S.D.	Experimental group 4 M2 x M72 n = 10 Mean ± S.D.	Significance
Thr	7.5 ± 1.19^{ab}	6.7 ± 0.55^{b}	7.3 ± 0.31^{ab}	7.1 ± 0.41^{ab}	7.8 ± 0.45^{a}	$P < 0.01$
Val	9.4 ± 1.02^{a}	7.9 ± 0.51^{c}	8.6 ± 0.37^{abc}	8.6 ± 0.37^{abc}	9.3 ± 0.50^{ab}	$P < 0.01$
Ile	7.9 ± 0.80^{ab}	7.0 ± 0.40^{b}	7.6 ± 0.22^{ab}	7.3 ± 0.35^{ab}	8.0 ± 0.72^{a}	$P < 0.01$
Leu	15.2 ± 1.11^{a}	12.9 ± 0.72^{c}	13.6 ± 0.45^{bc}	13.8 ± 0.46^{bc}	14.7 ± 0.87^{ab}	$P < 0.01$
Phe	7.4 ± 0.86^{ab}	6.6 ± 0.70^{b}	7.2 ± 0.41^{ab}	7.2 ± 0.36^{ab}	7.6 ± 0.39^{a}	$P < 0.01$
Lys	17.7 ± 0.89^{a}	15.4 ± 0.77^{c}	15.8 ± 0.64^{bc}	16.3 ± 0.86^{bc}	17.1 ± 1.05^{ab}	$P < 0.01$
His	5.5 ± 1.09^{ab}	5.0 ± 0.30^{b}	5.3 ± 0.27^{ab}	5.1 ± 0.43^{ab}	5.8 ± 0.39^{a}	$P < 0.05$
Arg	12.4 ± 0.50^{a}	8.8 ± 0.88^{c}	9.6 ± 0.52^{bc}	10.5 ± 1.11^{b}	11.6 ± 0.44^{a}	$P < 0.01$
Met	4.5 ± 0.93^{a}	3.6 ± 0.64^{b}	4.7 ± 0.23^{a}	4.4 ± 0.36^{a}	4.8 ± 0.44^{a}	$P < 0.01$
EAA_{sum}	87.4 ± 7.28^{a}	74.0 ± 4.60^{c}	79.8 ± 2.39^{bc}	80.1 ± 3.38^{b}	86.7 ± 4.49^{a}	$P < 0.05$
Asp	19.0 ± 0.69^{ab}	16.3 ± 1.22^{c}	17.5 ± 0.72^{bc}	17.7 ± 1.14^{bc}	19.7 ± 1.25^{a}	$P < 0.01$
Ser	6.8 ± 0.99^{a}	6.1 ± 0.55^{a}	6.7 ± 0.25^{a}	6.5 ± 0.30^{a}	6.9 ± 0.61^{a}	$P < 0.05$
Glu	26.3 ± 1.56^{a}	21.4 ± 1.55^{c}	22.2 ± 1.48^{bc}	23.2 ± 1.34^{bc}	23.8 ± 1.39^{b}	$P < 0.01$
Pro	6.2 ± 0.31^{a}	6.4 ± 0.35^{a}	6.8 ± 0.83^{a}	6.6 ± 0.76^{a}	6.3 ± 0.25^{a}	$P < 0.05$
Gly	9.5 ± 0.69^{a}	8.8 ± 1.05^{a}	10.0 ± 1.28^{a}	9.6 ± 1.06^{a}	9.9 ± 0.73^{a}	$P < 0.05$
Ala	10.4 ± 1.03^{ab}	9.7 ± 0.90^{b}	10.4 ± 0.56^{ab}	10.3 ± 0.65^{ab}	10.7 ± 0.84^{a}	$P < 0.05$
Tyr	5.7 ± 0.78^{a}	5.1 ± 0.49^{b}	5.8 ± 0.25^{a}	5.3 ± 0.30^{ab}	5.7 ± 0.28^{ab}	$P < 0.05$
$NEAA_{sum}$	83.8 ± 4.30^{a}	74.8 ± 6.36^{b}	79.3 ± 3.84^{ab}	79.2 ± 2.73^{ab}	83.0 ± 4.32^{a}	$P < 0.01$

EAA_{sum} - essential amino acid sum, $NEAA_{sum}$ - non-essential amino acids sum

Groups with different alphabetic superscript within each row differ significantly at the given level of probability. ROP – Ropsha Scaly Carp, TAT - Tataj Scaly Carp, M2 – Hungarian Mirror Carp, L15 – Hungarian Strain Carp, DOR70 – Israeli Mirror Carp, M72 – Northern Mirror Carp

From among male and female carp of different types of hybrids (or lines), the weight of males and females of the ROP × TAT hybrid was the highest ($P < 0.05$).

