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Influence of rearing conditions and feed on the biochemical composition of fillets of the European catfish (*Silurus glanis*)

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Abstract

The biochemical composition of European catfish (*Silurus glanis*) fillets reared under two conditions used in France was studied. The biochemical composition of the two feeds used was also analysed, in order to establish a relationship between European catfish fillet composition and feed. Dry matter, protein, lipid and carbohydrate contents were determined. The fatty acid profile was determined by GC-FID and GC/MS. This work has established that European catfish has a biochemical composition characteristic of semi-fat fish, that the protein content is affected by water temperature, and that the lipid content depends largely on feed. This work has also highlighted that the proportions of fatty acids can be affected by rearing conditions, by feed, or by both rearing conditions and feed with a significant interaction between these two factors.
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Keywords: European catfish; Freshwater fish; Biochemical composition; Rearing conditions; Feed

1. Introduction

For several years, fish consumption has been rising steadily. In 2000, saltwater fish represented three quarters of the world market (GLOBEFISH/FAO, 2001). Today, since saltwater fish can no longer meet the demand, there is a new interest in freshwater fish and their production rose by 140% between 1990 and 2000 (GLOBEFISH/FAO, 2001). In this context, the European catfish (*Siluris glanis*) is of real economic interest. Indeed, it is a freshwater fish similar to the United States catfish with a white flesh, without herringbones and which possesses a high food value (Martin, Poli, & Petillot, 1995).

In France, European catfish can be reared under two different conditions. The first enables European catfishes of commercial size to be obtained in one year and consists of rearing in indoor concrete ponds with renewed geothermal water. Under the second condition, rearing in outdoor ponds with no renewal of water, two years are necessary to obtain European catfish of commercial size. Moreover, to rear these European catfish, two different feeds are mainly used by French breeders, "FEED A" (SARB, Paris, France) and "FEED B" (BioMar SA, Nersac, France).

The most severe drawback with European catfish is that it is often characterised by very heterogeneous organoleptic qualities. Indeed, the colour, texture and odour of European catfish fillets may vary greatly, not only between the different rearing techniques, but also within the same technique (Martin & Poli, 1995). Moreover, these three organoleptic qualities play a very important role in the determination of fish quality by consumers. Colour often represents the only parameter used to decide which product to purchase, texture frequently represents an important criterion of rejection, and odour enables the evaluation of acceptance and of preference of a fish product (Boggio, Hardy, Babbitt, & Brannon, 1985; Martin & Poli, 1995; Pons & Fiszman, 1996).

Many studies have demonstrated that colour, texture and odour can be influenced by the biochemical composi-

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tion of the fillets. For example, the lipid content of fish fillet can affect the distribution of lipid-soluble pigments throughout the muscles and thereby their colour (Choubert & Blanc, 1989). It has been shown several times that the lipid content can also affect the firmness and juiciness of fish fillets, two important texture parameters, with higher contents corresponding to firmer and juicier fillets (Dunajski, 1979; Hernandez, Martinez, & Garcia Garcia, 2001; Howgate, 1977). Lastly, lipids, proteins and carbohydrates can form volatile compounds through enzymatic and chemical action (Mesias Iglesias, Henao Dabila, Maynar Marino, de Miguel Gordillo, & Marin Exposito, 1991), which means that fish fillet odour is dependent on these non-volatile odour precursors. Moreover, many studies have indicated that the biochemical composition of fish fillet is influenced by rearing conditions, such as water temperature (Fauconneau et al., 1993; Fauconneau & Laroche, 1996; Geri, Poli, Gualtieri, Lupi, & Parisi, 1995), rearing time (Fauconneau, Alami-Durante, Laroche, Marcel, & Vallot, 1995; Geri et al., 1995; Martin et al., 1995) or feed (Geri et al., 1995; Martin et al., 1995; Serot, Regost, Prost, Robin, & Arzel, 2001, 2002).

