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EFFECTS OF NATURAL ENVIRONMENT AND REARING CONDITIONS ON THE WELFARE AND PRODUCT QUALITY OF COMMON CARP (*CYPRINUS CARPIO* L.)

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1. BACKGROUND OF RESEARCH, OBJECTIVES

Common carp (*Cyprinus carpio*) is the dominant species in Hungary's fish production, with its share over 75%. This is largely mirrored in the national fish consumption habits as well, since carp is the mostly consumed fish of Hungary. In parallel with the alterations of the national consumption, the proportion of processed products is increasing, giving a more expressed basis for the research concerning slaughter value and flesh quality.

Consumer's perception of farmed carp in Hungary is bad, despite the high amount of consumption. The main drawbacks are the high number of bones, high fat content and off-flavour. These characteristics are related to the feeding and the rearing technologies.

Cheap, deep-frozen saltwater fishes are rivals of the Hungarian farmed fishes. Hungarian farmed fish species can succeed in the competition with import fishes, if the consistent quality and excellent price/value ratio are provided. Quality of saltwater farmed fishes is a well-studied area. In contrast, scientific literature of freshwater fishes' quality is scarce.

Consequently, the investigation of product quality of common carp is justified mainly from the less examined aspects, such as the effects of natural environment, regular exercise or perimortal stress on meat quality.

Production and consumption of carp dominate in South-Eastern Asia, Middle and Eastern Europe, while in developed countries of Europe and North America it is minimal or nil. Thus, small number of investigations focused on carp meat quality worldwide, mainly the slaughtering value and fat content were studied.

Environmental effect can alter the quality of common carp (BAUER AND SCHLOTT, 2009). Comparison of fat content of natural and farmed carps (LENGYEL ET AL, 2001), effects of natural feed and fodder (HANCZ ET AL. 1995)

and effect of strain on fat content (HANCZ ET AL., 2002) have been studied so far. Seasonal changes in body composition of carp is also well documented (KÖRMENDI ET AL., 2002).

Effect of regular training on body composition and meat quality is described mainly in homeothermic species (rat, human: HELGE ET AL., 1999 and 2001; rabbit: SZABÓ ET AL., 2005; migratory birds: GUGLIELMO ET AL., 2002). Literature concerning the regular exercise in fish is poor. Regular training induced adaptation consists of the transition from carbohydrates to FA oxidation (MANGONI AND WEBER 2007) and the proportion of red muscle fibers increases. Fat content of fish increases also, because the regular training influences the amount of the storage lipids (triacylglycerols) (SZABÓ ET AL., 2005) and the quality (composition) of the structural lipids (ANDERSSON ET AL. 1998) in the muscle tissue.

From the viewpoint of meat quality, it is important that the proportion of C20 and C22 PUFA increase mainly in the FA profile of the structural lipids (HELGE ET AL. 2001).

The extent of perimortal stress and its relation to the meat quality in cyprinids is poorly described. Mainly farmed saltwater (URBIETA AND GINES, 2000; HUIDOBRO ET AL, 2001; OLSEN AND MTSAI 2008) and freshwater (LINES AND MTSAI 2003) species representing high value are analyzed from this aspect. Handling prior to slaughter (transport, MERKIN AND MTSAI. 2010; crowding, BAGNI ET AL., 2007) may cause significant stress to the fishes and alters also the flesh quality.

Summarized, it can be stated that feeding was mainly studied previously among the factors influencing the meat quality and FA composition in common carp. Thus, the aim of the thesis (i.e. the studies in it) was to explore the further environmental factors which can alter the meat quality in common carp.

Objectives of the experiments are the followings:

I. Comparative study of common carps harvested at fish farms with different natural environment from the aspects of slaughtering indexes, conventional meat quality parameters and fillet red muscle proportion.

II. Construction of a swimming facility and analyse the effect of regular training on muscle phospholipid FA composition and peroxidation and concentration changes in serum parameters in one summer old common carps.

III. Effect of extreme thermal environment on FA composition of common carp in Lake Hévíz analysing the fillets and intestinal content.

IV. Follow up of the harvesting-transport-storing-slaughtering process with a model experiment. Determination of the extent of stress (blood cortisol concentration) during the experiment with serial samplings. Analysis of the effect of slaughtering method on meat quality.

