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Composition and quality attributes of fillets from different catfish species on the German market

Zusammensetzung und Qualitätsmerkmale von Filets verschiedener Welsarten auf dem deutschen Markt

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Summary

The purpose of this study was to examine the chemical, physical, and sensory characteristics of fillets from four different catfish species on the German market to compare the nutritional properties and enjoyment values for the consumer. Furthermore, a systematic comparison of regionally produced versus imported catfish is still missing in this case, in Germany. Products of European catfish *(Silurus glanis),* African catfish *(Clarias gariepinus),* African catfish hybrid (*Heterobranchus longifilis* x *Clarias gariepinus*) distributed under the brand name Claresse® and Pangasius *(Pangasianodon hypophthalmus)* were analysed. Highest water content (85.0 %) was found in Pangasius. Corresponding protein (11.1 %) and lipid content (1.0 %) were significantly lower compared to the remaining catfish species. European catfish had the highest lipid content (8.2 %) and concentrations of ∑EPA + DHA in muscle meat (0.4 g/100 g) followed by African catfish, and Claresse®. African catfish was characterised by high selenium content (576.1 µg/kg wet weight). Physical properties were examined showing highest water binding capacity and cooking losses for fillets of European catfish. Sensory quality varied between the catfish species. Regionally produced African catfish and Claresse® from the Netherlands, both resulting from recirculating aquaculture systems, were preferred by panel members. Catfish fillets from these two species available in Germany can be classified as recommendable for human consumption due to its chemical and sensory properties as well as the beneficial EPA, and DHA contents in conjunction with the selenium concentrations in the muscle meat. Therefore, we are convinced that fillets from these catfish species have excellent nutritional properties.

Keywords: Fish, nutritional value, fatty acids, sensory characteristics, texture

Zusammenfassung

Ziel dieser Studie war es, die chemischen, physikalischen und sensorischen Eigenschaften der Filets von vier verschiedenen Welsarten auf dem deutschen Markt zu untersuchen, um die ernährungsphysiologischen Eigenschaften und die Genusswerte für den Verbraucher zu vergleichen. Darüber hinaus fehlt in diesem Fall noch ein systematischer Vergleich von regional produzierten versus importierten Welsen in Deutschland. Produkte von Europäischem Wels *(Silurus glanis),* Afrikanischem Wels *(Clarias gariepinus),* Afrikanischem Wels-Hybrid mit Markennamen Claresse® (*Heterobranchus longifilis* x *Clarias gariepinus*) und Pangasius *(Pangasianodon hypophthalmus)* wurden analysiert. Für Panagasius wurde der höchste Wassergehalt (85,0 %) und entsprechend geringe Gehalte an Protein (11,1 %) und Fett (1,0 %) gefunden. Der Europäische Wels hatte den höchsten Fettgehalt (8,2 %) und höchste Konzentrationen von ∑EPA + DHA im Muskelfleisch (0.4 g/100 g), gefolgt von Afrikanischem Wels und Claresse®. Der afrikanische Wels war durch einen hohen Selengehalt (576.1 µg/kg Nassgewicht) gekennzeichnet. Das höchste Wasserbindevermögen verbunden mit einem hohen Kochverlust wurde bei Europäischen Welsen festgestellt. Zwischen den Welsspezies wurden unterschiedliche sensorische Eigenschaften festgestellt. Regional erzeugte Afrikanische Welse und Claresse® aus den Niederlanden, die beide aus Kreislaufsystemen stammten, wurden von dem Sensorik-Panel bevorzugt. Welsfilets dieser beiden Spezies sind in Deutschland erhältlich und können aufgrund ihrer chemischen und sensorischen Eigenschaften sowie der günstigen EPA- und DHA-Gehalte in Verbindung mit den Selenkonzentrationen im Muskelfleisch für den menschlichen Verzehr als empfehlenswert eingestuft werden. Daher sind wir überzeugt, dass Filets dieser Welsarten ausgezeichnete ernährungsphysiologische Eigenschaften aufweisen.

Schlüsselwörter: Fisch, Nährwerte, Fettsäuren, sensorische Eigenschaften, Textur

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Introduction

Catfish is one of the most speciose fish orders (Siluriformes), including several species that have a significant proportion of the growth of aquaculture to supply the world's population with fish products (Rehbein, 2011). Especially the Siluridae, Clariidae, Pangasiidae or Ictaluridae are farmed for commercial food supply. Leader in catfish farming are Asia, America, and Africa (Cacot and Hung, 2009). Catfish farming in Europe is developing for view years, but is still lagging behind.

In Germany, catfish products are mainly imported as frozen goods e. g. whole fish or fillets. The largest market share, but with decreasing tendency, has the fast-growing Asian white catfish (*Pangasianodon hypophthalmus* [Tra]), better known as "Pangasius" mainly from Vietnamese aquaculture (Klinkhardt, 2011). About 3.5 % in 2013, 2.9 % in 2014, and only 2.5 % in 2015 of the per-capita consumption of fish and seafood in Germany originates from Pangasius (FIZ, 2016). Pangasius reach marketable sizes of 0.6 to 1.5 kg within a growth period of about six to eight months (Karl et al., 2010). The fish is fed either by farm-made feed or by industrially produced pellets. Most feeds contain high amounts of vegetable ingredients and only a little amount of fish meal and oil. It is mainly processed to skinless, individually quick frozen (IQF) and glazed fillets in modern processing plants (Karl et al., 2010). Another catfish is the African catfish hybrid Claresse® from aquaculture in the Netherlands (Rehbein, 2011). The genetic interbreeding of two air breathing catfish species (*Heterobranchus longifilis* x *Clarias gariepinus*) has resulted in robust, rapidly growing, and tolerant animals. These catfish hybrids are reared in closed warm water recirculation aquaculture systems (RAS), fed by using commercial pellet feed and grow up to marketable sizes of around 1.1 kg for overall seven months until slaughter (Fishion-Aquaculture BV, 2011). In Germany, Claresse® is available as fresh or deep-frozen fillets in wholesale and retail (Anova Seafood BV, 2011).