Consequently, the comparison of the biochemical composition of fillets from European catfish reared under the two rearing conditions prevalent in France, with the two main feeds used by French breeders, represents a very important first step in explaining rearing method effects on the colour, texture and odour of fish fillets. The aims of this study are to carry out this comparison and to explain the differences between the European catfish fillet sets. As a preliminary, the composition of both feeds used was determined, to enable a better explanation of the feed effect.

2. Materials and methods

2.1. Reagents

Butylated hydroxytoluene, boron trifluoride/methanol (14%) and glucose standard solution at $1\ g\ l^{-1}$ were obtained from Sigma–Aldrich Chemie Gmbh (Munich, Germany). Hexane, toluene, phenol, trichloroacetic acid, sodium hydroxide, anhydrous sodium carbonate, Folin–Ciocalteau reagent and bovine albumin were purchased from Merck (Darmstadt, Germany). Acetone, anhydrous sodium sulfate, sulfuric acid, copper sulfate and sodiumpotassium tartrate were purchased from Cluzeau (Sainte-Foy-la-Grande, France).

2.2. European catfish

European catfish were reared under the two different conditions occurring in France. The ADARC experimental farm (Association pour le Développement de l'Aquaculture en Région Centre, Orléans, France) reared European catfish for two years in outdoor ponds with no renewal of water (water temperature could vary from 10 °C in winter to 25 °C in summer). The TAG company (Technologies Aquacoles Géothermiques, Hamipont, France) reared fish for one year in indoor concrete ponds with renewed geothermal water (water temperature between 27 °C and 31 °C). To rear these European catfish, two different feeds were used, "FEED A", which is used by almost all European catfish breeders in France, and "FEED B", a feed used specifically by the TAG company. Their compositions are reported in Table 1. For simplicity and clarity, fillets supplied by the ADARC experimental farm are called "OUTDOOR", and fillets supplied by the TAG company are called "INDOOR" in the rest of this paper. In each treatment (OUTDOOR "FEED A", INDOOR "FEED A", OUTDOOR "FEED B" and INDOOR "FEED B"). Catfish came from three different ponds but statistical treatments (three-way analyses of variance: pond factor, rearing condition factor and feed factor) showed that there were no significant differences between these ponds.

Fish were caught and manually slaughtered the same day. Then fish were manually eviscerated and filleted, mechanically skinned and finally fillets were manually trimmed. The average weight of fillets was 392 g (s.d. = 140); fillets represent the commercial form of this product. Fillets were transported under ice in polystyrene boxes. They were vacuum-packed and stored at −80 °C until biochemical composition analyses.

2.3. Biochemical composition analyses

2.3.1. Preparation of samples

Feed samples of 100 g were crushed with a Waring Blender (Milian SA, Geneva, Switzerland). Sealed bags containing fish fillets were immersed in water at 25 °C for 20 min to defrost samples just before analyses. Fillets were then crushed with the Waring Blender. Biochemical composition analyses were performed on three samples for each feed and on nine fillets for each catfish set. For dry matter, protein and carbohydrate contents, three measurements per feed and per fillet were performed while for the lipid content, two measurements per feed and per fillet were performed.

2.3.2. Dry matter content

Dry matter measurement was performed on a sample of 1 g (crushed feed or crushed fillet) by placing it in a drying oven at 103 °C for 12 h. The results are expressed in $g\ 100\ g^{-1}$ of feed or of fresh fillet.

Table 1
Biochemical composition of feeds: "FEED A" and "FEED B"

Components (in $g\ 100\ g^{-1}$ of feed)	"FEED A"	"FEED B"
Dry matter	90.8	92.2
Protein	51.2^{a}	46.1^{b}
Carbohydrate	4.1^{a}	5.2^{b}
Lipid	11.7^{a}	16.9^{b}

^{a,b}Values in the same row with different superscripts are significantly different ($p < 0.05$).