2. MATERIALS AND METHODS

In this chapter four separated experiments are described. All of our experiments were approved by the Animal Experimentation Ethics Committee of the Kaposvár University, as allowed by the Somogy County Animal Health and Food Control Authority.

2.1. Quality analysis of carps from different farms

2.1.1. Fish farms

Attala

The pond is built in hills, behind a dam. The surroundings of the farm is agricultural area. Main soils are clay and loess.

Nagyberki

The pond is built in hills, behind a dam. The surroundings of the farm is agricultural area. Main soils are clay and loess.

Fonyód-Zardavár

The pond is in plain, built around dikes. The farm is on peaty soil, there is a large reedy marsh around the pond

Szeged-Fehértó

The pond is in plain, built around dikes on salty, alkaline soil.

Table 1 Proximate basic data of the fish farms

Fish farms	TG1	TG2	TG3	TG4
Size of pond (ha)	18	23	15	241
Fish nutrition:				
Maize (%)	80	80	80	80
Wheat (%)	5	5	15	20
Triticale (%)	15	15	5	0
Rearing regime:	Polyculture	Polyculture	Polyculture	Polyculture
Stocked fish species (%):				
Common carp (*Cyprinus carpio*)	90	80	85	90
Grass carp (*Ctenopharingodon idella*)	5	5	5	2.5
Silver carp (*Hypothalmichthys molitrix*)	5	12	5	4.5
Pikeperch (*Sander lucioperca*)	0	0	5	0
Catfish (*Silurus glanis*)	0	3	0	5.5

2.1.2. Carp strains

Different carp strains were analyzed from each fish farm (Table 2).

Table 2 Analyzed carp strains and performance tests

Fish farms	Carp strains	Performance tests
Attala	Attala mirror	1999
Nagyberki	Attala scaled	-
Fonyód-Zardavár	Hortobágy scaled	1998; 2010
Szeged-Fehértó	Szeged mirror	2000; 2001; 2010

2.1.3. Sampling

Samples were collected in harvesting time of 2009 November-December directly after netting.10 individuals were collected from each farm. Sampling was repeated in the following year (2010).

2.1.4. Quality investigations

Carps were processed after percussive stunning in accordance with the rules of the CARP PERFORMANCE TESTING CODEX (2001).

Fillet pH was measured at 45 min and 24 h post mortem, by a Testo 205 precision pH meter (Testo AG, Lenzkirch, Germany). The colour (CIE Lab, L – lightness, a* – redness, b* – yellowness) of the fresh fillet was determined by a Minolta ChromaMeter 300 apparatus (Minolta, Osaka, Japan). Water holding

capacity was determined as dripping loss, cooking loss and thawing loss. Moreover, fillet dry matter content was determined by drying to constant weight at 103 °C. Fillet fat content was determined from raw samples by extraction with petroleum-ether and drying the extract at 103 °C to a constant weight according to ISO 6492 (ISO 1985).

2.1.6. Determination of red muscle

Red muscle ratio of fish was determined in cross-sectional fillet slices. Surface of slices was recorded as digital image with HP Precisionscan 5470. Scanned images were handled with GIMP for Windows 2.6.8. programe. Separation of red muscle fibers was carried out with an accepted method used to quantifying stained liver tissues (http://rsbweb.nih.gov/ij/docs/examples/stained-sections/index.html).

2.2. Effects of regular training on caps blood components and fillet phospholipid FA composition

2.2.1. Experimental animals

Two types of one-summer-old common carps (Attala mirror and Balaton lean) were introduced into a 500 l fish tank and overwintered in the Fish Laboratory of the Kaposvár University (Hungary). During the experimental period a commercial feed was fed *ad libitum*.

2.2.2. Swimming facility

The swimming facility was self-constructed, and installed to a recirculating system. It was a lengthwise halved plastic tube placed in a bigger trough. The ends of the tube were closed with a tightly woven mesh. Water velocity was adjusted by changing the level of the raceway and the volume of the influent water. Water velocity was measured with FP311 Global Water Flow Probe propeller-based current measuring instrument. Experimental fish groups were

exercised daily in a 35-day period, 30 minutes every day, at constant velocity (0.6 m/s).