On the German market, only small amounts (1 475 t in 2015 [Brämick, 2016]) of two regionally farmed catfish species produced in warm water RAS and ponds are offered with increasing tendency, the native European *(Silurus glanis)* and African catfish *(Clarias gariepinus)*. Warm water RAS in combination with biogas plants were developed mainly for rearing African catfish (Schmidt-Puckhaber, 2010) in Mecklenburg-Western Pomerania, using commercial pellet feed. Within approximately five months African catfish grow up to slaughter sizes of around 1.5 kg (Elis personal communication, 2011). European catfish, in Lower Saxony, in closed RAS are fed with pellet feed and growth in nine to ten months up to a size of 2.5 to 3.0 kg (Otto-Lübker personal communication, 2011). Rearing in ponds takes two years to reach commercial sizes (Hallier et al., 2007). Both species are regionally processed to fresh and deep frozen fillets, and sold in regional wholesale, retail or in direct selling (e. g. farm shops).

The consumer's acceptance of fish products depends on a consistent high quality. To assess the "inner" quality of fish and fishery products as described by Wedekind (1995b) and Boiţeanu et al. (2014), chemical, physical, sensory, and microbiological tests are essential. Quality investigations of catfish meat were subject of earlier publications (Jankowska et al., 2004; Usydus et al., 2011), still lacking systematic comparison of regionally produced versus imported catfish on the German market. The purpose of this study was to examine the chemical, physical, and sensory characteristics of frozen products from four different catfish species in Germany to compare the nutritional properties and enjoyment values for the consumers.

Materials and methods

Fish samples

The fillets of four different catfish species were obtained as individually quick frozen (IQF) fillets between 2009 and 2011. Samples of imported Claresse® from Aquaculture in the Netherlands and Pangasius from cultivation in Vietnam were bought as one kg packages from various wholesalers in Hamburg. Eight batches of IQF fillets from Claresse® were procured in 2011. Three batches of fillets from Pangasius were bought in 2009 (Pangasius 1) and further three batches were obtained in 2011 (Pangasius 2). Both sample batches should give an overview on IQF Pangasius fillets, currently available on the German market.

IQF-fillets from European and African catfish were bought in 2011 directly from the producer at their processing facilities, both located in Mecklenburg-Western Pomerania, Germany. 38 fillets of European catfish and 80 fillets of African catfish were individually packed in sterile plastic bags, airtight sealed for storage and transported in chill boxes with cooling packs within three hours to the institute in Hamburg. Table 1 shows detailed data about the four different catfish samples investigated. All samples were stored under identical conditions in a frozen storage chamber at –20 °C for subsequent investigation. They were examined before expiry of the "Best before" date to reduce possible influence of storage time on quality properties. The fillets were thawed under identical conditions overnight in a refrigerator at 6 °C before investigation. To simulate normal kitchen preparation by consumers, the released liquid due to thawing was discarded. For chemical analyses and for the determination of pH value, the samples were homogenized. For physical analyses and sensory investigations, the fillets were prepared according to sample preparation described in analytical methods.

Analytical methods

Water, ash and protein content

The water content was determined gravimetrically after drying an aliquot of the homogenate for 4 h at 105 °C. Percentage nitrogen was measured by using a LECO TruSpecN (LECO Instruments GmbH, Mönchengladbach, G) based on a modified procedure of the Dumas method (Miller et al., 2007). Percentage protein was calculated by multiplying % nitrogen by the factor 6.25 (AOAC, 2005). Ash content was determined according to a modified official method § 64 LFGB in Germany to measure ash in meat (LFGB, 2007).

Lipid content

The lipid content was determined using the method of Smedes (1999) with modification by Karl et al. (2012a). In brief, a quantity of 5 g fish muscle was extracted twice with a mixture of cyclohexane and isopropanol. After addition of deionised water, resulting organic phase was transferred to an evaporation flask. The lipid content was determined gravimetrically after evaporation of the organic solvent and drying of the residue. The lipid extracts were used for subsequent analysis of FA.

Fatty acid composition

Fatty acid methyl esters (FAME) were obtained from the extracted lipids by transesterification with methanolic potassium hydroxide (DGF, 1998). FA composition was determined according to the DGF standard method (DGF, 2000). Analyses were performed on a Hewlett Packard 7890A gas chromatograph (Agilent Technologies, Santa Clara, USA) equipped with split injection port, auto sampler, flame ionization detector (FID) and a 60 m fused silica capillary column (I.D.: 0.32 mm coated with 0.25 µm of DB-23, Agilent J&W). Nonadecanoic acid C19:0 was used as an internal standard. FAs in the range of 14:0 to 22:6 n-3 were estimated and represented as a percentage of all measured FAs. The amount of FAs expressed in g/100g of edible muscle tissue was calculated using a conversion factor of 0.956 (Karl et al., 2014) and the total lipid content of muscle tissue applying the following formula: FA content (g FA/100 g edible fish muscle) = (weight-% FAME x 0.956 x lipid content % [g lipid/100 g food]) / 100.

