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Research Article

# The seasonal fatty acids composition in different tissues of farmed common carp (*Cyprinus carpio*)

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**Abstract:** The seasonal fatty acid composition in viscera, muscle, bones, and skin of farmed common carp (*Cyprinus carpio*) was determined in spring (March), summer (June), autumn (September), and winter (December) (% of total fatty acids). Palmitic acid (C16:0) and oleic acid (C18:1n-9) were the most abundant saturated fatty acid (SFA) and monounsaturated fatty acids (MUFA), respectively. Linoleic acid (C18:2n-6), arachidonic acid (C20:4n-6), docosahexaenoic acid (DHA), and linolenic acid (C18:3n-3) were the most abundant polyunsaturated fatty acids (PUFA). All tissues had a lower percentage of MUFA but higher PUFA in the summer compared to the other seasons. The results of principle components analysis (PCA) and cluster analysis (CA) suggested that fatty acid composition of common carp in summer could be distinguished from other seasons, but source of the oil in the tissue could not be determined.

**Key words:** Polyunsaturated fatty acids, common carp, *Cyprinus carpio*, DHA, fatty acids

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## Introduction

It is well known that fish lipids are rich with long-chain n-3 polyunsaturated fatty acids (PUFA), especially eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). Previous research indicated that these fatty acids could protect against coronary heart disease, cancer, and inflammatory diseases (Harris & Von Schacky, 2004), and support the brain development of infants (Ruxton et al., 2004). Some PUFA cannot be synthesized in the human body and must be obtained through the diet (Barceló-Coblijn & Murphy, 2009). Thus, consumption of fish rich in n-3 PUFA is essential for people's health. Apart from sea species, freshwater fish are a very important source of PUFA as they are generally more capable of desaturating and elongating linoleic acids (C18:2n6) and linolenic acids (C18:3n3) than marine fish (Tocher, 2003).

Coupled with the limited resources of marine fish species and the growing demand for fish, freshwater fish are being widely cultured in many countries worldwide. Common carp (*Cyprinus carpio)* is one of the main freshwater fish species in China with ~2,900,000 tons produced in 2012 ranking it third among Chinese farmed freshwater fish species (Fishery Bureau of the Ministry of Agriculture of the People's Republic of China, 2013).

However, many factors can affect the fatty acid profile of fish such as species, fish feeding, size, age, reproductive status, temperature, and seasons. The impact of these factors on fatty acid profiles have been widely studied (Dal Bosco et al., 2012, Inhamuns & Franco, 2008) including common carp. Geri et al. (1995) stated that the fatty acids composition of muscle in common carp was influenced by age and rearing environment. Fontagné et al. (2000) focused mainly on the fatty acids profile of common carp with diverse feed supplementations. Fajmonova et al. (2003) evaluated the effect of sex, growth intensity, and cooking treatment on the fatty acid composition of common carp fillets. Guler et al. (2008) researched the effects of seasonal changes on the total fatty acid composition of carp muscle lipids in Beysehir Lake (Turkey).

However, no data was found in the literature comparing the fatty acid profiles of different tissues such as viscera, muscle, bone, and skin during the

different seasons. Such data would provide more extensive nutritional information for consumers, especially about PUFA. Thus, this study investigated changes in the fatty acid composition of different tissues in farmed common carp at different seasons. The data were analyzed further using principle components analysis (PCA) and cluster analysis (CA).

## 2. MATERIAL AND METHODS

### 2. 1 Materials

The common carps (n=3 at each determination) were from the same farm and roughly the same size (weight 1400±110 g, length 42±3 cm) and age (2-3 years old). They had been raised on a commercial formulated feed in ponds. They were captured at random from the same pond at an aquafarm (Miyun District of Beijing, China), at the beginning of March, June, September and December, respectively, and then transported live to the laboratory by fish van in water with added dissolved oxygen and killed by blows to the head with a wood club. Samples of head, viscera (including all contents in the belly: heart, liver, gonads, spleen, intestine, stomach, swim bladder, kidney, etc.), muscle, bones (without fins) and skin were separated and homogenized with a tissue grinder at 20000r/min for 30s (FM200, Fluko Company, Shanghai, China). The remaining muscle on the bone and the kidney was removed as much as possible by scraping with a small knife. Then the samples were collected in polyvinyl chloride bags and stored at -20°C. They were thawed with flowing tap water for further analysis (within one week).

### 2.2 Methods

#### 2.2.1 Extraction of total lipids

Using the method of Folch et al. (1957), samples (5 g) were extracted with a chloroform-methanol (2:1, v/v) solvent system for 24 h and then filtered with qualitative filter paper (102, Tezhong paper Ltd, Hangzhou, China). The filtrate was then added to 10 mL of distilled water, centrifuged at 2000 g for 10 min (TGL-16G, Pingfan Instrument, Shanghai, China) to obtain the chloroform-extracted fraction, and dried with nitrogen (purity ≥99.5% according to the manufacturer).