2.2.3. Sampling

Blood samples from the tail vein were taken from all fish at the start (timepoint 0), then every 9th day (timepoints 0, 1, 2, 3), 12 hours after the last exercise sessions, while training was omitted on the sampling days. As the primary aim of the study was to characterize the chronic, but not the acute effects of exercise, resting parameters were recorded.

On the 35th day of the experiment 12 male fish from each treatment (i.e. trained and control) were selected and over-anaesthetised with clove oil. A fast-twitch type muscle part of the left fillet was dissected freshly, washed in ice-cold physiological saline, wiped dry and stored frozen (- 70 ^{o}C) until analysis (as well as the plasma samples).

2.2.4. Chemical analysis

Clinical chemical analysis was performed on an automated equipment (Hitachi 917) in a single analytical run. Serum oxidized glutathione concentration was measured with the method of SEDLAK AND LINDSAY (1968), spectrophotometrically.

Sample total lipid content was extracted according to FOLCH ET AL. (1957), while lipid fractionation was performed according to LERAY ET AL. (1987). The derivatisation of PL fraction for subsequent gas chromatographic analysis was performed with the base-catalyzed $NaOCH_3$ method of CHRISTIE (1982). Gas chromatography was performed on a Shimadzu 2100 apparatus.

The malondialdehyde concentration was determined by the method of PLACER ET AL. (1966).

2.3. Effect of extreme thermal conditions on carp's fatty acid composition

2.3.1. Experimental animals and sampling

Lake Hévíz is the largest thermal lake in Europe. It is a geological and a balneological unique. The extent of the lake is 4.4 hectares, the bottom soil is peaty sludge. Compared to other natural waters (10-12 ^{o}C mean annual water temperature), Lake Hévíz varies between 24 ^{o}C and 38 ^{o}C (annual mean: 30.7 ^{o}C). Mean summer and winter temperatures are 33-35 ºC and 24-28 ºC, respectively.

Carp population of Lake Hévíz has a dwarfish habit, it is isolated from the nearby populations. Low growth rate and small adult size (maximum weight of 400-450 g in 8-9 years old fish; unpublished observations) may be consequences of the adaptation to the extreme environment. For this analysis fish (n=10, adult males, 344.2 ± 63.9 g) were caught by gill-net in December 2010, at 28 ^{o}C water temperature. Fish were dissected to sample the intestinal contents (being characteristic for the feed) and the fillet. Samples were stored at -70 ^{o}C until analysis.

2.3.2. Fatty acid analysis

Fatty acid analysis of fillet and intestinal content was carried out as described chapter *2.2.4.*

2.4. Effect of perimortal stress on carp's quality

2.4.1. Experimental animals and sampling

Altogether 60 market sized common carps were taken from a fish farm at harvesting time (middle of November 2011). After harvesting fish were immediately transported to the Fish Laboratory of Kaposvár University in an aerated fish tank. Fish were stocked in 500 L fish tanks (recirculation system, aerated).

To model the practice of the live fish trade in Hungary fish were kept at a high stocking density (0.075 kg L^{-1}) and low water temperature (6 °C). During the experiment carps were not fed.

2.4.2. Sampling

To determine the stress level, blood samples were taken at several time-points: after harvesting, after transporting to the laboratory, and during the keeping in the laboratory weekly. Final blood samples were taken after stunning and before gutting also. Blood samples from the tail vein were taken from all fish. After a 3 week-long keeping fish were slaughtered with three different methods (15 fish/group). Carps of the first group were stunned by a blow on head, those in the second were stunned by chilling in ice slurry. The third group was anesthetized by asphyxiation in CO_2 saturated water. Fish in each group were gutted immediately after stunning.

2.4.3. Quality parameters

Meat quality parameters were determined as described in chapter *2.1.4*. The recording rigor progression in gutted fish was carried out by the method of MØRKØRE ET AL. (2008). Measurements of rigor angle were done at 3, 6, 9, 12, 24 and 48 h *post mortem*. At the same timepoints fillet pH values were determined also.

2.4.3. Chemical analysis

The blood serum cortisol levels were estimated by radioimmunoassay (RIA) method with Kortizol [^{125}I] RIA kit (Izotóp Intézet Ltd., Budapest, Hungary) and gamma counter (Jeney et al, 1992).