Total phosphorus

The total phosphorus content was determined photometrically in the nitric acid extract of the ash according to a modified official German method § 64 LFGB to measure phosphorus in meat (LFGB, 2008).

Selenium measurements by HGAAS

Selenium (Se) was measured by high-resolution continuum source atomic absorption spectrometer (HGAAS) according to a procedure described in detail by Karl et al. (2012b). An aliquot of the homogenized sample were digested in a Milestone ultraCLAVE III microwave digestion system (Milestone SRL, Sorisole, I). The content of selenium was analysed by the continuous flow hydride system of the contrAA® 700 HGAAS (Analytik Jena, Jena, G).

Quality assurance of chemical analysis and AAS determination

The matrix standard meat reference material SMRD 2000 (LGC Standards GmbH, Wesel, G) was used as internal analytical quality control. Certified values are given for ash, moisture, lipid, nitrogen and phosphorus. Furthermore, certified cod liver oil (Fagron GmbH & Co. KG, Barsbüttel, G) was used as reference material for quality assurance of FAs with certified values given for FAs in the range of 14:0 to 22:6 n-3. The commercial reference material IAEA-407 of the International Atomic Energy Agency was used as quality control for selenium measurements with atomic absorption spectrometry (AAS). All analysed values of the above listed components and FAs showed excellent agreement with the certified values (data not shown). Samples were analysed following standard procedures in duplicate for all chemical analyses and the laboratory employees were the same.

pH determination

Homogenized samples were diluted 1 : 1 with deionised water, stirred and the pH values were measured by means of a pH-electrode (Oehlenschläger et al., 2002).

Determination of water binding capacity (WBC)

Water binding capacity (WBC) was measured as expressible moisture using the filter paper press method described by Detienne and Wicker (1999), modified by Schubring et al. (2003). Briefly, raw fillets were thawed and 2.0 cm diameter samples were cut out of dorsal muscle region. The samples (n = 13 to 78) were compressed to 75 % deformation and held at that point for 15 s using a texture analyser TA.XT2 (Stable Micro Systems, Godalming, UK). WBC was defined as expressible moisture, calculated according following equation: expressible moisture (%) = 100 x (initial weight – final weight) / initial weight.

Texture measurement (Hardness)

Hardness was measured as compression force (N) which is applied to deform the samples. The data acquisition was done automatically, during the compression procedure of same samples as described above for determination of WBC according to the modified method by Schubring et al. (2003).

Cooking loss

The cooking loss was determined gravimetrically according to an unpublished method of the Max Rubner-Institute in Germany. Thawed fillets of each species were sliced into portions with equal sizes (4.5 x 4.5 x 1.0 cm). The fillet portions (n = 10) were weighted and placed separately in

TABLE 1: *Detailed data to the four different catfish samples investigated.*

Species	*S. glanis* (European catfish)	*C. gariepinus* (African catfish)	*H. longifilis* x *C. gariepinus* (Claresse®)	*P. hypophthalmus* (Pangasius 1)	*P. hypophthalmus* (Pangasius 2)
Sample	IQF-fillets, glazed	IQF-fillets	IQF-fillets, glazed	IQF-fillets, glazed	IQF-fillets, glazed
Origin (from aquaculture)	Germany	Germany	The Netherlands	Vietnam	Vietnam
Purchase date	2011	2011	2011	2009	2011
Supplier	Producer	Producer	Wholesaler	Wholesaler	Wholesaler
Package Size	Individual fillets	Individual fillets	1 kg	1 kg	1 kg
Number of packages or fillets	38	80	8	3	3
Additives labelled	Water, 10 %	none	Water, 20 %	Water, 20 %; salt, citric acid (E 330)	Water, 10%; stabilizer: triphosphate (E 451), polyphosphate (E 452)
Investigations	average composition (water, ash, lipid, protein), phosphorus (P as phosphate P_2O_5), fatty acids (FA), pH value, water binding capacity (WBC), texture (hardness), cooking loss, sensory characteristics	average composition, P, FA, pH value, WBC, texture (hardness), cooking loss, sensory characteristics	average composition, P, FA, pH value, WBC, texture (hardness), cooking loss, sensory characteristics	average composition, P, FA, pH value	WBC, texture (hardness), cooking loss, sensory characteristics

IQF: individually quick frozen

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boilable plastic bags. The sealed bags were heated for 10 min in a water bath (90 °C) to ensure that the portions had reached a core temperature of at least 80 °C. The cooked fillet portions were removed from the bags, placed on a paper towel, cooled down within 30 min to room temperature and weighted again. Cooking loss was calculated after the equation: cooking loss (%) = 100 x (weight uncooked portions – weight cooked portions) / weight uncooked portions.