The evaluation of the FW_{rel} in dependence on individual groups was not clear-cut. Fillet ratios of ROP × TAT males, M2 line males and M2 × L15 hybrid males were comparable, and so were fillets of ROP × TAT hybrid females and M2 line female carp. In other cases, significant differences in values between the control (ROP × TAT hybrid males or females) and the experimental groups (M2 × DOR70 and M2 × M72 hybrid males or M2 × L15, M2 × DOR70 and M2 × M72 hybrid females) of carp were found.

There were no significant differences in soft roe weights (GW♂) or hard roe weights (GW♀) between different types of hybrids (or lines). Within individual groups, gonad weight and the GSI value in male carp were in all cases higher ($P < 0.05$) than the gonad weight and the GSI value in female carp.

The composition of amino acids (g) per 1 kg of skinned fillets in the monitored groups of the common carp irrespective of sex is given in Table 2. We found the same amino acid compositions in fillets of the control scaly hybrid (ROP × TAT) and in fillets of the M2 × M72 mirror carp with the exception of Glu, which was found in smaller quantities in M2 × M72 carp fillets ($P < 0.01$). Lower levels of Glu and other three amino acids ($P < 0.01$), i.e. Leu, Lys and Arg, were also found in other two experimental hybrids (M2 × L15, M2 × DOR70). Compared to the control ROP × TAT fillets, we found most differences in amino acid composition in the pure line M2 fillets, which beside lower ($P < 0.01$) levels of Glu, Leu, Lys and Arg contained less Val, Met, Asp ($P < 0.01$) and Tyr ($P < 0.05$) amino acids. On the other hand, levels of other 8 amino acids, i.e. Thr, Ile, Phe, His, Ser, Pro, Gly and Ala, were practically identical in fillets of all the carp groups studied. Differences in the content of specific amino acids were the reason for differences in overall contents of essential amino acids EAA_{sum} and non-essential amino acids $NEAA_{sum}$. The most abundant amino acids in carp fillets in the group monitored were Glu, Asp, Leu and Arg.

Sex dependence in amino acid composition was clearly demonstrated only in scaly ROP × TAT hybrid carp (Table 3). Almost all essential amino acids, i.e. Thr, Ile, Leu, Phe, Met ($P < 0.01$) and His ($P < 0.05$) as well as non-essential Ser ($P < 0.01$) were more abundant in male fillet proteins than in fillets of female carp. As a result, higher ($P < 0.01$) levels of EAA_{sum} (93.6 ± 2.25 g·kg^{-1}) were found in ROP × TAT males than in females (81.3 ± 4.35 g·kg^{-1}). In experimental mirror carp groups, only isolated differences in amino acid levels were found. Fillets of pure line M2 males contained less Ser ($P < 0.01$), fillets from mirror carp M2 × DOR70 males contained more Arg ($P < 0.01$), and M2 × M72 mirror carp showed a difference in total amino acids EAA_{sum} in dependence on sex ($P < 0.01$).

Discussion

Amino acid composition of fish muscle tissue is fairly stable for specific fish species (Kim and Lall 2000). Amino acid profiles of fillet protein in our experiment were similar to those reported for carp (Schwarz and Kirchgessner 1988; Fu et al. 2000; Buchtová et al. 2007a). Due to the genetic specification of the carp groups monitored, differences in the composition of specific amino acid and their total amounts were found especially between the scaly control (ROP × TAT) and the pure line M2. Fillets of other two experimental hybrids (M2 × L15, M2 × DOR70) differed from ROP × TAT carp fillets in their quantities of 4 amino acids and also in the EAA_{sum}. The composition of amino acids in the M2 × M72 hybrid was statistically comparable to that in the controls (ROP × TAT), with the exception of the non-essential Glu ($P < 0.01$). In all the cases mentioned, higher amino acid values were found in the hybrid controls ROP × TAT (Table 2).