2.3.3. Lipid analysis

2.3.3.1. Lipid extraction. Lipids were extracted on a sample of 10 g (crushed feed or crushed fillet) according to the Folch method (Folch, Lees, & Sloane Stanley, 1957), which is based on the use of a chloroform/methanol mixture (2/1, v/v). Their content was measured by a gravimetric method. The results are expressed in g 100 g^{-1} of feed or of fresh fillet.

2.3.3.2. Fatty acid analysis. The fatty acid profiles of fillets and feeds were determined after the methylation of the fatty acids by a mixture of boron trifluoride/methanol (14%) as described by Morrisson and Smith (1964). The methylated fatty acids (FAMES) were identified by comparison of their retention indices, calculated according to Van Den Dool and Kratz (1963), with those of authentic standards of a commercial solution (Sigma Chemical Co., St. Louis, MO). The identification of FAMES was confirmed by using a gas chromatograph (HP 5890 II, Hewlett Packard, Co., Palo Alto, CA) coupled with a mass spectrometer (MS) (HP 5971 II mass-selective detector (MSD), Hewlett Packard Co., Palo Alto, CA). One microlitre of each FAME extract was injected in split mode on an injector set at 250 °C. The split flow was 20 ml min^{-1}. The FAMES were separated on a capillary column (DB-23, 30 m length × 0.25 mm i.d. × 0.25 μm thickness, J & W Scientific, Folsom, CA) with the following oven temperature programming: 150 °C for 3 min, followed by an increase at a rate of 10 °C min^{-1} to 180 °C for 7 min, followed by a further increase at a rate of 5 °C min^{-1} to 215 °C for 15 min. The helium carrier gas flow was 1 ml min^{-1}. The MSD conditions were as follows: electron impact mode, 70 eV; temperature of interface, 250 °C; ion source temperature, 180 °C; mass range, m/z 33–300 amu; scan rate, 1.9 s^{-1}. The FAMES of European catfish fillets were identified by comparing their spectra with those of two libraries, a commercial one (NBS 75 k) and an internal laboratory library (Pennarun, Prost, Haure, & Demaimay, 2003; Serot et al., 2001).

The FAMES were quantified by using the same gas chromatograph with a flame ionization detector (FID). The temperature of the FID was set at 280 °C. The quantity of each fatty acid was expressed as a percentage of the total identified fatty acids (Pennarun et al., 2003).

2.3.4. Protein content

Protein content was measured, by the Lowry method (Lowry, Rosenbrought, Fau, & Randall, 1951) on an 8 mg sample (feed or fillet), previously lyophilised and crushed. Results were expressed in g 100 g^{-1} of feed or of fresh fillet.

2.3.5. Carbohydrate content

The carbohydrate content was measured, by the Dubois method (Dubois, Gilles, Hamilton, Rebers, & Smith, 1956) on a 4 mg sample (feed or fillet), previously lyophilised and crushed. Results were expressed in g 100 g^{-1} of feed or of fresh fillet.

2.4. Statistical treatment

Data acquisition and statistical treatment were performed with Statgraph 5.0 software (Manugistics, Rockville, MD). Estimated concentrations of dry matter, proteins, carbohydrates and lipids and proportions of fatty acids were averaged for each feed and each European catfish fillet set. Two-way analyses of variance (two-way ANOVAs: rearing condition factor and feed factor) were performed on these average values with a confidence level of 95% and they were then compared by least significance difference tests. Interaction between feed and rearing condition factors was also measured.