Sensory assessment

Sensory analyses of the catfish fillets were performed by a panel consisting of ten trained assessors from the Max Rubner-Institute. The assessors had experience with the application of the required test methods in the sensory profiling. To find possible attributes for the individual features, a sensory tasting of neutral, thawed and prepared fillets of all examined species were performed in advance according to the principles of official German methods § 64 LFGB to investigate food (LFGB, 2002a,b). The preferably referred feature properties and main attributes were used as standard. Thawed fillets or fillet portions (n = 4–5, each 150 g) were individually placed in boilable film-type pouches and heated for 10 min in a water bath (90 °C). After heat treatment, the blind-coded samples were immediately served. One fillet was shared by two experts. Tap water and unsalted crackers were used as palate neutralizers. The sessions were carried out in a sensory laboratory with separate booths. 100 point line scales with two anchor points to evaluate the intensity of the sensory attributes were used. Assessment included descriptive terms for the appearance (not shown in Figure 2), odour, taste and texture. At the end of the evaluation, panel members were asked to give a separate own feedback on the overall sensory quality

Statistical evaluation

Composition data, expressible moisture, hardness, cooking losses and sensory attributes were analysed by one-way ANOVA used to determine significant differences between more than two groups combined with post hoc Tukey-HSD test at variance homogeneity and by Dunnett-T3 test for variance inhomogeneity, respectively, using the SPSS 22.0 statistical software package (IBM© 2013). The significance level in all tests was set at 0.05.

Results and discussion

Proximate fillet composition, pH, selenium and phosphorus

The average composition (lipid, ash, protein, water) of the different catfish fillets, the pH value, selenium, and phosphorus content, given as P_2O_5 are summarised in Table 2 (mean values ± standard deviation [SD]). Water, protein, and lipid contents varied considerably and were significantly different ($P < 0.05$). Highest lipid content of 8.2 % was found in European catfish, corresponding to the lowest water content of 75.2 %. Similar values of lipid contents between 5.0 to 9.4 % were reported by Wedekind et al. (2002). He pointed out that increasing lipid contents lead to decreasing water contents in the corresponding muscle tissue (Wedekind, 1991). This was confirmed in our studied European catfish. The composition of Pangasius fillets was characterised by high water content of 85.0 %, low lipid and protein content of 1.0 % and 11.1 %. The data deviated completely from the other catfish species. Such results were already recorded from comparable Pangasius fillets by Karl et al. (2010). In their study, the water content ranged between 82.1 and 83.3 %. The corresponding lipid and protein contents were between 1.4 to 3.2 % and 13.3 to 15.7 %. Pangasius fillets which were purchased in Italy, on the Polish market and from supermarkets in Brazil had similar compositions (Polak-Juszczak, 2007; Usydus et al., 2011; Guimarães et al., 2016). Karl et al. (2010) reported that poly or diphosphates were added in four of six conventionally farmed Pangasii. Those additives are often used to enhance water content and thus weight. Another significant sign of water addition is a very high pH value (Karl et al., 2010), as found in our analysed Pangasius. The fillets showed significantly higher pH values of 8.2 to 8.6 compared with 6.5 to 6.6 of all other catfish fillets. Poly or diphosphates were not labelled for these considered Pangasius samples and the determination of the phosphorus contents gave no evidence for the use of such ingredients. Further investigations to determine the used additive (citric acid) was not performed. African catfish and Claresse® fillets had the highest protein contents of 19.6 % and 18.6 %, respectively. Their average lipid content was 5.2 % and 3.0 %. The composition of our African catfish samples corresponds well to published data (Polak-Juszczak, 2007). For Claresse®, lower lipid and higher water contents were observed as labelled, but these were in the range of natural fluctuations of the package declaration. Selenium and phosphorus are essential macro- and micro elements with importance for diverse biological functions or physiological body processes and health for both fish and humans. For examined catfish fillets, significant differences in the levels were seen in particular for selenium. Very high selenium content of 576.1 µg/kg wet weight (ww) was analysed in the meat of African catfish. The selenium value was about one hundred times higher than selenium values found in same catfish species from breeding in the Netherland (Polak-Juszczak, 2007). A portion (200 g) of examined African catfish could cover the recommended daily intake levels of selenium (e. g. World Health Organization WHO 30 to 40 µg or World Cancer research Fund WCRF 75 to 125 µg per day) (Alpers et al., 2008). In comparison, European catfish and Claresse® had four to five times less selenium in the fillet samples. Selenium values of 83 µg/kg and 132 µg/kg ww were detected. Selenium in Pangasius fillets was not determined. According to Polak-Juszczak (2007) and Öhrvik et al. (2012), the values for selenium differ between 53 µg/kg and 127 µg/kg in edible part of Pangasius. In general, freshwater fish species have lower contents of selenium in muscle tissue compared to marine fish.

Regarding the phosphorus content (calculated as P_2O_5), little higher values were found for African catfish and Claresse®. The phosphorus values of all catfish fillets ranged between 3.5 g/kg and 4.2 g/kg ww P_2O_5. The determined values for each species were comparable to reported data of phosphorus for catfish species (Polak-Juszczak, 2007; Karl et al., 2010). According to literature, fish feed is the main source of both trace minerals (Muscatello and Janz, 2009; Terpstra et al., 2010).

