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Retention of health beneficial components during hot- and cold-smoking of African catfish *(Clarias gariepinus)* fillets

Verbleiben von gesundheitlich vorteilhaften Bestandteilen im Filet von Afrikanischem Wels (Clarias gariepinus) während des Kalt- und Heißräucherns

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Summary

Changes in content of selenium and taurine, and the alteration of fatty acid profile have been studied in African catfish fillets subjected to a commercial cold- or hot smoking process. Selenium content and the fatty acid profile did not change significantly during neither of the smoking procedures. Losses of taurine were 32 % and 19 % during cold-smoking and hot-smoking, respectively. Significantly more taurine was lost during cold-smoking ($P < 0.05$), probably due to the prolonged brining and smoking procedure. The results support conclusions from other studies, showing that low molecular water soluble components are more susceptible to losses during processing of seafood.

Keywords: losses, selenium, taurine, fatty acids

Zusammenfassung

Veränderungen der Gehalte an Selen und Taurin und im Fettsäureprofil als Ergebnis eines industriellen Kalt- bzw. Heißräucherprozesses wurden in Filets von Afrikanischem Wels untersucht. Der Selengehalt und das Fettsäureprofil änderten sich bei keinem der zwei Räucherprozesse signifikant. Die Verluste an Taurin betrugen 32 % bzw. 19 % beim Kalt- bzw. Heißräuchern. Beim Kalträuchern ging signifikant mehr Taurin verloren ($P < 0.05$), was wahrscheinlich durch die längere Vorsalzungs- und Räucherzeit bedingt ist. Die Ergebnisse stützen die Ergebnisse anderer Untersuchungen, die ebenfalls zeigten, dass wasserlösliche Bestandteile bei der technologischen Verarbeitung von Fisch eher verloren gehen als an Protein-gebundene und Lipide.

Schlüsselwörter: Verluste, Selen, Taurin, Fettsäuren

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Introduction

In Europe, approximately 15 % of the total quantity of fish for human consumption is sold as a smoked product (Stolyhwo and Sikorski, 2005). Smoked fish are either produced through hot-smoking or cold-smoking, and both procedures generally include a brining procedure to increase storage stability, enhance water holding capacity and to obtain the desired sensory properties.

Processing of seafood may influence contents of health beneficial components (Careche et al., 2008). Components in seafood with proven or suggested health promoting properties include the long chained polyunsaturated fatty acids (n-3 LC-PUFA), selenium and taurine. The n-3 PUFAs are known to reduce several risk factors for cardiovascular disease (CVD), and multiple meta-analyses have reported significant lower mortalities by coronary heart disease (CHD) by increased seafood consumption (Bucher, Hengstler, Schindler & Meier, 2002; He et al., 2004; Wang et al., 2006).

Selenium in seafood is reported to be highly bioavailable (Fox et al., 2004) and has in some studies found to protect against certain forms of cancer (Clark et al., 1996; Bjelakovic, Nikolova, Simonetti & Gluud, 2004).

Taurine, a sulphonic organic acid that is abundantly and ubiquitously distributed in many tissues, has also received some attention because of the suggested beneficial health effects. The beneficial effects are suggested to arise either from synergistic actions with the n-3 PUFAs, or it may inherit beneficial effects on its own (Yamori et al., 2001; Yamori, Liu, Mizushima, Ikeda, Nara & Cardiac Study Group, 2006).

The significance of taurine for human health was underestimated for a long time. Since adults can produce taurine themselves from the amino acids methionine and cysteine and vitamin B6 it was assumed that it was not necessary to supplement taurine intake with foods. Later it was assumed that taurine supplement might be useful for vegetarians because taurine is only present in animal proteins (fish, eggs, meat, and milk) but not in plants. Taurine is beneficial because it protects the heart muscle from potassium losses which can lead heart beat irregularities. The positive effects of taurine in the prevention and treatment of cardiovascular disease, oedema, high blood pressure, and low blood sugar levels have been frequently confirmed. Further, it is presumed that a lack of taurine in the brain can increase the likelihood of epileptic fits.

The aim of this study was to investigate the changes in contents of taurine, selenium and fatty acid profile during a commercial cold smoking and hot smoking process of African catfish.

This study was part of the project "Seafood from source to Consumer Products" a project in the integrated project (IP) SEAFOODplus. The title of this sub-project was: Consumer driven development of innovative tailor-made seafood products with functional components of plant or marine origin to improve the health of the consumer (Careche et al., 2009).