#### 2.2.2 Preparation of fatty acid methyl esters (FAME)

The FAME was prepared according to method 991.39 of the AOAC (2002) with some modifications. An extract of 0.1 g was added to 3 mL of 0.5 M NaOH/methanol in a boiling water bath for 10 min, followed by mixing with 5 mL of a boron trifluoride:methanol ($BF_3$:$CH_3OH$) mixture (14:86; v/v) (Sigma–Aldrich Corporation, St. Louis, MO, USA). Then the solution was heated in the boiling water bath for another 2 min and 5 mL of heptane (95%, Lanyi Chemical Products Corporation, Ltd, Beijing, China) added. The solution was allowed to cool to room temperature, and NaCl (3 g) was added to prevent emulsion formation. Finally, the heptane-extracted fraction (upper phase) was dried with nitrogen and stored at -20°C prior to the FAME analysis, a maximum of one week.

#### 2.2.3 FAME analysis

Using the method of Chen (2012) with modifications, the FAME were analyzed using a gas chromatograph (GC-8600 Beijing Beifen-Tianpu Analytical Instrument (Group) Co., Ltd., Beijing, China), which was equipped with a SPTM-2560 capillary column (100 m × 0.25 mm I.D.; Supelco, Inc., Bellefonte, PA, USA) and a flame ionization detector (FID). The fatty acids were identified by comparing their retention times to that of a mixture of FAME standards (37 component FAME mixture, Supelco Inc.). The composition of the fatty acids was expressed as the relative percentage of the total fatty acids according to their peak areas. The relative content of each component was determined by the area normalization method and then calculated by the following equation: Area % FAX = [AX/AR]×100, where: FAX = fatty acid to be quantified, AX = area of the methyl esters X and AR = total area of the chromatogram (Memon et al., 2011).

### 2.3 Statistical analysis

All measurements were performed in triplicate and data are presented as the mean ± standard deviation (SD). Multiple group comparison were then done using one-way ANOVA followed by the least significant difference (LSD) procedure between means (significance was defined as $P < 0.05$). PCA (principle components analysis) and CA were used to group the data. Statistical analyses were done using IBM SPSS Statistics 20 (2011, IBM Corp., Armonk, NY, USA).

## 3. Results and discussion

### 3.1 Analysis of saturated fatty acids (SFA)

Table 1 shows variations of SFA in the total lipids of the different tissues during the four seasons. There were no significant differences in the proportion of total SFA, ranging from 23 to 30% ($P>0.05$). The proportion of SFA was reported to be constant in several freshwater fish species, at around 25% (Kinsella, et al., 1978), which was in agreement with the present study.

Palmitic acid (C16:0) was the most abundant SFA contributing approximately 14.9 to 18.1% of the total fatty acids. C16:0 of muscle ranged from 14.9 to 17.8%

for all seasons. Similar results for carp were reported by Guler et al. (2008) and Kołakowska et al. (2002). Stearic acid (C18:0), although much lower than palmitic acid, was another important SFA. A significantly high percentage of C18:0 was obtained from common carp skin in the spring (*P<0.05*). In addition, viscera contained a significantly higher percentage of C18:0 than other tissues in the summer (*P<0.05*). The C15:0 in common carp bone was higher in summer than in other seasons (P<0.05). There was also a higher C15:0 in muscle compared to other tissues in both summer and winter (*P*<0.05).

**3.2 Analysis of monounsaturated fatty acid (MUFA)**

Variations of MUFA (% of total fatty acids) in the total lipids of tissues are shown in Table 1. The content of total MUFA in common carp ranged from 25 to 47%. Sargent (1995) reported that MUFA were catabolized to provide metabolic energy during gonadal development, which might explain the reason why carp contained a lower percentage of MUFA in summer compared to other seasons (*P*<0.05). The present data indicated that the MUFA contents of carp viscera and muscle were higher than those of SFA in spring, autumn, and winter, which was consistent with the report of Yeganeh et al. (2012) for carp fillets.

Oleic acid (C18:1n-9) was the primary constituent of MUFA, which accounted for 18 to 38.8% of total fatty acids. Other researchers also found a dominance of C18:1n-9 in carp (Yeganeh, et al., 2012; Hong, et al., 2014). The proportion of C18:1n-9 in muscle in summer was the lowest for all tissues in all seasons (*P<0.05*). Palmitoleic acid (C16:1) was always the second major MUFA. C16:1 in winter was higher than that in summer for skin and muscle (*P<0.05*). The C16:1 of carp muscle ranged from 1.80 to 3.75%. Guler et al. (2008) and Kminkova, et al. (2001) found C18:1 and C16:1 to be the primary and secondary MUFA in carp in all seasons.