Fatty acid profile

The percentage of FAME in the extracted lipids from the fillets of the four catfish species is presented in Table 3. Fatty acid profiles (% of total FAME) differed considerably between species. Highest amounts of saturated fatty

TABLE 2: *Average composition of different catfish fillets (mean values ± SD).*

Species	*S. glanis* (European catfish)	*C. gariepinus* (African catfish)	*H. longifilis* x *C. gariepinus* (Claresse®)	*P. hypophthalmus* (Pangasius 1)
n (fillets)	20	20	20	5 and 4*
Water (%)	75.2 ± 2.6^{a}	76.3 ± 1.0^{a}	78.9 ± 1.0^{b}	85.0 ± 1.2^{c}
Protein (%)	15.9 ± 0.6^{a}	19.6 ± 0.6^{b}	18.6 ± 0.8^{c}	11.1 ± 0.7^{d}
Lipid (%)	8.2 ± 2.8^{a}	5.2 ± 1.3^{b}	3.0 ± 0.9^{c}	1.0 ± 0.2^{d}
Ash (%)	0.5 ± 0.1^{a}	0.7 ± 0.3^{a}	0.5 ± 0.1^{a}	1.7 ± 0.1^{b}
P_2O_5 (g/kg)	3.8 ± 0.1^{a}	4.2 ± 0.2^{b}	3.9 ± 0.3^{a}	3.5 ± 0.4^{ab}*
Se (µg/kg)	83.3 ± 10.0^{a}	576.1 ± 71.5^{b}	132.0 ± 13.4^{c}	n. d.
pH value	6.5 ± 0.2^{ab}	6.5 ± 0.1^{a}	6.6 ± 0.1^{b}	8.4 ± 0.2^{c}

n. d. = not determined. Mean values with different super scripts in a line are significantly different ($P < 0.05$).

acid fractions (SFA) were found in Pangasius fillets with 42.5 %, corresponding well with published data of Karl et al. (2010) (37.6 %, 38.1 %) and Usydus et al. (2011) (42.2 %). Lowest SFA contents were analysed for European catfish with 18.1 %. Fatty acid profiles of European-, African catfish and Claresse® fillets were dominated by the monounsaturated fatty acid fractions (MUFA) with 54.0 %, 47.0 % and 41.1 %, except for Pangasius fillets (35.6 %). For European and African catfish, similar data were reported by Hallier et al. (2007). The sum of percentage contents of SFA and MUFAs in the lipids of all species varied between 72.1 % and 78.1 % of the total FAME. It was noted that SFAs were dominated by palmitic acid (16:0) and oleic acid (18:1 n-9) was the major MUFA, but the percentage content varied again between species. This was in agreement with findings of Hallier et al. (2007). The total of polyunsaturated fatty acids (PUFA) ranged between 21.7 % and 27.7 % of the overall FAME with a high level of linoleic acid (18:2 n-6).

Comparing the fatty acid spectra of European catfish with those of the other catfishes, the highest percentage content of MUFAs and PUFAs of the total FAME were found for this species. Similar trends were specified by Hallier et al. (2007). In comparison, the lowest percentage content of PUFAs was found in Pangasius. This was in agreement with findings of Polak-Juszczak (2007). The proportion of summed n-3 PUFAs was between 9.0 to 10.9 % of all determined FAME. Most constituent of n-3 PUFAs were DHA and EPA with varied amounts between 5.1 % and 8.3 %. The highest percentage content of DHA was found in Pangasius. In contrast, the amount of EPA was relatively low. The highest proportions of n-3 PUFAs of the total FAME were analysed for African catfish and Claresse®. Possible reasons for this could be similar rearing conditions in warm water RAS feeding with commercial feed. According Jan-

TABLE 3: *Fatty acid (FA) profiles of total lipids (% of total FAME), values are means ± SD.*

Species		*S. glanis*	*C. gariepinus*	*H. longifilis* x *C. gariepinus*	*P. hypophthalmus**
FA common name	FA shorthand	(European catfish)	(African catfish)	(Claresse®)	(Pangasius 1)
Myristic acid	14:0	3.1 ± 0.20^{a}	3.5 ± 0.16^{b}	4.1 ± 0.58^{c}	6.7
Palmitic acid	16:0	11.5 ± 0.55^{a}	17.0 ± 0.69^{b}	21.6 ± 1.99^{c}	28.2
Stearic acid	18:0	3.5 ± 0.22^{a}	8.5 ± 0.79^{b}	11.0± 0.75^{c}	7.6
	∑SFA	**18.1**	**29.0**	**36.7**	**42.5**
Palmitoleic acid	16:1 n-7	5.1 ± 0.33^{a}	4.7 ± 0.15^{b}	7.0 ± 1.04^{c}	1.9
Oleic acid	18:1 n-9c	42.4 ± 1.39^{a}	36.0 ± 0.88^{b}	29.2 ± 4.09^{c}	30.6
Vaccenic acid	18:1 n-7	4.4 ± 0.10^{a}	4.9 ± 0.29^{b}	3.6 ± 0.36^{c}	1.2
Gondoic acid	20:1 n-9	2.1 ± 0.17^{a}	1.4 ± 0.13^{b}	1.3 ± 0.43^{b}	1.9
	∑MUFA	**54.0**	**47.0**	**41.1**	**35.6**
Linoleic acid	18:2 n-6c	18.0 ± 0.54^{a}	13.0 ± 0.66^{b}	10.8 ± 1.58^{c}	8.8
α-Linolenic acid	18:3 n-3	1.7 ± 0.13^{a}	1.0 ± 0.06^{b}	0.5 ± 0.03^{c}	0.7
Stearidonic acid	18:4 n-3	0.9 ± 0.08^{a}	0.8 ± 0.05^{b}	1.1 ± 0.28^{c}	0.3
Eicosadienic acid	20:2 n-6	0.5 ± 0.03^{a}	0.5 ± 0.04^{b}	0.4 ± 0.06^{c}	0.7
Arachidonic acid	20:4 n-6	0.2 ± 0.02^{a}	0.3 ± 0.02^{b}	0.2 ± 0.05^{b}	2.1
Eicosapentaenoic acid (EPA)	20:5 n-3	2.1 ± 0.14^{a}	2.6 ± 0.19^{b}	3.0 ± 0.33^{c}	1.1
Docosapentaenoic acid (DPA)	22:5 n-3	1.3 ± 0.14^{a}	2.1 ± 0.14^{b}	2.1 ± 0.22^{b}	0.8
Docosahexaenoic acid (DHA)	22:6 n-3	3.0 ± 0.32^{a}	3.9 ± 0.28^{b}	4.2 ± 0.06^{b}	7.2
	∑PUFA	**27.7**	**24.2**	**22.3**	**21.7**
	∑EPA + DHA	5.1	6.5	7.2	8.3
	∑n-3	**9.0**	**10.4**	**10.9**	**10.1**
	∑n-6	18.7	13.8	11.4	11.6
Ratio	n-3/n-6	0.5	0.8	1.0	0.9
∑n-3 fatty acids	(g/100 g)	0.7	0.5	0.3	0.1
∑EPA + DHA	(g/100 g)	0.4	0.3	0.2	0.1