Material and Methods

Raw material and experimental design

African catfish (n = 14) was reared at the Institute of Marine Resources and Ecosystem Studies (IMARES, IJmuiden, The Netherlands) as previously described by Schram, Pedrero, Camara, van der Heul and Luten (2008). The fish were given a feed supplemented with selenium-enriched garlic. The fish were stunned, slaughtered, gutted and the gills were removed. The individuals were individually vacuum-packed and stored frozen for 6 months. One day before being brined and smoked they were thawed. The fish was manually filleted and left hand fillets were either hot-smoked (n = 8) or cold-smoked (n = 6). Right hand fillets were frozen and freeze-dried and acted as controls for contents of components before processing. Smoking was carried out at a commercial smoke house (Die Räucherei, Klein Meckelsen, Germany), and followed standard procedures for the processing of cold- and hot smoked fish. The weight of the fillets were recorded before and after smoking, and all smoked fillets were frozen, then lyophilized and shipped to laboratories participating in this study for subsequent analysis of proximate composition, selenium, free amino acids and fatty acid composition.

Smoking procedures

Fillets subjected to hot smoking were brined for 20 min in a saturated NaCl-solution before they were put in a Bastra smoking oven (Bayha and Strackbein GmbH, Arnsberg, Germany). A multistep procedure which involved repeating steps of drying, smoking and curing was applied. Temperature in smoking chamber increased from 55 °C to 90 °C during the process, and total processing time was 143 min. The core temperature of the fish after smoking was 62 °C.

Fillets subjected to cold smoking were brined for 60 min in saturated NaCl-solution before they were put in a Bastra smoking oven (see above). The smoking procedure involved repetitive processes of drying and smoking at 26 °C for a total of 6 h.

Liquid smoke, Enviro 24 SF, was applied both during hot and cold smoking.

Analysis

Duplicate samples were analyzed for proximate composition. Official AOAC methods for analysis (Cunniff & AOAC International, 1995) were used for the determination of moisture (method 925.04), protein (method 981.10) and ash (method 938.08). The factor used to convert nitrogen to the crude protein value was 6.25 and an in-house reference sample served as quality control. The determination of fat content was performed according to Smedes (1999). The concentration of selenium and free amino acids (FAA) were determined as previously described by Mierke-Klemeyer et al. (2008). Fatty acid methyl esters (FAMEs) were prepared according to the procedure described by Bandarra, Batista, Nunes, Empis and Christie (1997).

Statistical analysis and calculations

True retention (TR) was calculated as described by Murphy, Criner and Gray (1975). Values are presented as mean ± standard deviation (SD). Statistical analyses were performed with SPSS 15.0 (SPSS Inc., Chicago, IL, USA). Significant differences between treatments were determined by one way analysis of variance (ANOVA) with post hoc comparison using the Tukey test. Level of significance was set to $P < 0.05$.

TABLE 1: *Proximate composition (g/100 g) of raw, cold smoked and hot smoked African catfish fillets*

	Raw	Cold smoked	Hot smoked
Water	75.9 ± 1.0[a]	62.6 ± 1.7[b]	66.7 ± 1.9[c]
Protein	17.3 ± 0.6[a]	19.5 ± 1.5[b]	21.5 ± 0.9[c]
Fat	5.6 ± 1.1	7.1 ± 1.4	7.3 ± 1.0
Ash	1.0 ± 0.1[a]	4.8 ± 0.7[b]	3.7 ± 0.9[c]

[a,b,c]: Different letters indicate significant difference between groups

Results and Discussion

Proximate composition (Tab. 1) of raw fillets of African catfish was similar to values reported in other studies, but had a slightly lower water content (Mierke-Klemeyer et al., 2008). Both processes, cold smoking and hot smoking, led to dehydration of the fillets, which in turn increased the relative content of protein and fat. As the smoking procedures included brining with saturated NaCl-solution, the ash values increased considerably for cold- and hot-smoked fillets.

The concentrations of selenium and FAA in raw African catfish are shown in Table 2. Of the 22 amino acids determined only 2 were present in minor concentrations (aspargic acid and asparagine < 0.01 mg/kg dry weight), all other were above 0.1 mg/kg dry weight. Highest concentrations were detected for glutamic acid (0.69 mg/kg dry weight), glycine and alanine (1.22 mg/kg dry weight each), lysine (0.85 mg/kg dry weight) and the dipeptide anserine (beta-Alanyl-N(pi)-methyl-L-histidine) (0.54 mg/kg dry weight).