2.5. Statistics

In all instances from the basic dataset outlier values were filtered and the remaining data were tested for normality (Shapiro-Wilk test).

In the first experiment ANOVA (GLM, Univariate) with Tukey *"post-hoc"* test ($P<0.05$) was used to compare the body shape, slaughtering and flesh quality parameters and to ascertain the between-group differences. Fixed factors were sex and strain. As the four strains represented two varieties (mirror and scaled), differences according to variety were evaluated with t-test. Relation among traits was described by linear regression and correlation.

In the second experiment, in case of the blood metabolites, between-group differences were analysed by independent samples t-test at the significance level of 0.05 at each timepoint, while within group, time-dependent alterations (differences among timepoints) were analysed with oneway ANOVA with the Tukey post *"hoc test"* (marked by uppercase superscripts in Table 2).

By the muscle PL and malondialdehyde analysis between-group differences were analysed by independent samples *t*-test at the significance level of 0.05

In the third experiment to seek for differences between the Hévíz and published data (i.e. pairwise comparison), the Mann-Whitney U test was used. To explore the classification pattern of the fillet FA profile among literature data and those of the Hévíz population, Discriminant Factor Analysis (DFA) was used.

In the fourth experiment for the analysis of the extent of stress caused by handling and stunning methods, and effect of stunning method on meat quality ANOVA (Tukey "*post hoc"*) was used.

In all instances SPSS for Windows 10.0 (1999) was used, for DFA of Hévíz carp AlphaSoft 12.3 software was used (Alpha MOS, Toulouse, France).

3. RESULTS

3.1. Meat quality analysis of common carps from different fish farms

In the experiment carps were collected from different fish farms. The aim was to evaluate the impact of the environment on the slaughter characteristics and the meat quality.

The slaughter value of the mirror varieties tended to exceed that of the scaled type carps, the Attala mirror strain providing significantly the highest slaughter value. For the calculated body shape indices (profile, cross-sectional, head and tail index) the influence of strain was statistically proven. The profile and the head index of the scaled genotypes were higher, as compared to the mirror strains, while the cross-sectional index was identical in all four strains in study. The above differences were more pronounced when only the two varieties (i.e. scaled vs. mirror) were compared.

Although all carp strains have typical body shape description indices, their common contribution to slaughter value can be characterized as weak. Fillet yield seems to be less related to these indices.

The fat content values falling below the literature data on farmed carps suggest that the natural feed components play an important role in the composition of carp diet. Fillet fat content was significantly affected by strain, the difference between mirror and scaled types was not significant.

The value of cooking loss was the highest in the Attala mirror with significant effect of strain, while other strains' cooking loss values were similar. The highest thawing loss was found in the Hortobágy scaled, and in the extent of spontaneous dripping there was no difference between groups.

Considering flesh colour (L, a*, b*) all fillet samples were identical. The colour characteristics of carp indicate a rather homogenous population, albeit the strain and even sex exerted a statistically significant effect on all colour measures.

The pH value at 45 min post mortem was always higher than at 24 hours *post mortem*. The between-group differences by both pH values were identical. The pH value of the fillet was significantly influenced by the strain as a fixed factor.

The red muscle fibres were concentrated around the spine, near the lateral line and the pectoral fin in the fillet. The red muscle ratio ranged between 11.06 and 13.3%. There was no significant difference between the strains by the red muscle proportion in the fillet.

3.2. Effect of regular swimming on fillet phospholipid fatty acid composition and blood serum composition

In the experiment one summer old common carps were exercised 30 minutes/day in an artificial water flow during a 35-day period. Blood samples were taken four times and fast-twitch type muscle samples were taken at the end of the experiment. Blood serum components, fillet phospholipid fatty composition and malondialdehide concentration was determined.

The 5 week regular training significantly decreased the proportion of myristic (C14:0), margaric (C17:0) and arachidonic (C20:4 n6, ARA) acids, while increased the proportion of behenic acid (C22:0). Interestingly, in the calculated fatty acid groups only the total n6 proportion showed significant proportional modification (decrease) as a response to regular swimming exercise. A possible mechanism underlying the lowered proportion of ARA may be the activation of phospholipase A_2, suggesting membrane structure changes (damages) in the muscle cell.