3. Results and discussion

3.1. Biochemical composition of feed

The biochemical compositions of both feeds used to rear European catfishes are presented in Tables 1 and 2. As is usually the case for fish feed, they included between 45 and 55 g of protein per 100 g of feed. Indeed, this is necessary to cover fish protein needs and, more particularly, fish amino acid needs (Mambrini & Kaushik, 1995). Lipids represented between 10 and 20 g 100 g^{-1} of feed, the levels classically found in fish feed to provide optimal growth (Proteau, 1993). Carbohydrates were present in low amounts, about 5 g 100 g^{-1} of feed, which is also frequently the case in fish feed (Proteau, 1993). "FEED A" included a higher lipid content and lower protein and carbohydrate contents than "FEED B" (Table 1). Nine fatty acids were present in significantly different proportions in the feeds (Table 2). They included saturated fatty acids (SFAs), monounsaturated fatty acids (MUFAs) and polyunsaturated fatty acids (PUFAs). Three fatty acids were characterised by very different proportions in the feeds. Stearic acid (18:0) and eicosapentaenoic acid (20:5n-3) were present in higher proportions in "FEED A" than in "FEED B" and (20:1n-9) was present in a much lower proportion in "FEED A" than in "FEED B".

3.2. Characterization of the biochemical composition of European catfish fillet sets

The biochemical compositions of the different European catfish fillet sets are presented in Tables 3 and 4. These tables also show the biochemical composition of European catfish fillets analysed by Martin and Poli (1995), in order to compare our results with previously published data.

European catfish fillets contained 3.7 g of lipid for 100 g of fresh fillet (Table 3), which indicates that European catfish is a semi-fat fish. Dry matter and protein contents were, respectively, 22.1 and 17.3 g 100 g^{-1} of fresh fillet on average, confirmed this assertion; semi-fat fish are known to have a dry matter content close to 22.8 g 100 g^{-1} of fresh fillet and a protein content close to 19.0 g 100 g^{-1} of fresh fillet (Jacquot, 1961). With 0.1 g

Table 2
Fatty acid profile of feeds: "FEED A" and "FEED B"

Fatty acids (as % of the total fatty acid)	"FEED A"	"FEED B"
14:0	7.5[a]	6.2[b]
16:0	20.8[a]	18.2[b]
17:0	0.0[a]	1.1[b]
18:0	4.9[a]	2.9[b]
20:0	0.0	0.4
∑SFA	33.2[a]	28.8[b]
14:1n-5	0.4	0.5
16:1n-7	8.0[a]	7.1[b]
18:1n-9 *trans*	14.6	14.9
18:1n-9 *cis*	3.7	4.1
20:1n-9	2.8[a]	11.4[b]
∑MUFA	29.5[a]	38.0[b]
18:2n-6	5.9	6.3
20:2n-6	0.0	0.2
20:4n-6	1.1[a]	0.6[b]
∑n-6 PUFA	7.0	7.1
18:3n-3	1.0[a]	1.6[b]
20:3n-3	0.0	0.0
20:5n-3	15.9[a]	11.3[b]
22:6n-3	13.4	13.3
∑n-3 PUFA	30.3[a]	26.1[b]
(n-3)/(n-6)	4.3	3.7
∑PUFA	37.3[a]	33.3[b]

[a,b]Values in the same row with different superscripts are significantly different ($p < 0.05$).

100 g^{-1} of fresh fillet on average, carbohydrates were present in very low concentrations, as is usually the case in the great majority of fish species (Sainclivier, 1983). Sixteen fatty acids were identified and quantified in European catfish fillet sets (Table 4). The fatty acid profile of European catfish fillets was characterized by a relatively high proportion of MUFAs, 40.5% of total lipids. SFAs and PUFAs represented, respectively, 27.0% and 32.2% of total lipids. The major MUFA found in European catfish fillets was oleic acid (18:1n-9), which represented 26.5% of total lipids. As in the majority of fish fillets, palmitic acid (16:0), with 17.5% of total lipids, was the main SFA (Orban et al., 2000). Among PUFAs, n-3 PUFAs represented the largest part, 24.0% of total lipids, and the main n-3 PUFA was found to be docosahexaenoic acid (22:6n-3), 14.1% of total lipids. The proportion of n-6 PUFAs was found to be quite low, 8.2% of total lipids, and they were mainly represented by linoleic acid (18:2n-6), 6.8% of total lipids. High levels of docosahexaenoic acid (22:6n-3) and of linoleic acid (18:2n-6) have usually been found in other fish species (Orban et al., 2000; Serot et al., 2001, Serot, Regost, & Arzel, 2002).