According to Fu et al. (2000), these differences may be related to changes in genetic information on the basis of which muscle proteins are synthesized. The origins of F1 parents of the ROP × TAT hybrid are very distant (ROP: Russia, TAT: Hungary) and might hypothetically

Table 3. Amino acid composition (in g·kg^{-1} wet tissue) in skinned fillet of the common carp (*Cyprinus carpio*, Linnaeus 1758) in relation to sex (male vs. female)

Index	Control group ROP x TAT Mean ± S.D.		Experimental group 1 M2 Mean ± S.D.		Experimental group 2 M2 x L15 Mean ± S.D.		Experimental group 3 M2 x DOR70 Mean ± S.D.		Experimental group 4 M2 x M72 Mean ± S.D.		Significance
	Male n = 5	Female n = 5	Male n = 5	Female n = 5	Male n = 5	Female n = 5	Male n = 5	Female n = 5	Male n = 5	Female n = 5	
Thr	8.5 ± 0.40^{a}	6.4 ± 0.61^{c}	6.3 ± 0.35^{c}	7.1 ± 0.43^{bc}	7.2 ± 0.42^{bc}	7.3 ± 0.19^{bc}	7.2 ± 0.30^{bc}	7.0 ± 0.51^{bc}	7.8 ± 0.56^{ab}	7.9 ± 0.38^{ab}	$P < 0.01$
Val	9.9 ± 0.64^{a}	8.8 ± 1.12^{abc}	7.7 ± 0.19^{c}	8.2 ± 0.62^{bc}	8.6 ± 0.54^{bc}	8.7 ± 0.09^{bc}	8.8 ± 0.26^{abc}	8.3 ± 0.29^{bc}	9.2 ± 0.54^{ab}	9.3 ± 0.51^{ab}	$P < 0.01$
Ile	8.5 ± 0.45^{a}	7.2 ± 0.31^{bc}	6.9 ± 0.23^{c}	7.1 ± 0.54^{bc}	7.5 ± 0.29^{bc}	7.6 ± 0.13^{abc}	7.1 ± 0.27^{bc}	7.4 ± 0.36^{bc}	7.9 ± 0.80^{ab}	8.0 ± 0.71^{ab}	$P < 0.01$
Leu	16.1 ± 0.63^{a}	14.3 ± 0.57^{b}	12.5 ± 0.41^{c}	13.3 ± 0.76^{bc}	13.5 ± 0.64^{bc}	13.7 ± 0.17^{bc}	13.8 ± 0.55^{b}	13.7 ± 0.39^{bc}	14.5 ± 1.10^{b}	14.8 ± 0.66^{ab}	$P < 0.01$
Phe	8.1 ± 0.46^{a}	6.7 ± 0.44^{bc}	6.3 ± 0.53^{c}	7.0 ± 0.75^{bc}	7.0 ± 0.49^{bc}	7.4 ± 0.18^{abc}	7.2 ± 0.42^{abc}	7.2 ± 0.32^{abc}	7.5 ± 0.42^{ba}	7.7 ± 0.37^{ab}	$P < 0.01$
Lys	18.2 ± 0.76^{a}	17.3 ± 0.82^{ab}	14.8 ± 0.36^{c}	16.0 ± 0.56^{bc}	15.7 ± 0.73^{bc}	16.0 ± 0.61^{bc}	16.5 ± 0.96^{ab}	16.0 ± 0.75^{bc}	16.8 ± 1.04^{ab}	17.5 ± 1.04^{ab}	$P < 0.01$
His	6.6 ± 0.15^{a}	4.5 ± 0.26^{c}	4.8 ± 0.22^{c}	5.2 ± 0.28^{bc}	5.4 ± 0.35^{bc}	5.3 ± 0.20^{bc}	5.3 ± 0.38^{bc}	5.0 ± 0.48^{bc}	5.7 ± 0.52^{b}	5.8 ± 0.26^{b}	$P < 0.05$