**3.3 Analysis of PUFA**

As shown in Table 1, the amount of PUFA ranged from 25.5% in skin in winter to 42.1% of bone in summer. The MUFA contents of carp were higher than those of SFA and PUFA in all seasons except summer. PUFA contents in the present study were higher than those of SFA in all seasons. Additionally, the total PUFA content of carp were higher in summer than other seasons (*P<0.05*).

The common carp had low levels of total n-3 PUFA (3.19-7.69%), but high levels of total n-6 PUFA (20.89-36.7%), which was in accordance with the study on fatty acid composition of other freshwater species (Kaneniwa et al., 2000). Tissues in summer contained more n-3 and n-6 PUFA in comparison to other seasons, and viscera and muscle had more n-3 PUFA content in summer compared with bones and skin (*P*<0.05). However, n-6 PUFA patterns were different. Bones and skin contained a higher proportion of n-6 PUFA during summer, whereas viscera and muscle did not. The unique PUFA composition of summer samples might be attributed to the different rearing environment in summer, such as higher water temperature; longer daylight hours; greater intake of feed by fish; higher activity of fish and so on.

As shown in Table 1, C18:3n-3 and DHA were the major n-3 PUFA and C18:2n-6 and arachidonic acid (C20:4n-6) were the predominant n-6 PUFA. Many reports admitted the prevalent contents of C18:2n6, EPA, DHA, C18:3n-3, and C20:4n-6 in carp muscle (Kminkova et al., 2001; Guler et al., 2008; Li et al., 2011;Yeganeh et al., 2012).

C18:2n-6ranged from 19.3 to 33.2% and it was higher than reported data for bighead carp (ranging from 2.98-17.2%) (Hong et al., 2015). The carp bone had more C18:2n-6 than the viscera and muscle in summer (*P*<0.05). Although C20:4n-6 accounted for a relatively low proportion, it plays an important role in a variety of physiological functions including osmoregulation and cardiovascular function (Cejas, et al., 2004). Carp muscle had more C20:4n-6 than other tissues in spring (*P*<0.05).The contents of C20:4n-6 of carp skin in autumn was much lower than that for the other seasons (*P*<0.05).

As the most dominant n-3 PUFA in common carp, C18:3n-3 ranged from 1.62% for viscera in winter to 3.35% for skin in summer. According to Table 1, muscle and skin contained more C18:3n-3 in summer than other seasons (*P*<0.05). The results obtained by Li et al. (2011) for linolenic acid in cultured common carp (3.3%), were similar to the data from the present study, where the percentage of C18:3n-3 in carp muscle for all seasons ranged from 1.70 to 3.25%. The value of C18:3n-3 in common carp was lower compared with most freshwater fish, including bighead carp, grass carp, black carp, and silver carp (Li et al., 2011; Hong et al. 2015). EPA is an important essential fatty acid of the n-3 series in the human diet because it is the precursor to the 3-series eicosanoids (Jalili, 2012). The contents of EPA in common carp tissues varied at 0.16-1.15% (viscera), 0.28-1.09% (muscle), 0.07-0.30% (bone) and 0.07-0.26% (skin) for all seasons. Similarly, the EPA of the edible meat of common carp was 0.6% (Li et al., 2011).