The slight oxidation of margaric acid may be related to the phenomenon, that its preference in the β-oxidation is similar to that of palmitic acid (C16:0).

Behenic acid is an important component of muscle sphyngomyelins and most likely this fraction responded sensitively to the regular training. The fillet

malondialdehyde concentration of the trained group increased significantly, which suggests an increased level of *in vivo* lipid peroxidation.

In the blood, within the nitrogenous serum compounds the training protocol led to a significant increase of the albumin concentration at timepoint 3, while neither total protein, nor creatinine indicated the effect of regular swimming. The serum oxidized glutathione concentration was higher at the final sampling in the trained fish. Protein catabolism was not induced by the swimming treatment.

The contribution of esterified fatty acids (dominantly triacylglycerols of lipoproteins) to fuel exercise metabolism of freshwater fish is still unknown, but seems to be important, based on our findings. It seems thus that not stored, but circulating triacylglycerols serve as an important fuel source for fish muscles, which is not typical for homeothermic vertebrates (TURCOTTE, 1999).

Total and HDL cholesterol fractions failed to respond quantitatively to exercise training. However, the relation of the two cholesterol fractions (HDL% in total) was significantly lowered by the exercise to the end of the training period, while both groups showed an age associated increase in this parameter. Taking the above results into account it seems that carps provide burst-like, intensive but short exercise bouts, of which the energy requirement may by primarily covered from circulating and not intramuscular lipids.

The typical hepatic and muscle enzymes ALT and AST reacted to the exercise with elevated serum activity values, at the final sampling. The markedly elevated activities regularly indicate hepatocellular and sarcolemmal damage.

It is thus supposed that glycolytic potential was only slightly increased. Lactate dehydrogenase (LDH) was showing non-significantly higher activities throughout the study in the trained carps.

We found significantly higher oxidized glutathione levels in the trained group at the final sampling. GSH is a potent antioxidant, preventing cellular

membrane lipids which are targets of oxidative damage during strenous exercise (KERKSICK AND WILLOUGHBY, 2005). Taking the gamma-GT results also into account we suppose a mild alteration of the glutathione redox status due to exercise in which GSH oxidation was augmented.

Based on the less fluctuating ion concentrations and the slight training associated between group differences sarcolemma damage was not supposed in our study.

3.3. Effects of extreme environmental conditions on the fillet fatty acid (FA) profile of carps

The thermal effects were analyzed on the Hévíz indigenous carp population, on its fillet quality. Fish were collected with a gill-net. Ten adult, male individuals (344.2±63.9 g mean BW) were dissected and for the determination of the dietary fatty acid profile intestinal content was as well collected. The fatty acid profile of fillet and intestinal content was determined with gas chromatography.

Based on the results it was stated that carps in the Lake Hévíz do not undergo starvation. This was underpinned by that fact that both intestinal content and deposited visceral fat were found in large amounts.

The fatty acid composition of intestinal content contained large proportions of arachidonic (C20:4 n6, ARA, 6.55%) and docosahexaenoic acids (C22:6 n3), latter component contributed dominantly to the fact that the total n3 FA proportion was ca. 20%. It was thus supposed that carps ingest and utilize the microflora growing on the decomposing macrophyte remains in the lake sediment. The unsaturation index (UI) of intestinal content largely exceeded that of the fillet (170 vs. 126.7); this refers to a specific (likewise inverse) type of thermal adaptation; namely high or increasing proportions of arachidonic and docosahexaenoic acids in the lipids of carp (hepatic phospholipids) refer to cold acclimation (FARKAS 1984). Thus, it seems that besides relatively rich dietary

PUFA supply, warm thermal environment did not necessitate an expressed recruitment of these fatty acids into the fillet lipids.

It is as well an interesting finding that the level of saturated FAs in the Hévíz carp fillet lipids was 5-10% higher, as compared to all literature data (incl. tropic environments as well). We hypothesize the thermal adaptation process behind this result.

Comparing our fillet FA data to those in the widespread literature from nearly all individual FA proportion values were significantly different. Using the discriminant factor analysis method (DFA), involving the fatty acids C14:0, C18:1 n9, C18:2 n6, C20:1 n9 and C20:4 n6 the Hévíz sample showed obvious isolation from all other groups.