Our results are very close to those reported in the literature for fish fillets (Geri et al., 1995; Moreira, Visentainer, de Souza, & Matsushita, 2001; Orban et al., 2000) and, more particularly, to those reported for *Silurus glanis* by Martin et al. (1995). Dry matter, protein and lipid contents were nearly identical to those measured by this team. Concerning the fatty acid profile, only the proportions of two fatty acids (20:5n-3 and 22:6n-3) distinguish our results from those of Martin et al. (1995). Indeed, the analyses performed by this team indicated that 20:5n-3 and 22:6n-3 represented, respectively 4.3 and 8.5% of total lipids, while our analyses indicated that they represented respectively, 8.5 and 14.1% of total lipids. The most probable hypothesis that could explain this divergence is based on the fact that Martin's team used a feed different from ours. Indeed, feeds can include different fatty acid sources, such as fish oils or vegetable oils, which lead to different feed fatty acid profiles. Moreover, it has been widely demonstrated that the fatty acid profile of fish fillets is very dependent on the fatty acid profile of feed (Orban et al., 2000; Regost et al., 2001). Martin and Poli (1995) specified that with feed including at least 10% of lipids, which was the case with the feed that they used and with ours, the fatty acid profile of European catfish fillets was close to that of the feed used.

3.3. Rearing conditions and feed effects on European catfish fillet biochemical composition

Biochemical components affected only by rearing conditions.

In this study, two main factors could be responsible for the differences observed between OUTDOOR and INDOOR fillets: water temperature and rearing time. In the OUTDOOR rearing method, because it fluctuated according to the outside temperature, the temperature of the rearing water could vary from 10 °C in winter to 25 °C in summer. In the INDOOR treatment, the temperature of the rearing water ranged between 27 °C and 31 °C all year long, thanks to the use of geothermal water. To obtain marketable fillets, European catfishes were reared for two years with the OUTDOOR rearing method and

Table 3
Influence of rearing conditions (rearing method and feed) on the biochemical composition of European catfish fillets

Components (in g 100 g^{-1} of fresh fillet)	OUTDOOR "FEED A"	OUTDOOR "FEED B"	INDOOR "FEED A"	INDOOR "FEED B"	*Silurus glanis*[c]	Feed effect	Rearing method effect	Interaction feed – rearing method
Dry matter	21.7	21.8	21.9	23.1	21.5	ns	ns	ns
Protein	15.9[a]	16.0[a]	18.6[b]	18.8[b]	17.5	ns	s	ns
Carbohydrate	0.10	0.08	0.13	0.09	–	ns	ns	ns
Lipid	2.9[a]	4.9[b]	2.5[a]	4.4[b]	3.3	s	ns	ns

[a,b]Values in the same row with different superscripts are significantly different ($p < 0.05$). s: significant effect ($p < 0.05$); ns: no significant effect ($p > 0.05$).
[c] Values come from Martin and Poli (1995).

Table 4
Influence of rearing conditions (rearing method and feed) on the fatty acid profile of European catfish fillets