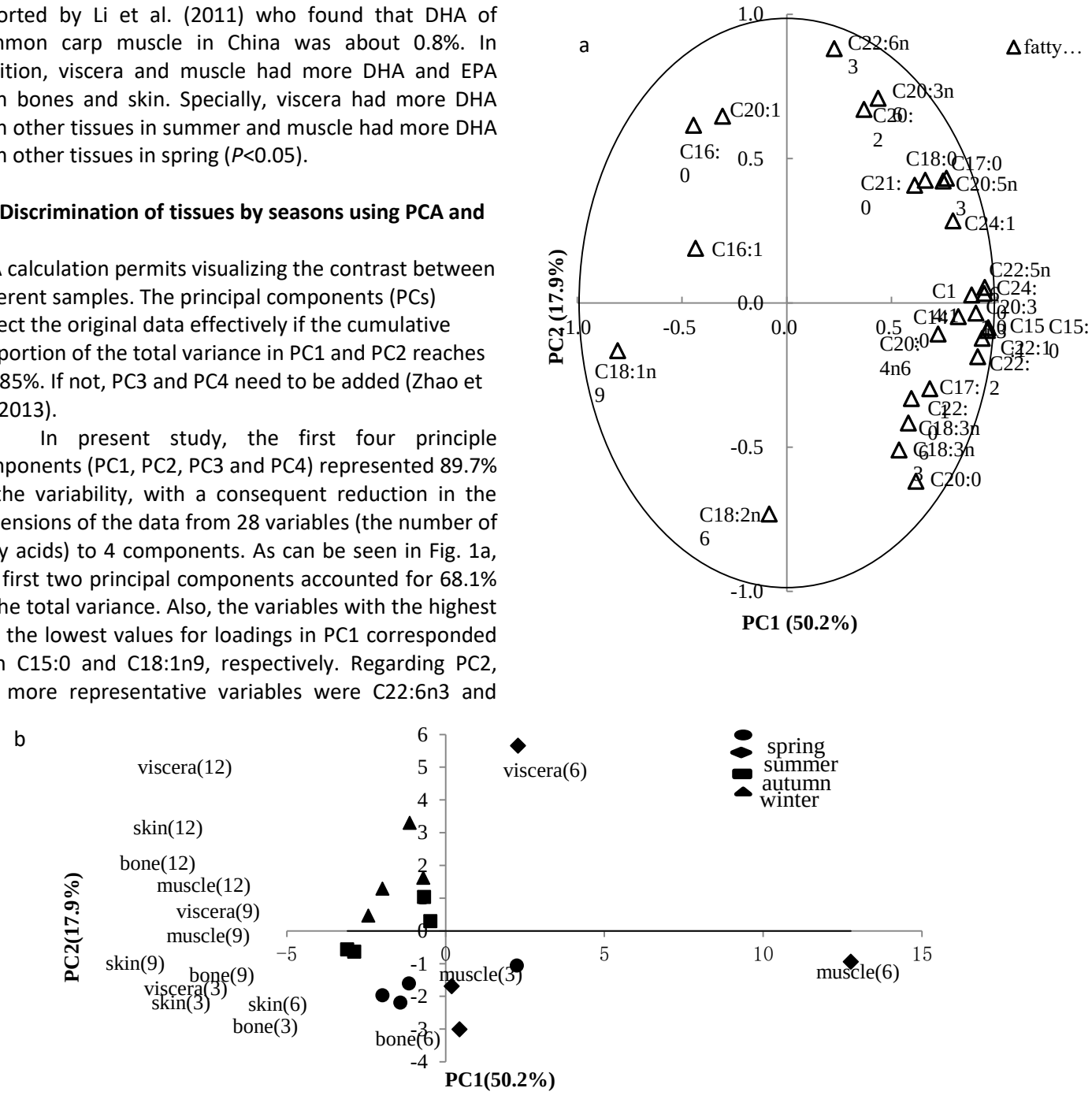
However, the level of EPA in common carp was much lower in comparison to the results from previous studies (Guler et al., 2008; Kminkova et al., 2001). Zuraini et al. (2006) showed that DHA decreases the concentration of low density lipoprotein cholesterol in plasma. The level of DHA varied from 0.49% of skin in spring to 4.87% of viscera in summer and was always higher than that of EPA (0.07% ~ 1.15%). It was consistent with previous studies that DHA is usually more abundant than EPA (up to 2–3 times) (Kołakowska et al., 2002). The DHA of carp muscle accounted for 1.5-2.46% of total fatty acids for all seasons. The result was in accordance with results reported by Li et al. (2011) who found that DHA of common carp muscle in China was about 0.8%. In addition, viscera and muscle had more DHA and EPA than bones and skin. Specially, viscera had more DHA than other tissues in summer and muscle had more DHA than other tissues in spring ($P$<0.05).

### 3.4 Discrimination of tissues by seasons using PCA and CA

PCA calculation permits visualizing the contrast between different samples. The principal components (PCs) reflect the original data effectively if the cumulative proportion of the total variance in PC1 and PC2 reaches 70–85%. If not, PC3 and PC4 need to be added (Zhao et al., 2013).