*) n = mixed sample of 5 fillets, all other examined species n = 20 fillets. Mean values with different super scripts within a line are significant different ($P < 0.05$).

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kowska et al. (2007) such influences have an apparent impact on the fatty acid composition. The n-3 PUFAs including Eicosapentaenoic acid (EPA) plus Docosahexaenoic acid (DHA) levels were calculated as g FA per 100 g of the edible muscle tissue and varied due to the different lipid content of the species investigated. The amounts of total n-3 PUFAs in the muscle meat were high for European catfish (0.7 g/100 g ww) and low for Pangasius (0.1 g/100 g ww). The amounts of n-3 PUFAs for African catfish and Claresse® ranged in between. The analysed data for both catfish species did not meet the specified values described by the distributors (Anova Seafood BV, 2011; Fischgut Nord e. G., 2011). Claresse® should contain 0.75 g/100 g n-3 FAs and African catfish even 1.0 g/100 g n-3 FAs in muscle tissue. In both cases, about 50 % lower values were identified. With view on the essential fatty acids EPA and DHA, European catfish had the highest proportion (0.4 g/100 g ww), the lowest amounts were recorded for Pangasius (0.1 g/100 g ww). The values of the other two catfish species ranged in between. From the point of the nutritional and health aspects, 250 mg EPA and DHA per day should be consumed to reduce the risk of cardiovascular disease and sudden cardiac death (SCD) (Wolfram et al., 2015). The results showed that a daily intake of one portion (200 g fish fillet) of European-, African catfish or Claresse® could help in the prevention of such diseases. At least 300 g per day of Pangasius fillets should be consumed, in order to comply with recommendations.

TABLE 4: *Cooking losses of different catfish fillets (mean values ± SD; n = 10 fillet portions).*

Species	*S. glanis* (European catfish)	*C. gariepinus* (African catfish)	*H. longifilis* x *C. gariepinus* (Claresse®)	*P. hypophthalmus* (Pangasius 1)
Fillet portions, weight before cooking (g)	35.5 ± 4.3	37.5 ± 3.8	33.1 ± 4.0	25.6 ± 3.6
Fillet portions, weight after cooking (g)	26.2 ± 3.4	28.8 ± 3.4	24.9 ± 3.4	19.1 ± 2.8
Cooking loss (%)	26.3 ± 1.1[a]	23.5 ± 1.7[b]	25.0 ± 2.9[ab]	25.3 ± 2.0[ab]

Mean values with different super scripts in a line are significantly different ($P < 0.05$).

Physical quality attributes

The comparison of the hardness and expressible moisture of the different catfish fillets is given in Figure 1. The expressible moisture (%) characterises the WBC of the muscle tissue. WBC decreased from European catfish to Pangasius (European catfish > African catfish > Claresse® ≥ Pangasius).

European catfish fillets had the best water retention. A study of Wedekind (1995) showed a sight worse WBC for African catfish then for African catfish hybrids. Our results differed and showed a better WBC for African catfish. Pangasius had highest water losses and lowest WBC. Tri and polyphosphates (labelled), which are water binding additives, were used in the processing of the analysed Pangasius fillets. Therefore it can be assumed that the fillet weights were elevated with water. During the analysis the muscle flesh was compressed and the intramuscularly bonded water was obviously pressed out. The hardness after compression was used as measure for the texture of the untreated, thawed fillets. The hardness of Pangasius, Claresse® and African catfish fillets were comparable, only European catfish fillets were significantly softer ($P < 0.05$). This is possibly due to the fact that African catfish and Claresse® were higher in protein than European catfish. For Pangasius, such comparisons are not seen. Rao et al. (2013) analysed Pangasius fillets treated with phosphates and reported that the texture of their samples was relatively firm. Such relations may also apply to the examined Pangasius samples. Further reasons for the differences in texture and WBC could be species specific or the result of different technological procedures in the rearing and processing especially during the freezing process or nonconformity in the storage conditions. Lietzow (2010) pointed out, that slow freezing promotes the damage to the tissue structure of the fish fillets, resulting in tissue water loss, drying out and hardening of texture.

