Proximate Composition, Microbiological Quality and Sensory Attributes of Mahi-mahi (*Coryphaena hippurus*) and Emperor Sea Bream (*Lethrinus* spp.) Fillets Sold on Retail Market

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**Abstract**

The nutritional quality of newly introduced exotic fishes and especially those marketed processed as frozen and glazed fillets often raises questions due to the lack of information concerning the chemical composition and the variability of the raw material. This also includes substances added to increase the water-binding ability.

**Aim:** This paper aims to assess the quality of exotic fish fillets sold on the German market, through the evaluation of physical and chemical parameters, microbiological quality and sensory attributes.

**Keywords:** chemical composition, quality, microbiology, sensory assessment, exotic fish

**INTRODUCTION**

Fish quality is influenced by many factors. For fish as food the biochemical composition and the sensory characteristics are important. The consumer’s acceptance mainly depends on the safety, a consistent and high quality with health-promoting and good organoleptic properties of the products. With regard to the latter, sensory methods based on appearance and colour, odour, taste and texture of the fillets can give a good answer, whether a product will satisfy the consumer demands. To assess the „inner” quality, chemical, physical and microbiological tests are necessary.

Nowadays foods and ingredients come from many different parts of the world. Global food becomes more and more important in many branches of the food industry (e.g. the famous “Fast-Food” chains) and the global trade shows that the success of a food product has often little to do with its freshness or nutritional quality. Also the term „natural” has lost importance. Additives are often used to influence taste and texture of food. Phosphates as ingredients for many finished products have become increasingly important, from cheese to soft drinks. For fish, the addition of phosphate is strictly regulated by the EU (EU, 2013).

Deep frozen products made of mahi-mahi and emperor sea bream are newly introduced on the German market. Mahi-mahi (*Coryphaena hippurus*), also sold as dolphin fish, is a pelagic fish of the Eastern Pacific Ocean and belongs to the same family as the better known pompano dolphinfish (*Coryphaena equiselis*). It is an appreciated food on the local Asian markets. Different *Lethrinidae* species are sold as emperor sea bream, which belong to the perch-like fishes. The main distribution areas are the tropical waters of the Pacific from East Africa to Japan (FishBase, 2014).
The aim of this study was to assess the nutritional quality, microbiological status and sensory attributes of frozen fillets from the families Lethrinidae and Coryphaenidae sold on the German market by analysing the chemical composition, evaluating the bacterial load and the sensory quality.

MATERIALS AND METHODS

Fish samples

According to the labelling, both fish species were caught in the Pacific Ocean, FAO area No. 71. Mahi-mahi (Coryphaena hippurus) was imported frozen as boneless and skinned portions via Vietnam. Emperor sea bream (Lethrinus spp.) was processed in Thailand to the same product type. According to the ingredient list, both were glazed and contained 80% fish and 20% water, respectively.

Several packs of 1000 g with the same lot number each, were purchased in December 2012 (mahi-mahi), December 2012 and January 2013 (emperor) from a wholesale, stored under identical conditions in a frozen storage chamber (−25 °C) at the Max Rubner-Institute in Hamburg (Germany) and were analysed in October-November 2013. Details to the samples are given in Table 1.

Analytical methods

Sample preparation and pH-values measurement

10 frozen glazed samples of each product (from each species) were taken. They were weighed frozen, thawed overnight at +4 °C and weighed once again the next day. For the following analytical investigations, the samples were individually homogenised for 30 seconds at 5000 rpm, using a blender (Grindomix GM 200; Retsch, Haan, Germany).

The pH-values were measured with a pH meter (Calimatic 761; Knick, Berlin, Germany) in 10 g of homogenised muscle, diluted with 10 mL of distilled water in order to simplify the reading.

Water, ash, protein and fat content

The water content was determined gravimetrically after drying an aliquot of the homogenate for 12 h at 105 °C, followed by the estimation of the ash content according to Antonacopoulos (1973). Samples were placed into a muffle furnace at 550 °C for 4 h, cooled in a desiccator and reweighed.