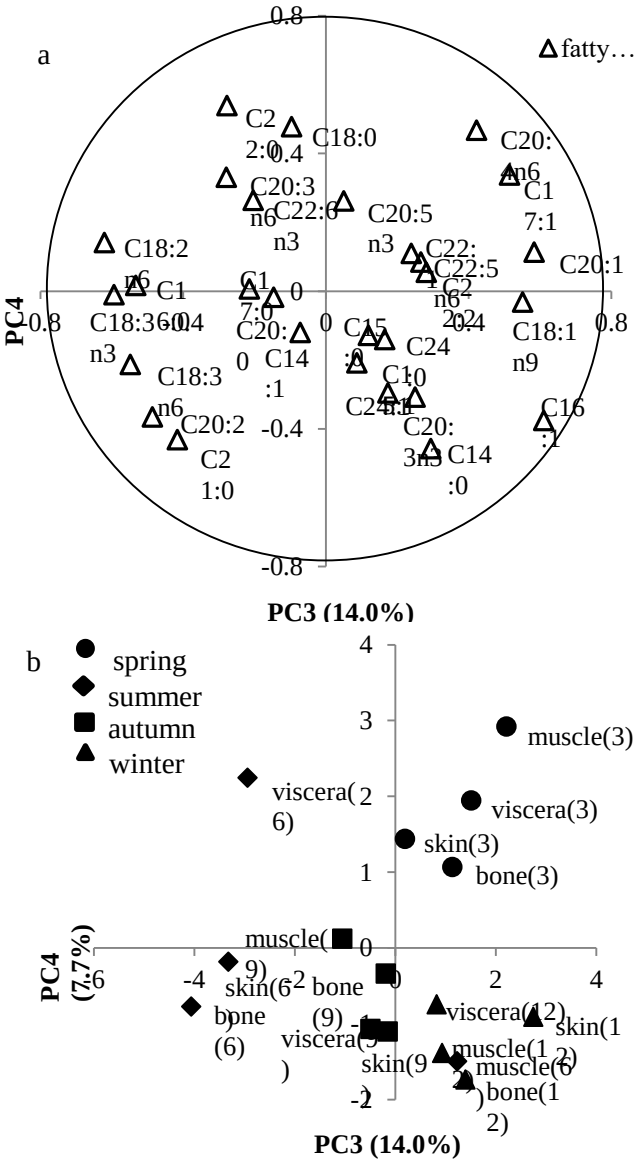
In present study, the first four principle components (PC1, PC2, PC3 and PC4) represented 89.7% of the variability, with a consequent reduction in the dimensions of the data from 28 variables (the number of fatty acids) to 4 components. As can be seen in Fig. 1a, the first two principal components accounted for 68.1% of the total variance. Also, the variables with the highest and the lowest values for loadings in PC1 corresponded with C15:0 and C18:1n9, respectively. Regarding PC2, the more representative variables were C22:6n3 and C18:2n6. Those fatty acids are the best defined when extracting the first two principle components. Results of the score plot for the first two principal components showed a difference between summer and other seasons for the tissues (Fig. 1b). Fatty acids compositions in summer were separated from the other samples at the direction of PC1. However, the sample of muscle in spring also showed positive scores according to PC1.

**Fig. 1** Principal component analysis of fatty acids in common carp for the first two factors: (a) loadings plot and (b) scores plot.



As shown in Fig.2, the major fatty acids of tissues over the four seasons with high loadings in PC3 and PC4 were C16:1 and C20:4n6, which led to higher scores for tissues in spring compared with other seasons except for the viscera in summer. Samples in spring were separated from others due to their location in first quadrant. As may be seen, there was no clear distribution of scores based on the tissues.

**Fig. 2** Principal component analysis of fatty acids in common carp samples for the third and fourth factors: (a) loadings plot and (b) scores plot.




CA was used to determine whether the analyzed samples belong to different groups according to the similarities in the characteristic values of the sample objects. The displayed cluster plot was used for a direct visual model of the relationship and diversity of the samples. The statistical study of the differences between clusters of different tissues for different seasons was carried out by independently analyzing each of their fatty acid compositions (Zhao et al., 2013).

As shown in Fig. 3, CA divided all tissues of common carp during the four seasons into five groups based on their average fatty acids profiles. Muscle in summer, viscera in summer, and muscle in spring were classified into a single group (group 1, group 2 and group 4, respectively). Bones and skin in summer belonged to group 3, and the remaining samples were in group 5. In addition, group 5 could be divided further into three groups: tissues (viscera, muscle, bones and skin) in winter; tissues in spring except for muscle, and tissues in autumn. Fatty acids compositions of tissues in summer were not in the same group as samples for other seasons, implying their unique characteristic, which was consistent with the principle components analysis in Fig. 1. Likewise, the outcome of the single grouping of viscera in summer and muscle in spring appeared to be consistent with the principle components analysis in Fig. 1 and Fig. 2, respectively.

**Fig. 3** Cluster analysis of fatty acids composition of tissues (viscera, muscle, bones, and skin) in common carp by season. Clustering was based on the squared Euclidean distance and the between-groups linkage method.