The cooking losses are given in Table 4. Equivalent fish samples were subjected to thermal treatment. African catfish had the lowest cooking loss of 23.5 %, European catfish the highest with 26.3 % and the values of Claresse® and Pangasius fillets ranged in between.

For European catfish, our data were comparable to results of Wedekind, et al. (2002). They found cooking losses of 23.35 % and 26.33 %. It was noted that the cooking losses were due to outgoing liquefied fat. Our European catfish samples had highest lipid values compared to the other catfish species. Therefore, such a context would be possible. Several publications provide information on cooking losses, which are influenced by different fish origin (genetic variation), gender, sexual maturity and feeding modalities (Wedekind, 1991; Wedekind, 1995). According to Strebl-Schneider (2010), cooking losses depend on the property of the muscle protein and give information on the WBC of fish muscle. For Afri-

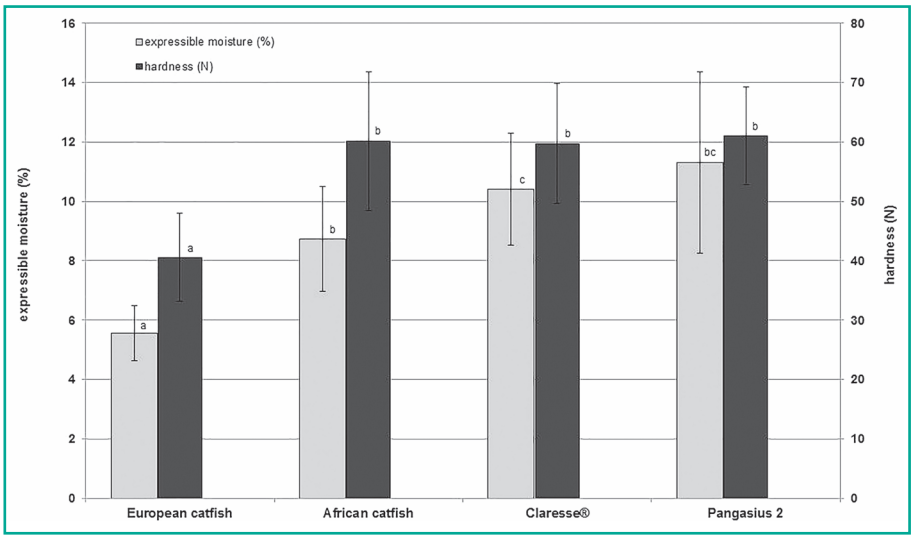

FIGURE 1: *Expressible moisture (%) and hardness (N) of different catfish species, untreated fillets (mean values ± SD; n = 3–20 fillets). Different letters on columns show significant differences between the mean values ($P < 0.05$).*

can catfish, the lowest cooking losses could be related to the fact that the fillets had the comparatively highest protein contents. Thus, the observed differences in texture, WBC and cooking losses have multiple reasons and need further observation.

Sensory evaluation

The main sensory attributes for texture, odour and taste of the different cooked catfish species and their mean intensity (%) are illustrated in Figure 2. The sensory attributes were judged quite differently by the panel members. The texture of Claresse® fillets were assessed as being more crumbly, fibrous and less succulent. This could be in context with the low lipid content. In contrast, Pangasius and European catfish fillets were appeared as particularly succulent and in comparison significantly softer ($P < 0.05$). In the case of European catfish the significantly higher lipid content influenced the consistency of the muscle flesh. The results of the physical examinations, e. g. the soft texture and relatively high cooking losses, supported this assumption. Wedekind et al. (2002) reported that fatty European catfishes had a softer consistency. The consistency properties for African catfish were assessed positive by the sensory panellists. In terms of the quality attributes odour and taste all catfish fillets had a more or less pronounced sweet note. The perceived sweetness in cooked fish mostly results from the free amino acid glycine and partially from the free amino acid proline (Schubring and Oehlenschläger, 2009). In our sensory evaluation, Claresse® and African catfish fillets had a fresh odour and were good in taste. In contrast, European catfish fillets were attributed with high variation in odour and taste. Primarily a musty smell and flavour were found, which was associated with the rearing in natural ponds. This flavour was considered as deviant. Geosmin and 2-Methylisoborneol (MIB) are responsible for the musty impression. Studies have shown that freshwater fish and their flavour profiles were significantly influenced by the rearing conditions. A distinct off-flavour occurred in catfish from pond rearing. Zimba et al. (2012) pointed out, that high economic losses are associated with the occurrence of off-flavour because the consumers reject such products. In comparison, Pangasius fillets had an unique strange smell and taste of ammonia (not shown in Figure 2). Such sensory errors are associated with spoilage of fish, in which the biochemical degradation processes of fish muscle and the microbiological degradation has begun (Schubring and Oehlenschläger, 2009). When asked for the subjective overall quality, the results for the preference by the trained panellists reflected back their sensitivity to variations in consistency and flavour. The fillets of catfish species from closed warm water RAS were preferred by the panel members and were assessed as good products with respect to their sensory quality. In contrast, the deviations in smell and taste from European catfish and Pangasius as described above were distinctly noticeable which devalued the sensory quality according to the subjective impressions of the panel members (results not shown in Figure 2). Overall, the African catfish was favoured by the trained panel.