True retention for selenium and taurine during smoking are presented in Fig 1. The concentration of selenium was high due to feeding the African catfish with the selenium-enriched feed, and comparable to levels found in previous enrichment studies (Schram et al., 2008). The retention of selenium was 110 ± 14 % for cold-smoked fillets and 101 ± 9 % for hot-smoked fillets. Previous studies reporting retention and losses of selenium during processing have found selenium to be well retained during processing. In a recent study investigating retention of selenium during household preparation of African catfish, the retention was 91 %, 97 % and 104 % for baking, boiling and deep-frying, respectively (Mierke-Klemeyer et al., 2008).

The retention of taurine was 68 ± 11 and 81 ± 7 % for cold-smoked and hot-smoked fillets, respectively. Losses during cold smoking were significantly higher than hot smoking ($P > 0.05$). Previous studies have found taurine to be susceptible to be lost during various processing conditions. Two studies on household preparation of fish have reported losses of taurine to 25–40 % (Larsen, Stormo, Dragnes & Elvevoll, 2007; Mierke-Klemeyer et al., 2008). A survey on taurine content in various seafood products found taurine concentrations to be significantly lower in processed food, compared to the corresponding raw materials (Dragnes, Larsen, Ernstsen, Mæhre & Elvevoll, 2009). The susceptibility for taurine to be lost during processing

TABLE 2: *Concentration (mean ± SD) of selenium (µg/g dry weight) and free amino acids (FAA) (mg/g dry weight) in raw African catfish fillets*

	Concentration
Selenium	3.32 ± 0.59
Taurine	5.20 ± 0.94
Aspargic acid	< 0.01
Threonine	0.41 ± 0.15
Serine	0.20 ± 0.06
Asparagine	< 0.01
Glutamine	0.24 ± 0.08
Glutamic acid	0.69 ± 0.30
Sarcosine	0.30 ± 0.48
Proline	0.18 ± 0.06
Glycine	1.22 ± 0.32
Alanine	1.22 ± 0.34
Valine	0.17 ± 0.04
Methionine	0.11 ± 0.06
Cysthathionine	0.09 ± 0.12
Iso-leucine	0.12 ± 0.04
Leucine	0.33 ± 0.12
Tyrosine	0.12 ± 0.04
Phenyl alanine	0.11 ± 0.04
Ornithin	0.20 ± 0.13
Lysine	0.85 ± 0.46
Histidine	0.23 ± 0.09
Anserine	0.54 ± 0.20
Arginine	0.19 ± 0.09

TABLE 3: *Fatty acid profile (% of total fatty acids) of raw, hot smoked and cold smoked African catfish fillets*

	Raw	Cold smoked	Hot smoked
14:0	3.8 ± 0.2	3.8 ± 0.2	3.8 ± 0.1
16:0	20.8 ± 0.9	20.7 ± 0.7	20.5 ± 1.4
18:0	19.2 ± 2.0	18.8 ± 1.9	19.4 ± 1.7
∑SFA	45.6 ± 2.3	45.4 ± 2.1	45.5 ± 2.8
16:1	5.1 ± 0.3	5.2 ± 0.4	5.3 ± 0.3
18:1	2.9 ± 0.2	2.8 ± 0.3	3.0 ± 0.2
20:1	1.7 ± 0.2	1.6 ± 0.1	1.5 ± 0.3
∑MFA	10.4 ± 0.4	10.3 ± 0.4	10.5 ± 0.5
18:2n6	10.1 ± 0.8	10.3 ± 0.7	10.3 ± 1.2
18:3n3	1.7 ± 0.2	1.8 ± 0.1	1.8 ± 0.2
18:4n3	1.0 ± 0.1	1.1 ± 0.1	1.1 ± 0.0
20:4n6	0.6 ± 0.1	0.6 ± 0.1	0.6 ± 0.3
20:4n3	0.6 ± 0.0	0.5 ± 0.2	0.5 ± 0.2
20:5n3	6.8 ± 0.4	6.9 ± 0.2	7.3 ± 0.3
22:5n6	0.1 ± 0.5	0.0 ± 0.0	0.3 ± 0.8
22:5n3	1.8 ± 0.5	1.9 ± 0.1	1.6 ± 0.8
22:6n3	9.2 ± 1.0	9.2 ± 1.1	9.5 ± 0.9
∑PUFA	40.2 ± 2.5	40.3 ± 2.0	41.1 ± 1.9
∑n3	27.9 ± 1.7	27.7 ± 1.3	28.4 ± 1.6
∑n6	11.9 ± 1.0	12.0 ± 0.7	11.9 ± 1.5
∑n3/∑n6	2.3 ± 0.2	2.3 ± 0.1	2.4 ± 0.3
n-3 HUFA	17.8 ± 1.6	18.0 ± 1.3	18.5 ± 1.5
DHA/EPA	1.3 ± 0.1	1.3 ± 0.2	1.3 ± 0.1
N. I.*	3.8 ± 1.0	4.0 ± 0.6	2.9 ± 1.1