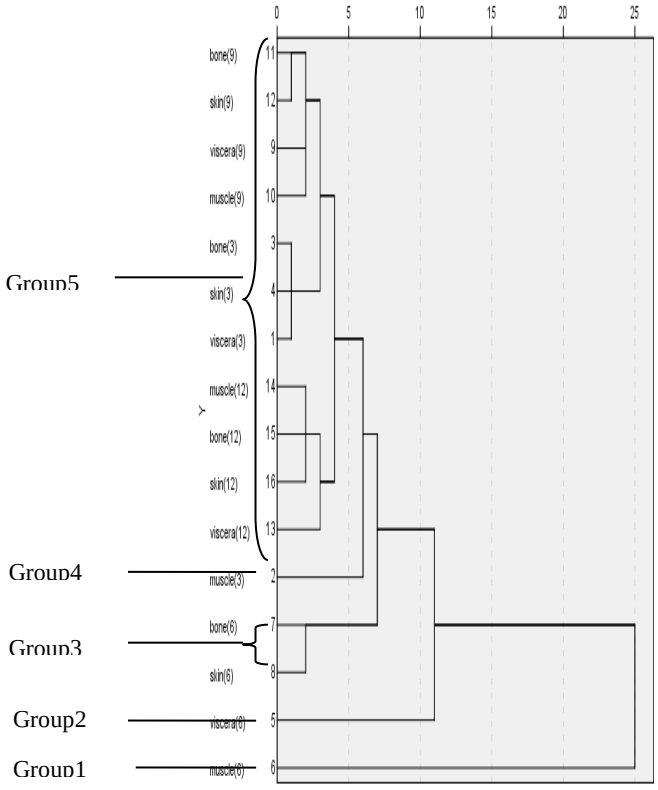


Table 1 Variations of the composition of the main fatty acids (% of total fatty acids) in the total lipids of tissues (viscera, muscle, bones, and skin) from farmed common carp during the four seasons