Conclusions

Distinct differences in fillet quality of the four catfish species were evident. African catfish and Claresse® were characterised by high amounts of protein and essential

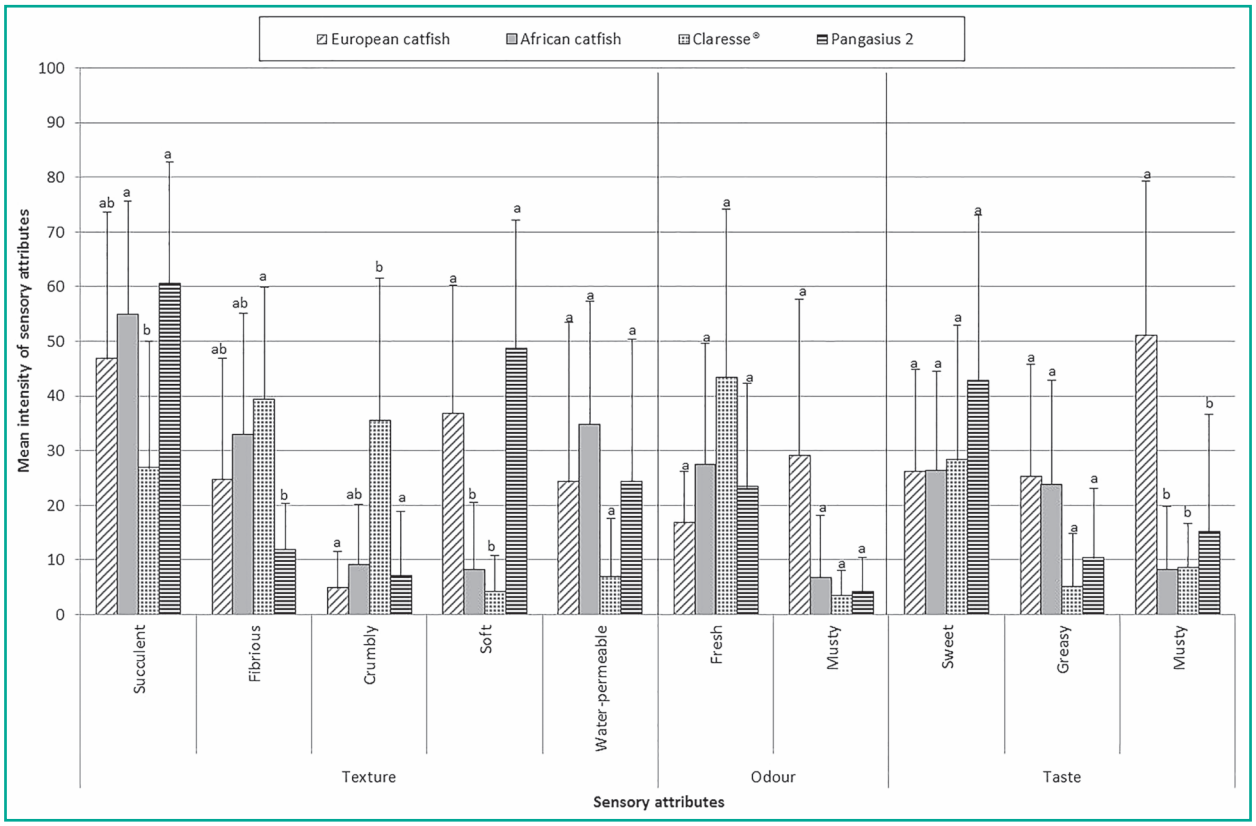

FIGURE 2: *Main sensory profiles of the prepared fillets of European and African catfish, Claresse® and Pangasius 2. Y-axis: Mean intensity of sensory attributes in %. Different letters on columns show significant differences between the mean intensity ($P < 0.05$).*

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polyunsaturated n-3 fatty acids of the total FAME. The African catfish had comparatively higher phosphorus and selenium contents. A portion (200 g) per day of examined African catfish could cover the recommended daily intake levels of selenium. European catfish fillets had highest lipid contents. In terms of the essential, long chain n-3 fatty acids EPA and DHA, this catfish had the highest contents in the edible portion followed by African catfish and Claresse®. A daily intake of 200 g fish fillet of European, African catfish as well as Claresse® could cover the daily needs. In comparison, Pangasius fillets were characterised by high amounts of water and low lipid and protein contents. 300 g of these fillets per day should be consumed to fulfil the nutritional and health recommendations of n-3 FA (EPA and DHA) to prevent inter alia cardiovascular diseases. The assessment of physical characteristics and sensory attributes showed similarities for African catfish and Claresse®, with firm muscle tissue and relative low WBC. In addition, African catfish had low cooking losses. Both species had fresh flavour and were good in taste. The sensory assessment resulted in preference of the panel members for the catfishes from closed warm water RAS, which should promote such aquaculture systems for these species in order to strengthen the regional German catfish market. Especially the fillets of regionally produced African catfish were preferred because of good in taste and odour. We found that the filet quality and sensory properties together with low cooking losses classified especially the African catfish and Claresse®, both produced in a moderate price range, are recommendable for human consumption with beneficial nutritional properties.

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Conflict of interest

The authors herewith declare that they have no conflict of interest.

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