Fatty acids (as % of the total fatty acid)	OUTDOOR "FEED A"	OUTDOOR "FEED B"	INDOOR "FEED A"	INDOOR "FEED B"	*Silurus glanis* [d]	Feed effect	Rearing method effect	Interaction feed – rearing method
14:0	4.0[a]	5.2[b]	4.8[c]	4.6[c]	4.3	s	s	s
16:0	18.7[a]	15.9[b]	19.0[a]	16.3[b]	18.9	s	ns	ns
17:0	0.2[a]	1.0[b]	0.2[a]	0.5[c]	0.6	s	ns	ns
18:0	5.5[a]	3.1[b]	4.6[c]	4.1[c]	3.6	s	s	s
20:0	0.1	0.1	0.0	0.1	0.2	ns	ns	ns
∑SFA	28.5[a]	25.3[b]	28.7[a]	25.6[b]	27.6	s	ns	ns
14:1n-5	0.3	0.4	0.3	0.4	0.3	ns	ns	ns
16:1n-7	7.7[a]	10.2[b]	6.6[c]	6.6[c]	9.0	s	s	s
18:1n-9 *trans*	23.1[a]	19.5[b]	23.0[a]	20.6[b]	27.8	s	ns	ns
18:1n-9 *cis*	5.4[a]	5.3[a]	4.5[b]	4.5[b]		ns	s	ns
20:1n-9	4.7[a]	6.8[b]	5.4[a]	6.9[b]	4.2	s	ns	ns
22:1					2.9			
∑MUFA	41.1	42.1	39.7	39.0	44.2	ns	ns	ns
18:2n-6	6.5[a]	6.9[a]	6.0[b]	7.8[c]	6.5	s	s	s
20:2n-6	0.5	0.4	0.5	0.5	0.4	ns	ns	ns
20:4n-6	1.1[a]	0.7[b]	1.0[a]	0.8[b]	0.8	s	ns	ns
22:4n-6					0.2			
22:5n-6					0.9			
∑n-6 PUFA	8.2[a]	8.0[a]	7.4[b]	9.1[c]	8.8	s	s	s
18:3n-3	1.0[a]	1.4[b]	1.1[a]	1.5[b]	1.5	s	ns	ns
18:4n-3					1.0			
20:3n-3	0.1[a]	0.1[a]	0.0[a]	0.3[b]	0.4	s	s	s
20:5n-3	7.6[a]	9.7[b]	7.9[c]	8.9[b]	4.3	s	ns	ns
22:5n-3					0.9			
22:6n-3	13.5[a]	13.5[a]	15.1[b]	14.4[b]	8.5	ns	s	ns
∑n-3 PUFA	22.2	24.6	24.2	25.0	16.6	ns	ns	ns
(n-3)/(n-6)	2.7[a]	3.1[b]	3.3[b]	2.7[a]	1.9	s	s	s
∑PUFA	30.4[a]	32.6[b]	31.6[a]	34.1[c]	25.4	s	s	ns

[a,b,c]Values in the same row with different superscripts are significantly different ($p < 0.05$). s: significant effect ($p < 0.05$); ns: no significant effect ($p > 0.05$).
[d] Values come from Martin and Poli (1995).

only for one year with the INDOOR one. This difference in rearing time to obtain fillets of the same size was mainly due to the water temperature, because the growth rate increased with increasing temperatures (van Ham et al., 2003).

Two-way ANOVAs performed on biochemical component concentrations showed that protein contents were significantly affected only by rearing conditions (Table 3). OUTDOOR fillets were characterised by a lower concentration in protein than INDOOR ones. This result is probably due to the difference in water temperature between the two rearing conditions. Indeed, Azevedo, Young Cho, Leeson, and Bureau (1998) Buentello, Gatlin, and Neill (2000) have already observed in catfish fillets that a higher water temperature produces fillets richer in protein. They have specified that this phenomenon could be due to an increase in feed intake and feed conversion ratio by fish when water temperature increases.

It is interesting to note that many authors have indicated that rearing conditions, and particularly water temperature, can influence the lipid content of fish fillets (Fauconneau et al. 1995, 1996; Martin & Poli, 1995; van Ham et al., 2003). Some have shown that the higher the water temperature, the greater the fat content (Fauconneau et al., 1993, 1995; Martin & Poli, 1995, 1995). They explained this phenomenon by the fact that warmer water stimulates feed intake, and thus the storage of lipids. Others have observed the opposite phenomenon, which they explained by the growth rate stimulation produced by higher temperatures. According to these authors, higher growth rates involve higher metabolic energy requirements, this energy being taken from lipid reserves (van Ham et al., 2003). In our case, no significant rearing condition effect was observed for lipid content (Table 3).