Investigating the possible origin and role of the above mentioned FAs, the first (myristic acid) may be of both endogenous and exogenous origin. It has to be however emphasized that the proportion of this FA was 2.5-5 times higher in the Hévíz population, as compared to the literature data, with a surprisingly minor presence in the diet. Oleic acid (C18:1 n9) is a desaturation product of stearic acid, thus its origin is, similarly to myristic acid, double, meanwhile its (and its precursors, C18:0) dietary occurrence was high (18.1%). Linoleic acid (C18:2 n6) is essential for vertebrates and its dietary provision was very similar to its tissue presence. In case of its endogenously further elongated and desaturated product, arachidonic acid (C20:4 n6), the diet seemed to be rather rich, leading to a percentage contribution of over 4% in the fillet lipids. This level was only comparable to that measured in other natural and warm ponds in Turkey by GULER ET AL. (2008) and KALYONCU ET AL. (2010). Interestingly, Hungarian fishpond data were also not statistically different (TRENOVSZKI ET AL., 2011) from the Hévíz data for this acid, most probably due to the feeding of linoleic acid rich components (sunflower seed). This was supported by the relatively high fillet linoleic acid proportion in the fillet of those carps.

3.4. Effects of perimortal stress on the meat quality of carp

In the study the fish harvesting-transport-storage-slaughter process was followed-up, so as to determine the effects of stress on the meat quality.

Harvesting and transportation had both significant impacts on the blood cortisol concentration of carp. The highest stress for the fish was caused by the transportation. During the further keeping – despite the high stocking density – stressors were minimized to the second week.

Stunning method had a significant impact on the blood cortisol concentration. According to our results, minimal stress was caused by the percussive stunning. It was followed by the CO_2 asphyxiation and the biggest stressor was the alive chilling.

The stunning method did not significantly affect any of the conventional meat quality parameters, and between-group differences were also not detected. In the different characteristics concerning water holding capacity (cooking, dripping and thawing losses) no inter-group differences were found, while handling these three traits together (total moisture loss) a more expressed difference was found among groups. The larges moisture loss was achieved by the group chilled alive, while the lowest by that treated with CO_2.

Concerning flesh color, this was the trait providing the largest difference among groups. While the lightness (L) of fillets was identical, the redness (a*) and the yellow (b*) color components was higher by the CO_2 treated fish, as compared to all other groups, which were nearly identical. This difference was attributed to the remnant blood in the fillet. The stunning method itself did not exert a significant effect on the *rigor mortis* and pH value of the flesh. The evolvement of rigor declination was highly similar in the groups stunned with head-blow and alive chilling. By the CO_2 treated fish the rigor started ca. 6 hours later and the ultimate rigor declination remained below the values reached by the other two groups.

Within 24 hours *post mortem* the increasing lactate concentration within the flesh is associated with the pH fall and thus with the perimortal glycolytic activity, referring to physical activity and stress. The pH fall of CO_2 treated fish was marked in the first 24 hours, as compared to those killed either with head-blow or alive chilling. This is associated with the above-mentioned glycolytic activity, since head-blow leads to the cessation of all movements, while the other two treatments induce very active movement types, in particular in the first phase after the initiation of the treatment.

4. CONCLUSIONS

In the experiment "**quality analysis of common carps from different fish farms"** four important Hungarian carp strains were compared based on their slaughter characteristics and fillet flesh quality parameters. Despite large differences in the body shape and slaughter weight, the pH and the water holding capacity of the divergent strains were highly similar in the fillet. In contrast, the fillet fat content differed considerably, most probably as a result of the altering additional feeding and natural feed uptake at the different ponds. Our results underscore the practical experience that Hungarian carp population provides large variance in the body composition and slaughter characteristics.

Therefore, efforts should be made to unify the production technology in the Hungarian carp production. These actions are necessary to receive a balanced quality, thereby the demand for carp could be increased.

Based on the results of the **training study** it was concluded that common carp is able to perform regular swimming exercise which slightly but definitely influences the phospholipid fatty acid composition of its fast-twitch muscle. Alterations of the FA profile (reduced n6 and ARA proportions) echo those found in other homeothermic vertebrates and might be associated with altered cytokine production and the activation of the sphingomyelin- signalling pathway. In addition, the *in vivo* lipid peroxidation of fillet lipids decreased due to the training

From the results of the blood analysis slightly elevated lipoprotein utilization, severe hepatocellular damage can be supposed. Based on the finally increased albumin concentration we supposed slight hipervolemia, while increased oxidized glutathione concentration referred to elevated antioxidant capacity. It was assumed that even longer term regular strenuous exercise exerts only mild effect on the substrate metabolism of carp.