Protein nitrogen was measured with a LECO TruSpecN (LECO Instruments GmbH, Mönchengladbach, Germany), based on the principles of the Dumas combustion method (Miller et al., 2007). The analyser utilised a combination of flow-through carrier gas, highly selective infrared (IR) and thermal conductivity detectors, resulting in a simultaneous determination of C,H,N,S elements in less than four minutes. The device was connected to an Easy-To-Use Windows-Based Operating Software®. Protein percent was calculated multiplying %N by 6.25 (AOAC, 2005).

The lipid content was determined by the method of Smedes (1999), modified by Karl et al. (2012): A quantity of 5 g muscular tissue was mixed in a 100 mL centrifuge tube, using an Ultra Turrax (IKA®- Labortechnik, Staufen, Germany) together with 36 mL of cyclohexane and isopropanol (16:20, w/w). 20 mL water was added to the mixture and the contents were stirred once again, using

Tab.1. Details for deep-frozen products of Coryphaena hippurus (mahi-mahi) and Lethrinus spp. (emperor sea bream)

<table>
<thead>
<tr>
<th>Sample</th>
<th>Description</th>
<th>No of samples analysed</th>
<th>Average weight in frozen state</th>
<th>Average weight in thawed condition</th>
<th>Glaze and water loss on thawing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coryphaena hippurus (mahi-mahi)</td>
<td>Portioned raw fillets without skin, glazed, boneless, frozen</td>
<td>10</td>
<td>213 g</td>
<td>174 g</td>
<td>18.2 ±2.0%</td>
</tr>
<tr>
<td>Lethrinus spp. (emperor sea bream)</td>
<td>Portioned raw fillets without skin, glazed, boneless, frozen</td>
<td>10</td>
<td>198 g</td>
<td>135 g</td>
<td>31.6±6.0%</td>
</tr>
</tbody>
</table>
an Ultra Turrax. The mixture was subjected to centrifugation for 5 minutes at 2000 rpm at room temperature (Megafuge 1.0, Kendro, Osterode, Germany), which led to the formation of a well-defined two-phase system. The organic layer was separated from the aqueous layer and transferred to a pre-weighed flask for evaporation. The aqueous layer was re-extracted, using 20 mL of a mixture of 13% (w/w) isopropanol in cyclohexane, and after centrifugation, the organic layers were combined. The lipid content was determined gravimetrically after evaporating the organic solvent and drying of the total lipid extract for 1 hour at 105°C.

**Total phosphorus content**

Total phosphorus content was determined photometrically after extraction from the ash according to the German official method § 64 LFGB (Lebensmittel- und Futtermittelgesetzbuch) for the measurement of phosphorus in meat (LBFG, 2008). Briefly summarised, ashed homogenised fish samples (5 g) were dissolved in 20% HNO₃ (v/v) by heating in a boiling water bath for 30 min. After addition of 0.25% aqueous ammonium monovanadate (w/v) and 5% ammonium heptamolybdate (w/v) to an aliquot of the nitric acid solution, the mixture formed a yellow coloured complex, whose absorbance was photometrically measured at 430 nm. Quality assurance of the chemical analysis was performed by analysing a reference material (muva-Referenzmaterial Nahrungsergänzungsmittel 752; http://www.muva.de/). Results showed an excellent agreement with the certified value.

**Total volatile basic nitrogen**

Total volatile basic nitrogen (TVB-N) was determined after preparing an extract, using 180 mL of 6% HClO₄ (w/v) and 20 g of homogenised muscular fish tissue. The filtrated perchloric acid extract was used to determine the TVB-N content (EU, 2005).

**Salt content**

NaCl was extracted with water from a homogenised sample (5 g) and estimated in an aliquot part (acidified with some drops of diluted HNO₃) by titration with 0.1 N AgNO₃ solution by means of an autotitrator (Metrohm 716 DMS; Deutsche Metrohm, Filderstadt, Germany) (Karl et al., 2002).