Arg	12.4 ± 0.53^{a}	12.3 ± 0.53^{a}	8.3 ± 0.62^{c}	9.3 ± 0.88^{bc}	9.3 ± 0.43^{bc}	9.9 ± 0.46^{b}	11.4 ± 0.58^{a}	9.5 ± 0.31^{b}	11.4 ± 0.46^{a}	11.8 ± 0.33^{a}	$P < 0.01$
Met	5.3 ± 0.40^{a}	3.7 ± 0.26^{bc}	3.6 ± 0.84^{c}	3.5 ± 0.46^{c}	4.6 ± 0.21^{ab}	4.9 ± 0.15^{ab}	4.2 ± 0.34^{bc}	4.6 ± 0.29^{ab}	4.7 ± 0.49^{ab}	4.9 ± 0.43^{ab}	$P < 0.01$
EAA_{sum}	93.6 ± 2.25^{a}	81.3 ± 4.35^{b}	71.3 ± 3.27^{c}	76.7 ± 4.36^{bc}	78.9 ± 2.77^{bc}	80.7 ± 1.75^{b}	81.6 ± 3.16^{b}	78.6 ± 3.23^{bc}	85.6 ± 5.10^{b}	87.7 ± 4.08^{a}	$P < 0.01$
Asp	19.2 ± 0.40^{ab}	18.7 ± 0.84^{b}	15.4 ± 0.70^{c}	17.3 ± 0.83^{bc}	17.4 ± 0.94^{b}	17.5 ± 0.52^{b}	18.4 ± 0.99^{ab}	17.0 ± 0.85^{bc}	19.5 ± 1.67^{a}	19.8 ± 0.82^{a}	$P < 0.01$
Ser	7.6 ± 0.36^{a}	5.9 ± 0.43^{bc}	5.7 ± 0.26^{c}	6.6 ± 0.38^{b}	6.6 ± 0.28^{b}	6.7 ± 0.26^{b}	6.5 ± 0.25^{b}	6.4 ± 0.37^{bc}	6.6 ± 0.74^{b}	7.1 ± 0.36^{ab}	$P < 0.01$
Glu	25.4 ± 0.32^{a}	27.1 ± 1.84^{a}	20.4 ± 0.92^{b}	22.4 ± 1.47^{b}	23.1 ± 1.23^{b}	21.4 ± 1.28^{b}	23.9 ± 1.50^{b}	22.6 ± 0.80^{b}	22.8 ± 0.90^{b}	24.7 ± 1.04^{ab}	$P < 0.01$
Pro	6.4 ± 0.24^{a}	6.1 ± 0.34^{a}	6.3 ± 0.26^{a}	6.5 ± 0.40^{a}	6.5 ± 0.51^{a}	7.0 ± 1.07^{a}	6.1 ± 0.45^{a}	7.1 ± 0.68^{a}	6.2 ± 0.15^{a}	6.5 ± 0.2^{a}	$P < 0.05$
Gly	9.9 ± 0.47^{ab}	9.1 ± 0.70^{ab}	8.1 ± 0.62^{b}	9.5 ± 0.90^{ab}	9.5 ± 0.73^{ab}	10.5 ± 1.57^{a}	9.0 ± 0.25^{ab}	10.2 ± 1.24^{a}	9.7 ± 0.70^{ab}	10.1 ± 0.77^{a}	$P < 0.01$
Ala	11.0 ± 0.54^{a}	9.8 ± 1.04^{ab}	9.2 ± 0.75^{b}	10.1 ± 0.81^{ab}	10.2 ± 0.36^{ab}	10.6 ± 0.70^{ab}	10.1 ± 0.84^{ab}	10.6 ± 0.34^{ab}	10.7 ± 0.82^{ab}	10.7 ± 0.95^{ab}	$P < 0.01$
Tyr	6.4 ± 0.28^{a}	5.0 ± 0.38^{b}	4.9 ± 0.50^{b}	5.3 ± 0.43^{b}	5.9 ± 0.32^{a}	5.8 ± 0.18^{a}	5.2 ± 0.24^{b}	5.4 ± 0.36^{b}	5.7 ± 0.25^{a}	5.7 ± 0.34^{a}	$P < 0.01$
$NEAA_{sum}$	85.9 ± 1.74^{a}	81.7 ± 5.26^{a}	69.9 ± 3.63^{b}	77.7 ± 4.96^{ab}	79.2 ± 2.61^{a}	79.4 ± 5.13^{a}	79.2 ± 3.04^{a}	79.2 ± 2.73^{a}	81.3 ± 4.09^{a}	84.7 ± 4.23^{a}	$P < 0.01$