In conclusion, regular swimming can reduce the abundant and less favorable n6 fatty acid proportion of fish.

The intestinal content of the **Hévíz drawf carps** provided evidence for a dominantly benthic feed basis of this isolated population. However, the relatively high supply of arachidonic and docosahexaenoic acids did ultimately not lead to extraordinary high tissue proportion of these fatty acids, instead, the fillet lipids were strongly saturated. This refers to a specific thermal adaptation. The classification based merely on the fillet fatty acid profile was successful, and provided reliable separation of the Hévíz population from widespread literature data published, with tendentious similarity to data obtained under warm climatic conditions and natural feeding.

It is necessary to perform further investigations for the better understanding of the feeding habits and special thermal adaptation of Hévíz carps.

It is proposable to carry out a year-long monitoring of FA profile supplemented by microscopic and chemical analysis of the feed. This complex analysis can lead to wide knowledge of Hévíz carp.

From the results of the **analysis of perimortal stress** and on its influence on meat quality can be concluded the follows: significant stress was caused to fish by harvesting and transport, nevertheless during further keeping at a high stocking density and low water temperature (besides appropriate oxygenation and food deprivation) stressors were discontinued or minimized.

From the aspect of animal welfare the most human method to stun the carp is a blow on the head. Live chilling is less recommended method in carp slaughtering process, considering that the highest stress was caused by this treatment and the shelf life of the fillet was compromised. CO_2 asphyxiation and percussive stunning led to favorable post mortem pH development. Considering the remnant blood in the fillet, eventually blow on the head led to the best fillet quality and this method is less objectionable from animal welfare aspects.

5. NEW EXPERIMENTAL RESULTS

1. It was found that the carp population in study is rather variable in its body shape, slaughtering characteristics and fillet lipid content, meanwhile in conventional meat quality descriptors (pH, water holding capacity and colour) it is rather homogenous.

2. A digital image handling procedure was successfully adapted for the quantitative determination of the red muscle content of the carp fillet.

3. It was described that via a special thermal adaptation the Hévíz carp population incorporates a determinant saturated fatty acid moiety into its fillet lipids in spite the very rich dietary presence of the longchain, polyunsaturated n3 and n6 fatty acids (arachidonic and docosahexaenoic acids).

4. As a result of short-term, regular strenuous exercise bouts the phospholipid fatty acid profile of carp fillet contained decreased proportions of total n6 fatty acids, in particular arachidonic acid. Moreover, the training induced elevated level of *in vivo* lipid peroxidation was confirmed trough the increased fillet malondialdehyde concentration.

5. Metabolic adaptation to short-term, regular strenuous exercise bouts was characterized with blood serum biochemicals in carp; it was found that training induces increased serum albumin levels (hypervolemia), and does not lead to protein breakdown. The primarily important fuels were serum triglycerides, meanwhile serum AST and ALT activities were increased and the level of oxidized glutathione increased. The serum sodium concentration provided an age dependent increase, irrespective of the training.

6. It was established that from the stunning methods tested (blow to the head, CO_2 asphyxation and alive chilling) the blow to the head leads to the lowest stress niveau in carps.

7. From within three different stunning methods (blow to the head, CO_2 asphyxation and alive chilling) alive chilling significantly decreases the post mortem pH fall of the carp fillet.

6. SCIENTIFIC PAPERS AND LECTURES ON THE SUBJECT OF THE DISSERTATION

Articles in foreign languages

Varga, D., Szabó, A., Romvári, R., Hancz, Cs. (2010): Comparative study of the meat quality of common carp strains harvested from different fish ponds. Acta Agraria Kaposvariensis. 14: 301-306.

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Varga, D., Romvári, R., Horn, P., Hancz, Cs., Molnár, T., Szabó, A. (….): Environmental factors influencing the slaughter value and the flesh quality of common carp in four tipical fish farms in Hungary. Acta Alimentaria. (*Accepted)*

Articles in Hungarian

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