**Microbiological methods:**

For microbiological counts of total viable counts (TVC) and the specific spoiling organisms (SSO, *Shewanella putrefaciens*), samples of 10 g tissue from five individual frozen fillets from mahi-mahi and emperor sea bream were taken and homogenised in sterile NaCl-Peptone solution. After homogenisation decimal dilutions were inoculated on modified plate count agar, containing ferrous citrate according to Lyngby-agar. Plates were incubated for 3 days at 20 °C, prior to counting colonies; numbers of all colonies gave TVC counts, counts of black colonies by iron precipitation gave numbers of SSOs.

**Sensory assessment**

Mahi-mahi and emperor sea bream samples were subjected to sensory evaluation, in order to describe their species characteristics. Skinned fillets were placed in individual boilable film-type pouches and heated for 8 minutes in a water bath (90 °C). After heat treatment the samples were blind coded and served immediately to a panel of trained tasters. Two experts shared one fillet each. Tap water and unsalted crackers were used for cleaning the palate.

Tasting sessions were conducted in a sensory analysis laboratory with separate cabins. In total, 6 assessors trained in the evaluation if fish were asked to describe and comment the prepared samples. Assessments included appearance, odour, taste and texture. Attributes were described in terms, mainly based on sensory lexicon of Drake et al. (2006). A spider diagram showed the most important attributes. The length of a spoke is proportional to the number of namings for an attribute, relative to the maximum of 6 (number of panellists).

**RESULTS AND DISCUSSION**

**Proximate composition and pH**

The few available studies investigating mahi-mahi, refer especially to the histamine content (Chen et al., 2011; Kim et al., 2002), oxidative stability of red muscle (Dekkers et al., 2011), carbon monoxide treatment (Anderson et al., 2005) or the effect of smoking on the chemical and microbiological composition (Kristinsson et al., 2007); those investigating the emperor sea bream refer to the short-term preservation in ice (Jeyasekaran et al., 2004) and also to histamine (Shakila et al., 2003).

The chemical composition, pH-values and the TVB-N values of the fillet flesh of mahi-mahi and emperor sea bream analysed in the present study
are summarized in Table 2. The water content varied between 77.9% and 80.3% in mahi-mahi with an arithmetic mean of 79.3% and between 74.8% and 77.6% in the emperor sea bream with an arithmetic mean of 75.9%, respectively.

Lipid, ash and salt content of mahi-mahi were comparable to the emperor sea bream values. Due to the low lipid content, both species can be classified as lean species. The protein amount of emperor sea bream was significantly higher compared to mahi-mahi and many other common fish species.

The flesh contained 300 mg NaCl/100 g, respectively, which is low compared to many other food products and suitable for a low-salt diet or at least a reduction of the daily sodium consumption. In general, the sodium (Na) content of untreated sea and freshwater fish is between 30-100 mg Na/100 g (=75-250 mg NaCl/100 g). Frozen sea fish fillets can have slightly higher concentrations caused by washing with sea water (Max Rubner-Institute, 2013).

The natural phosphorus (P) content in fish muscle varies little between fish species. Higher levels may occur in products when phosphate-containing additives, capable of increasing the water-binding capacity, were used during processing. The application of di-, tri- and polyphosphates (E 450, E 451 and E 452) is permitted in untreated frozen fish fillets and shrimps. It is limited and must be labelled in every case. Currently the maximum permitted level in Switzerland and EU is 5 g/kg (calculated as P₂O₅).

This does not include the natural phosphorus content which is on average 2.2 g/kg (± 5.7 g P₂O₅/kg) with a range between 1.0 and 4.0 g P/kg. This variability may be related to biological factors and can also be caused by bone fragments (Wheeler and Hebard, 1981). In mahi-mahi samples, investigated in this study, slightly higher values of total phosphates content were found (with the medium value of 5.2±0.7 g/kg P₂O₅).

The pH of fresh fish is between 6.6 and 6.8 (Food Safety Authority of Ireland, 2011). In the present study, the pH values of emperor sea bream (6.4±0.1) were in a normal range (6.3 to 6.6) for fresh fish and comparable to those reported by Jeyasekaran et al. (2004) for this species. In mahi-mahi (pH 7.5±0.5) values were significantly higher which was not correlated with quality deteriorations. Using the TVB-N-values to classify the analysed samples, mahi-mahi and emperor sea bream must be rated as relatively fresh processed fish, respectively.