| Fatty acids | | Spring (March) | Summer (June) | Autumn (September) | Winter (December) |
|---|---|---|---|---|---|
| **c15:0** | Viscera | 0.05±0.01$^{Aa}$ | 0.14±0.03A$^{Ba}$ | 0.10±0.09$^{Aa}$ | 0.05±0$^{Ba}$ |
| | Muscle | 0.27±0.33$^{Aa}$ | 0.66±0.38$^{Aa}$ | 0.12±0.03$^{Aa}$ | 0.16±0.06$^{Aa}$ |
| | Bone | 0.05±0.01$^{Ab}$ | 0.16±0.05$^{ABa}$ | 0.07±0.01$^{Ab}$ | 0.06±0.01$^{ABb}$ |
| | Skin | 0.06±0.02$^{Aa}$ | 0.11±0.03$^{Ba}$ | 0.06±0$^{Aa}$ | 0.11±0.05$^{ABa}$ |
| **c16:0** | Viscera | 16±1$^{Aa}$ | 20±3$^{Aa}$ | 18±1$^{Aa}$ | 18±1$^{Aa}$ |
| | Muscle | 16±1$^{Aa}$ | 15±2$^{Aa}$ | 18±1$^{Aa}$ | 18±0$^{Aa}$ |
| | Bone | 17±1$^{Aa}$ | 18±1$^{Aa}$ | 17±1$^{Aa}$ | 18±2$^{Aa}$ |
| | Skin | 17±1$^{Aa}$ | 17±2$^{Aa}$ | 17±1$^{Aa}$ | 17±0$^{Aa}$ |
| **c18:0** | Viscera | 4.4±0.4$^{Aa}$ | 5.9±0.7$^{Aa}$ | 4.7±1.1$^{Aa}$ | 4.4±0.3$^{Aa}$ |
| | Muscle | 4.8±0.2$^{Aa}$ | 5.5±0.8$^{ABa}$ | 4.8±0.6$^{Aa}$ | 4.1±0.1$^{Aa}$ |
| | Bone | 4.2±0.4$^{Aa}$ | 4.0±0.3$^{Ca}$ | 4.2±0.2$^{Aa}$ | 3.7±0.4$^{Aa}$ |
| | Skin | 4.7±0.4$^{Aa}$ | 4.1±0$^{BCb}$ | 4.0±0$^{Ab}$ | 4.1±0$^{Ab}$ |
| **SFAs** | Viscera | **23±0**$^{Aa}$ | **30±3**$^{Aa}$ | **25±4**$^{Aa}$ | **25±1**$^{Aa}$ |
| | Muscle | **24±0**$^{Aa}$ | **30±6**$^{Aa}$ | **26±0**$^{Aa}$ | **25±0**$^{Aa}$ |
| | Bone | **24±1**$^{Aa}$ | **26±1**$^{Aa}$ | **24±1**$^{Aa}$ | **25±3**$^{Aa}$ |
| | Skin | **25±2**$^{Aa}$ | **25±2**$^{Aa}$ | **23±1**$^{Aa}$ | **24±0**$^{Aa}$ |
| **c16:1** | Viscera | 3.0±0.7$^{Aa}$ | 1.6±0.1$^{Aa}$ | 2.1±0.5$^{Aa}$ | 3. 6±1.5$^{Aa}$ |
| | Muscle | 2.1±0.3$^{Aab}$ | 1.8±0.1$^{Ab}$ | 2.3±0.8$^{Aab}$ | 3.8±1.1$^{Aa}$ |
| | Bone | 3.0±1.4$^{Aa}$ | 2.1±0.2$^{Aa}$ | 2.3±0.6$^{Aa}$ | 4.1±1.4$^{Aa}$ |
| | Skin | 2.2±0.1$^{Ab}$ | 2.0±0.2$^{Ab}$ | 2.4±0.6$^{Ab}$ | 4.4±0$^{Aa}$ |
| **c18:1n9** | Viscera | 34±3$^{Aa}$ | 21±1$^{Ba}$ | 30±11$^{Aa}$ | 33±6$^{Aa}$ |
| | Muscle | 34±5$^{Aa}$ | 18±0$^{Cb}$ | 31±4$^{Aa}$ | 33±3$^{Aa}$ |
| | Bone | 36±1$^{Aa}$ | 26±0$^{Ab}$ | 35±1$^{Aa}$ | 36±1$^{Aa}$ |
| | Skin | 35±2$^{Aa}$ | 26±0$^{Ab}$ | 37±2$^{Aa}$ | 39±2$^{Aa}$ |
| **MUFAs** | Viscera | **41±4**$^{Aa}$ | **28±1**$^{BCa}$ | **36±10**$^{Aa}$ | **40±8**$^{Aa}$ |
| | Muscle | **40±3**$^{Aa}$ | **26±1**$^{Cb}$ | **37±5**$^{Aa}$ | **41±5**$^{Aa}$ |
| | Bone | **42±3**$^{Aa}$ | **29±1**$^{ABb}$ | **40±2**$^{Aa}$ | **43±3**$^{Aa}$ |
| | Skin | **40±2**$^{Ab}$ | **31±2**$^{Ac}$ | **42±2**$^{Ab}$ | **47±2**$^{Aa}$ |
| **c18:2n6** | Viscera | 28±2$^{Aa}$ | 23±4$^{Ca}$ | 27±2$^{Aa}$ | 21±2$^{Aa}$ |
| | Muscle | 26±3$^{Aa}$ | 25±3$^{BCa}$ | 26±1$^{Aa}$ | 23±5$^{Aa}$ |
| | Bone | 27±2$^{Aab}$ | 33±1$^{Aa}$ | 29±2$^{Aab}$ | 23±6$^{Ab}$ |
| | Skin | 29±0$^{Aa}$ | 32±2$^{ABa}$ | 28±2$^{Aa}$ | 19±0$^{Ab}$ |
| **c18:3n3** | Viscera | 2.1±0.1$^{Aa}$ | 2.3±0.5$^{Ba}$ | 2.4±0.3$^{Aa}$ | 1.6±0.2$^{Aa}$ |
| | Muscle | 2.2±0.4$^{Ab}$ | 3.3±0.1$^{Aa}$ | 1.9±0.1$^{Ab}$ | 1.7±0.01$^{Ab}$ |
| | Bone | 2.4±0.4$^{Aab}$ | 3.2±0.2$^{ABa}$ | 2.3±0.3$^{Aab}$ | 1.9±0.4$^{Ab}$ |
| | Skin | 2.3±0.4$^{Ab}$ | 3.4±0.3$^{Aa}$ | 2.2±0.3$^{Ab}$ | 1.8±0.1$^{Ab}$ |
| **c20:4n6** | Viscera | 1.24±0.40$^{ABa}$ | 0.83± 0.21$^{Aa}$ | 0.62±0.50$^{Aa}$ | 0.60±0.15$^{Aa}$ |
| | Muscle | 1.63±0.21$^{Aa}$ | 1.61±1.26$^{Aa}$ | 0.58±0.33$^{Aa}$ | 0.73±0.26$^{Aa}$ |
| | Bone | 0.82±0.13$^{Ba}$ | 0.51±0.10$^{Aab}$ | 0.38±0$^{Ab}$ | 0.56±0.20$^{Aab}$ |
| | Skin | 0.64±0.05$^{Ba}$ | 0.54±0.07$^{Aa}$ | 0.32±0.04$^{Ab}$ | 0.63±0.08$^{Aa}$ |
| **c20:5n3 EPA** | Viscera | 0.29±0.06$^{Aa}$ | 1.15±0.6$^{Aa}$ | 0.16±0.18$^{Aa}$ | 0.78±0.7$^{Aa}$ |
| | Muscle | 0.57±0.25$^{Aa}$ | 1.09±0.49$^{Aa}$ | 0.28±0.29$^{Aa}$ | 0.49±0.38$^{Aa}$ |
| | Bone | 0.30±0.01$^{Aa}$ | 0.26±0.02$^{Ab}$ | 0.07±0$^{Ab}$ | 0.22±0.03$^{Ab}$ |
| | Skin | 0.25±0.01$^{Aa}$ | 0.26±0$^{Aa}$ | 0.07±0.03$^{Aa}$ | 0.07±0.03$^{Aa}$ |
| **c22:6n3 DHA** | Viscera | 1.2±0.6$^{Ba}$ | 4.9±1.6$^{Aa}$ | 2.2±2.2$^{Aa}$ | 3.1±1.7$^{Aa}$ |
| | Muscle | 2.2±0.3$^{Aa}$ | 1.5±1.0$^{Ba}$ | 1.9±0.7$^{Aa}$ | 2.5±0.8$^{Aa}$ |