Two-way ANOVAs performed on the fatty acid proportions showed that two fatty acids (18:1n-9 *cis* and 22:6n-3) were significantly affected only by rearing conditions (Table 4). 18:1n-9 *cis* was present at higher concentration in OUTDOOR fillets, while 22:6n-3 was present at higher concentration in INDOOR fillets. Several studies have shown that fatty acid profiles of fish fillets could be affected not only by water temperature (Tocher & Sargent, 1990) but also by rearing time (Kiessling et al., 2001). Robin, Regost, Arzel, and Kaushik (2003) and Tocher et al. (2004) have specified that the effect of these two rearing parameters is mainly due to the fact that they significantly

influence fish metabolic activity. More particularly, Tinsley, Krueger, and Saddler (1973) have shown in salmon fillets that the proportion of 22:6n-3 tends to decrease with rearing time. This result was also observed in our European catfish fillets. OUTDOOR fillets that came from European catfishes reared for two years, contained a lower proportion of 22:6n-3 than INDOOR fillets that came from European catfishes reared for one year. Geri et al. (1995) have shown in carp fillets that the proportion of n-3 PUFAs tends to decrease with colder water. This phenomenon could also explain why OUTDOOR fillets that came from European catfishes reared in temperate water, possessed a lower proportion of 22:6n-3 than INDOOR fillets that came from European catfishes reared in geothermal water.

3.3.1. Biochemical components affected only by feed

Two-way ANOVAs performed on biochemical component concentrations showed that lipid contents were only significantly affected by feed (Table 3). "FEED A" fillets were characterised by lower concentrations in lipid than "FEED B" ones. This phenomenon is very likely due to the higher lipid content of "FEED B" compared to "FEED A" (respectively, 16.9 and 11.7 g 100 g^{-1} of feed). This relation between feed lipid content and fish fillet lipid content has been widely reported (Regost et al., 2001).

Two-way ANOVAs performed on fatty acid proportions showed that seven fatty acids (16:0, 17:0, 18:1n-9 *trans*, 20:1n-9, 18:3n-3, 20:4n-6 and 20:5n-3) were significantly affected by feed only (Table 4). 16:0, 18:1n-9 *trans* and 20:4n-6 were present at higher concentrations in "FEED A" fillets, while 17:0, 20:1n-9, 18:3n-3 and 20:5n-3 were present at higher concentrations in "FEED B" fillets.

The proportions of five of them, 16:0, 17:0, 20:1n-9, 18:3n-3 and 20:4n-6, fluctuated in the same way in fillets and in feed. 16:0 and 20:4n-6, present in significantly higher proportions in "FEED A" than in "FEED B", were also present in significantly higher proportions in "FEED A" fillets than in "FEED B" fillets. The same phenomenon was noticed for 17:0, 20:1n-9 and 18:3n-3, present in significantly lower proportions in "FEED A" than in "FEED B", and also present in significantly lower proportions in "FEED A" fillets than in "FEED B" fillets. Thus, these results confirmed what has been shown by many studies: the fatty acid profile of fish fillets generally reflects that of the feed used (Martin & Poli, 1995; Orban et al., 2000; Regost et al., 2001). This phenomenon could also be observed for the five fatty acids, whose proportions were not influenced by feed (20:0, 14:1n-5, 18:1n-9 *cis*, 20:2n-6 and 22:6n-3). Indeed, their proportions were not significantly different in both feeds used and were very close to those measured in the fillets.

For the last two fatty acids, 18:1n-9 and 20:5n-3, whose proportions were significantly affected by feed only, their respective proportions in both feeds used did not explain this feed effect. Indeed, while no significant difference was highlighted between the 18:1n-9 proportions in both feeds used, its proportions were significantly higher in fillets coming from European catfishes fed with "FEED A" than in those fed with "FEED B". For the fatty acid 20:5n-3, its proportions were higher in "FEED B" fillets than in "FEED A" ones, while its proportions were lower in the feed "FEED B" than in the feed "FEED A". The proportions of these two fatty acids were not only affected by feed. This result could be explained by the fact that, although the fatty acid profile of fish fillet reflects in great part the fatty acid profile of feed, there are obviously some differences between these two fatty acid profiles (Hardy, Scott, & Harrell, 1987; Robin et al., 2003). These differences are due to the fact that from the feed to the fish fillet, fatty acids are affected by many metabolic parameters, such as preferential assimilation (Linares & Henderson, 1991), or elongation and desaturation processes (Henderson & Sargent, 1985).