Because of the high pH of 7.5 in combination with a TVB-N-content of 15.5 mg/100 g, it can be suggested that during mahi-mahi processing, a pH increasing phosphate based additive was used. But this can only be proofed by chromatographic methods, detecting the different phosphate fractions (Kaufmann et al., 2005).

**Chemical spoilage indicators**

In freshly caught fish the TVB-N-content is generally superior to 10 mg/100 g and does not exceed 15 mg/100 g, except for pelagic fish. Unsuitable as a freshness indicator, TVB-N can

<table>
<thead>
<tr>
<th>Species</th>
<th>Coryphaena hippurus (mahi-mahi)</th>
<th>Lethrinus spp. (emperor sea bream)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water (%)</td>
<td>79.3±0.9</td>
<td>75.9±0.9</td>
</tr>
<tr>
<td>Protein (%)</td>
<td>18.0±0.9</td>
<td>23.5±0.9</td>
</tr>
<tr>
<td>Lipid (%)</td>
<td>0.9±0.3</td>
<td>0.7±0.2</td>
</tr>
<tr>
<td>Ash (%)</td>
<td>1.4±0.2</td>
<td>1.2±0.1</td>
</tr>
<tr>
<td>P₂O₅ (g/kg)</td>
<td>5.2±0.7</td>
<td>4.7±0.6</td>
</tr>
<tr>
<td>TVB-N (mg/100 g)</td>
<td>15.5±2.3</td>
<td>20.6±2.2</td>
</tr>
<tr>
<td>NaCl (%)</td>
<td>0.3±0.0</td>
<td>0.3±0.1</td>
</tr>
<tr>
<td>pH</td>
<td>7.5±0.5</td>
<td>6.4±0.1</td>
</tr>
</tbody>
</table>
be used as an indicator of spoilage of some fish species, such as rockfish (*Sebastes* spp.), blackbelly rosefish (*Helicolenus dactylopterus*), and cape redfish (*Sebastichthys capensis*) with a limit of 25 mg TVB-N/100 g flesh, respectively. Species belonging to the *Pleuronectidae* family (with the exception of halibut, *Hippoglossus* spp.) have a limit of 30 mg TVB-N/100 g flesh. For Atlantic salmon (*Salmo salar*) and species belonging to the *Merlucciidae* and *Gadidae* family it is 35 mg TVB-N/100 g flesh, respectively (EU, 2005).

Reports show that TVB-N can serve as a good biochemical indicator of chilled mahi-mahi quality deterioration (Antoine et al., 2002). Although there are no maximum allowable levels prescribed by law for mahi-mahi and emperor sea bream, the threshold of spoilage during fish storage is considered to be 30 mg/100 g TVB-N (Liston, 1982; Farn and Sims, 1986; Connell, 1995). TVB-N in all the investigated samples from this study was lower and between 10.2 and 23.2 mg/100 g. These TVB-N results indicate a sufficient fish freshness of the used raw material. The values were lower than those reported by Antoine et al. (2002) which were between 24 and 74 mg TVB-N/100 g during a one week storage at 7 °C of gutted and headed fresh mahi-mahi in which the threshold TVB-N-value was reached on day 3 of storage (30 mg/100 g TVB-N). Jeyasekaran et al. (2004) reported initial amounts of 11.5 mg TVB-N/100 g for *Lethrinus miniatus*.

### Microbiological results of mahi-mahi and emperor sea bream

The TVC (total viable counts) of the mahi-mahi fillets varied from $3.5 \times 10^3$ to $8.2 \times 10^4$/g, the numbers of SSO (*Shewanella putrefaciens*) detected were low and ranged from "not detectable" to $2.4 \times 10^2$/g fillet, indicating a good or sufficient microbiological status (see Tab. 3). But nevertheless, the pH-values of the homogenates were relatively high and varied from 7.3 to 8.3. Values above ~7.5 normally indicate that to some degree ammoniacal spoilage of the fillets had taken place before freezing. So these microbiological data can conclusively be clarified only in comparison with results of sensory evaluations.