| | | | | | |
|---|---|---|---|---|---|
| | Bone | $0.6\pm0.1^{Bb}$ | $1\pm0.2^{Bab}$ | $0.9\pm0^{Aab}$ | $1.2\pm0.3^{Aa}$ |
| | Skin | $0.5\pm0.2^{Bb}$ | $1.3\pm0.2^{Ba}$ | $1.0\pm0.2^{Aa}$ | $1.3\pm0.1^{Aa}$ |
| **n-3** | Viscera | $3.8\pm0.8^{Ba}$ | $7.8\pm1.0^{Aa}$ | $5.1\pm2.8^{Aa}$ | $5.3\pm1.7^{Aa}$ |
| | Muscle | $5.2\pm0.3^{Aab}$ | $7.5\pm1.5^{ABa}$ | $4.3\pm1.1^{Ab}$ | $4.7\pm0.7^{Aab}$ |
| | Bone | $3.5\pm0.3^{Bb}$ | $4.4\pm0.1^{Ca}$ | $3.4\pm0.3^{Ab}$ | $3.5\pm0^{Ab}$ |
| | Skin | $3.2\pm0.2^{Bb}$ | $5.0\pm0.1^{BCa}$ | $3.4\pm0.5^{Ab}$ | $4.0\pm0.9^{Aab}$ |
| **n-6** | Viscera | $31\pm3^{Aa}$ | $28\pm4^{Ca}$ | $30\pm0^{Aa}$ | $24\pm4^{Aa}$ |
| | Muscle | $30\pm2^{Aa}$ | $31\pm1^{BCa}$ | $28\pm2^{Aa}$ | $25\pm5^{Aa}$ |
| | Bone | $29\pm2^{Aab}$ | $37\pm1^{Aa}$ | $30\pm3^{Aab}$ | $25\pm6^{Ab}$ |
| | Skin | $31\pm1^{Ab}$ | $35\pm0^{ABa}$ | $29\pm2^{Ab}$ | $21\pm0^{Ac}$ |
| **PUFAs** | Viscera | $\mathbf{35\pm4}^{Aa}$ | $\mathbf{37\pm3}^{Ba}$ | $\mathbf{36\pm3}^{Aa}$ | $\mathbf{31\pm6}^{Aa}$ |
| | Muscle | $\mathbf{36\pm5}^{Aab}$ | $\mathbf{40\pm1}^{ABa}$ | $\mathbf{33\pm3}^{Aab}$ | $\mathbf{31\pm5}^{Ab}$ |
| | Bone | $\mathbf{33\pm3}^{Aab}$ | $\mathbf{42\pm1}^{Aa}$ | $\mathbf{34\pm3}^{Aab}$ | $\mathbf{29\pm6}^{Ab}$ |
| | Skin | $\mathbf{34\pm1}^{Ab}$ | $\mathbf{41\pm 0}^{ABa}$ | $\mathbf{33\pm3}^{Ab}$ | $\mathbf{26\pm1}^{Ac}$ |

*Values are expressed as Mean±SD of triplicate measurements. The same lowercase letters (a, b, c) in same row indicate insignificance difference ($P$>0.05). The same capital letters (A, B, C) in same column for the same fatty acid indicate insignificance difference ($P$>0.05).

## 4. Conclusion

Common carp in summer could be distinguished from other seasons based on fatty acids composition. The contents of fatty acids in common carp were normally: MUFA> PUFA> SFA except during the summer, when the order became: PUFA> SFA> MUFA for viscera and muscle and PUFA> MUFA> SFA for bones and skin, respectively. Considering the high amount of PUFA, common carp is best consumed in the summer. The viscera of common carp were a good source of PUFA, although these are normally not consumed. However, they might be extracted for use in fish oil capsules. Thus, fish oil from summer fish could be distinguished but the oil from the various tissues could not..

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## Conflict of Interest statement

The authors declare that there are no conflicts of interest.

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