3.3.2. Biochemical components affected both by rearing conditions and feed

Five fatty acids (14:0, 18:0, 16:1n-7, 18:2n-6 and 20:3n-3) were significantly affected both by rearing conditions and feed (Table 4). Moreover, there was always a significant interaction between rearing conditions and feed factors. This means that the fatty acid proportions were not affected by feed in the same way in both rearing conditions. While no significant feed effect was observed on INDOOR fillets for 14:0, 18:0 and 16:1n-7, OUTDOOR "FEED A" fillets were poorer in 14:0 and 16:1n-7 and richer in 18:0 than OUTDOOR "FEED B" ones. On the contrary, while no significant feed effect was observed on OUTDOOR fillets for 18:2n-6 and 20:3n-3, INDOOR "FEED A" fillets were poorer in 18:2n-6 and 20:3n-3 than INDOOR "FEED B" ones.

A first hypothesis that could explain this interaction is based on the fact that feed assimilation is affected by rearing conditions. Such a phenomenon has already been highlighted by Tocher et al. (2004) in rainbow trout fillets. More particularly, they showed that the feed effect on the fatty acid profile of the fillets depended at least partially on water temperature. Indeed, they demonstrated that water temperature had a significant effect on fatty acid desaturation/elongation and β-oxidation and so could interact with the feed effect. A second hypothesis that could explain the interaction between rearing conditions and feed factors is based on the fact that there were significant weight differences between the European catfish fillet sets. Indeed, OUTDOOR "FEED A" and INDOOR "FEED A" fillets were characterised by very close average weights (respectively 408.8 g and 394.5 g) but the average weight of OUTDOOR "FEED B" fillets was significantly lower (252.6 g) than these two sets, while that of INDOOR "FEED B" fillets was higher (512.2 g). The influence of the fillet weight on the fatty acid profile has already been highlighted by Fauconneau and Laroche (1996) and by Martin et al. (1995) on catfish and European catfish fillets respectively. More particularly, Martin et al. (1995) have shown that the higher the fillet weight, the lower the ratio of unsaturated fatty acids to saturated fatty acids.

4. Conclusions

This work has established that European catfish fillets contain on average 77.9% of water, 17.3% of proteins, 3.7% of lipids and 0.1% of carbohydrates. Among the lipids, MUFAs represent 40.5%, SFAs, 27.0% and PUFAs, 32.2% of total lipids. This work has also established that protein content is affected by water temperature, that lipid content depends largely on feed and that the proportions of fatty acids can be affected by rearing conditions, by feed, or by both rearing conditions and feed, with a significant interaction between these two factors.

Further investigations are necessary to elucidate precisely the influence of rearing conditions and feed on the fatty acid profile of European catfish fillets. These investigations could consist of studying the assimilation of fatty acids coming from feed and their transformation by European catfish, either thanks to fatty acid labelling with ^{14}C (Linares & Henderson, 1991) or measurement of the activity of elongation and desaturation enzymes of fatty acids (Tocher et al., 2004). Indeed, nearly all the fatty acids whose proportions fluctuated significantly according to rearing conditions and feed are known to be part of the metabolic pathways of conversion of fatty acids in fish (Bell, Henderson, & Sargent, 1986; Sprecher, Luthria, Baykousheve, & Mohammed, 1995).

Moreover, since the biochemical composition of European catfish can be affected by rearing conditions and/or feed, it will be interesting to analyse in a further study the effect of these different biochemical compositions on the organoleptic qualities (colour, texture and odour) of European catfish fillets.

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