EAA_{sum} - essential amino acid sum, $NEAA_{sum}$ - non-essential amino acids sum
Groups with different alphabetic superscript differ significantly at the given level of probability. ROP – Ropsha Scaly Carp, TAT - Tataj Scaly Carp, M2 – Hungarian Mirror Carp, L15 – Hungarian Strain Carp, DOR70 – Israeli Mirror Carp, M72 – Northern Mirror Carp

be the reason for differences in the amino acid composition, especially compared to the pure M2 line, whose origin is genetically identical (Hungary). In our experiment, however, differences in the amino acid composition will more probably be connected with earlier onset of sexual maturity in males (Table 1). Sex dependence was demonstrated mainly in scaly hybrid ROP × TAT, especially in terms of their essential amino acid composition (Table 3). The differences found are probably linked with a higher production of sex hormones of steroid nature in sexually mature males that positively affect anabolic biochemical processes and enhance proteosynthesis of muscle proteins and thus also the abundance of certain amino acids. Higher levels of these amino acids in fillets of ROP × TAT male carp were the reason for their higher representation in ROP × TAT carp fillets with no sex differentiation, and, consequently, the reason for the differences demonstrated in amino acid composition in relation to the genetic specification in the carp groups studied (Table 2).

Another hypothetical reason for the differences ascertained in amino acid composition might be different chemical composition of the diet fed to the fish with regard to the nutrient composition (protein and its constituent amino acids), or differences in nutrient requirements. According to Jobling (1994), nutritional requirements of fish of the same age reared in the same environment and under the same feeding regime are influenced by their size and degree of sex maturity. Akiyama et al. (1997) reported that variations in amino acid requirements of different species possibly reflect true differences between phylogenetically distinct families or species. In view of differences found in growth rates between individual groups (Table 1), unequal intakes of plant and animal protein (especially essential amino acids) may have ensued as a result of trophic competition. According to Limin et al. (2006) no fish can grow or reproduce without a continuous supply of protein. Metailler et al. (1981) demonstrated that the content of essential amino acids is the principal factor in their dietary value. Growth and food conversion efficiencies can be maximized by manipulating the composition of the dietary amino acids. However, Yamamoto et al. (2000) published that not only dietary protein levels and amino acid profiles, but also dietary fat levels influence tissue amino acids levels.

In view of the results presented, the only hybrid comparable to the ROP × TAT control with regard to amino acid composition (except Glu) is the M2 × M72 hybrid. Fillets of other experimental groups (M2, M2 × L15, M2 × DOR70) contained generally less amino acids. In terms of sex differences (female carp v. male carp), fillets of male ROP × TAT controls showed the greatest abundance of essential amino acids, amino acid compositions in fillets of male and female mirror carp were practically the same.

Hodnocení složení aminokyselin ve filetech lysých hybridů kapra obecného (*Cyprinus carpio* Linnaeus, 1758)

Cílem práce bylo sledovat zastoupení aminokyselin v bílkovinách filetu u nově vyšlechtěných lysých linií kapra obecného. K pokusu bylo použito plemeno maďarského lysce (M2) na mateřské pozici. Na něj byli kříženi mlíčáci jiných plemen (vrcholové křížení). Byli to maďarský lysec (M2) pro produkci čistého plemene, maďarská lysá linie (L15), izraelské plemeno (DOR70) a severský lysý kapr (M72). Jako kontrola sloužil šupinatý hybrid ropšínského (ROP) a tatajského plemene (TAT). S ohledem na genetickou specifikaci sledovaných skupin kapra byly zjištěny četné rozdíly ($P < 0.01$ resp. $P < 0.05$) v zastoupení konkrétních aminokyselin (EAA: Val, Leu, Lys, Arg, Met; NEAA: Asp, Glu, Tyr) a jejich celkových množství (EAA_{sum}; $NEAA_{sum}$) mezi šupinatou kontrolou (ROP × TAT) a čistou linií M2. Vyšší hodnoty aminokyselin byly zjištěny u kontrolních hybridů. Zastoupení aminokyselin ve svalovině filetu experimentálních lysců (M2 × L15, M2 × DOR70) bylo prakticky stejné. Ve srovnání s kontrolou (ROP × TAT) obsahovaly tyto skupiny kapra méně ($P < 0.01$) Leu, Lys, Arg a Glu. Statisticky srovnatelné zastoupení aminokyselin s kontrolou (ROP × TAT) bylo zjištěno pouze u hybrida M2 × M72 s výjimkou

Glu, kterého tento hybrid obsahoval méně ($P < 0.01$). V závislosti na pohlaví (jikernačky vs. mlíčáci) obsahoval nejvíce esenciálních aminokyselin filet samců kontroly ROP × TAT, u lysců bylo zastoupení aminokyselin ve filetech obou pohlaví prakticky stejné.

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