*: Not identified

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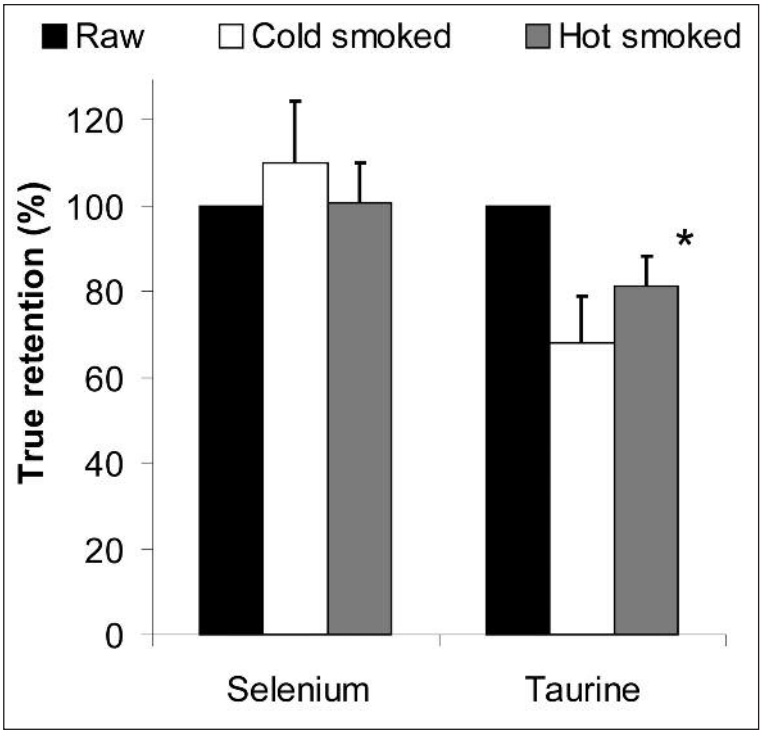

FIGURE 1: *True retention of selenium and taurine during hot- and cold-smoking of African catfish fillets. Asterisk indicate significant difference between cold- and hot-smoking.*

may arise from the fact that it is low molecular, water soluble and occurs exclusively in free form. Thus, it may be easily lost during brining as it diffuses into the brine, and during further processing and storage taurine will generally be lost as drip.

The fatty acid profiles of raw, hot-smoked and cold-smoked fillets are shown in Table 3. No significant changes in fatty acid profile were observed during both smoking procedures. This is in accordance with other studies (Mierke-Klemeyer et al., 2008), showing that short-term processing procedures which do not involve addition or treatment with fat generally do not influence fatty acid profile of seafood. Concerning the two most important fatty acids eicosapentaenoic acid (20:5 n-3) and docosahexaenoic acid (22:6 n-3) it is of utmost importance that these two highly unsaturated long chain fatty acids which are quite susceptible to oxidation are not affected by either the hot smoking or the cold smoking process. The concentrations in the raw material prior to smoking amounted to 6.8 % (20:5 n-3) and 9.2 % (22:6 n-3) of total fatty acids, while in the final smoked products the concentrations were found to be 6.9 % and 9.2 %, respectively, in hot smoked African catfish and 7.3 % and 9.5 %, respectively, in cold smoked African catfish.

Conclusions

Selenium was well retained during cold-smoking and hot-smoking of African catfish, and the fatty acid profile did not change. Taurine, as has been shown for other processing conditions, was susceptible to leakage and leaching out from the fish fillet, thus lowering the content.

The results demonstrate that under the conditions applied during commercial cold and hot smoking processes some of the most beneficial components in fish flesh as selenium, taurine and polyunsaturated long-chain fatty acids are retained completely or to a great extent. This means that hot and cold smoked fishery products offer the consumer almost the same nutritional benefits as fresh fish does. These important findings are especially of great importance for those consumer groups who refrain from eating fresh fish or fishery products with a "fishy" taste, because also when consuming smoked fish with its completely different sensory characteristics in appearance, taste and texture as an alternative, they take up all the beneficial components they need.

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