The TVC of the emperor sea bream fillets varied in a range from $1.4 \times 10^4$ and $5.9 \times 10^4$, the SSO (*Shewanella putrefaciens*) were in none of fillets detectable. The pH of the homogenates was between 6.26 and 6.46, which is a normal range for fresh fish fillet. The pH-values and the TVC indicate a good microbiological quality of the fillets.

### Sensory evaluation

Spider charts are really useful to show sensory attributes and their importance. The results for cooked emperor sea bream and mahi-mahi are summarized in Figures 1 and 2, respectively. The descriptions for the fried fish samples are comparable and not shown here.

Sensory results for emperor sea bream samples showed that in general the appearance

<table>
<thead>
<tr>
<th>Fillet</th>
<th>TVC/g</th>
<th>SSO/g</th>
<th>pH of homogenate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mahi-mahi</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>$5.9 \times 10^4$</td>
<td>17</td>
<td>8.00</td>
</tr>
<tr>
<td>2</td>
<td>$3.5 \times 10^3$</td>
<td>nd</td>
<td>8.31</td>
</tr>
<tr>
<td>3</td>
<td>$8.2 \times 10^4$</td>
<td>$2.4 \times 10^2$</td>
<td>7.31</td>
</tr>
<tr>
<td>4</td>
<td>$1.5 \times 10^4$</td>
<td>54</td>
<td>7.92</td>
</tr>
<tr>
<td>5</td>
<td>$3.1 \times 10^4$</td>
<td>$1.4 \times 10^2$</td>
<td>7.62</td>
</tr>
<tr>
<td>Emperor sea bream</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>$2.8 \times 10^4$</td>
<td>nd</td>
<td>6.31</td>
</tr>
<tr>
<td>2</td>
<td>$1.4 \times 10^4$</td>
<td>nd</td>
<td>6.26</td>
</tr>
<tr>
<td>3</td>
<td>$1.6 \times 10^4$</td>
<td>nd</td>
<td>6.29</td>
</tr>
<tr>
<td>4</td>
<td>$4.7 \times 10^4$</td>
<td>nd</td>
<td>6.29</td>
</tr>
<tr>
<td>5</td>
<td>$5.9 \times 10^4$</td>
<td>nd</td>
<td>6.46</td>
</tr>
</tbody>
</table>

(nd: not detectable)
of the flesh and the texture were comparable to chicken breast which is known for other deep frozen fish fillets. The taste was more or less neutral. Off-flavour was mentioned, but only slightly present.

Mahi-mahi samples were tested in the same session under the same conditions. The flesh of mahi-mahi was found to be very special and not comparable to that of known Atlantic species. Tuna or mackerel are the most comparable species. The taste was intensive and pleasant. However, there is the risk that with prolonged frozen storage time also in a lean species like mahi-mahi some unimportant rancidity can occur in the fillet. Despite of the same NaCl content, the flesh of the mahi-mahi samples tasted more salty compared to emperor sea bream samples.

CONCLUSION

Pleasant sensory properties, low microbiological charge and low fat contents of emperor sea bream and mahi-mahi lead to the conclusion that these exotic fish products are a valuable enrichment of fish products on the market. However, mahi-mahi belongs to those species that contain high levels of free histidine in their muscle, which can result in increased histamine contents and allergy-like symptoms of scombroid poisoning. In order to guarantee a safe product, a proper and high quality processing must be ensured.

Acknowledgements

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REFERENCES


Fig. 1. Spider diagram of cooked emperor sea bream (Lethrinus spp). Main attributes based on the number of namings by the panellists. A= appearance; O= odour; T= taste; TX= texture

Fig. 2. Spider diagram of cooked mahi-mahi (Coryphaena hippurus). Main attributes based on the number of namings by the panellists. A= appearance; O= odour; T= taste; TX= texture