Arch Lebensmittelhyg 61,
40–49 (2010)
DOI 10.2376/0003-925X-61-40

ISSN 0003-925X

Korrespondenzadresse:
monika.manthey@mri.bund.de

Max Rubner-Institute, Federal Research Institute of Nutrition and Food, Department of Safety and Quality of Milk and Fish, Hamburg, Germany

Quality of organically and conventionally farmed rainbow trout *(Oncorhynchus mykiss)* and smoked products thereof from the German market

Qualität von frischen und heißgeräucherten Regenbogenforellen (Oncorhynchus mykiss) aus konventioneller und ökologischer deutscher Aquakultur

Monika Manthey-Karl, Horst Karl, Ines Lehmann, Carsten Meyer, Ute Ostermeyer, Reinhard Schubring

Summary

The composition and the quality status of organically and conventionally farmed rainbow trout *(Oncorhynchus mykiss)* from German aquaculture and hot-smoked products thereof were investigated. The chemical composition of raw trout exhibited differences in the fat content of the edible part (1.7–4.7 %). All contaminant levels were far below national limits. Portion size samples had appreciable amounts of n-3-fatty acids EPA and DHA as well as a high vitamin D content. Differences among some fatty acids between both raising forms were nourish-physiologically insignificant. The overall quality and the microbiological status of freshly harvested rainbow trout from all selected farms were excellent. Differences in quality attributes were observed between different farms, but not between organic and conventional rearing and processing conditions.

The effect of cold storage at +4 °C up to 24 days was studied by monitoring the microbiological, chemical, physical and sensory changes occurring in unwrapped hot-smoked rainbow trout and in vacuum-packed products. No reproducible effects of the production style on the shelf life were observed in the analyzed samples. The sensory quality decreased throughout the storage period, but none of the samples was spoiled at the end of storage.

Keywords: aquaculture, quality assessment, storage behaviour, smoked rainbow trout, composition

Zusammenfassung

Es wurden die Zusammensetzung und die Qualität sowohl frischer als auch heißgeräucherter Regenbogenforellen *(Oncorhynchus mykiss)* aus konventioneller und ökologischer deutscher Aquakultur untersucht. Die Rohware aus verschiedenen Zuchtbetrieben unterschied sich vor allem im Fettanteil (1,7–4,7 %). Die Gehalte an organischen Schadstoffen lagen unterhalb der gesetzlichen Grenzwerte. Das Muskelfleisch enthielt relativ hohe Gehalte an den ungesättigten Fettsäuren EPA und DHA und an Vitamin D. Unterschiede in der Fettsäurezusammensetzung zwischen den beiden Aufzuchtsformen waren ernährungsphysiologisch unbedeutend. Die sensorische und mikrobiologische Qualität frischer Forellen war sehr gut. Insgesamt konnten sowohl in den frischen rohen Forellen als auch in den Räucherforellen weder reproduzierbare Auswirkungen der Produktionsform noch qualitative Unterschiede festgestellt werden.

Konventionelle heißgeräucherte ganze Forellen sowie vakuumverpackte ganze Fische und Filets aus ökologischer Herstellung wurden bei +4 °C gelagert. TVB-NWert und physikalische Methoden (Farbmessung, elektronische Nase) waren zur Verfolgung von Qualitätsveränderungen ungeeignet. Die untersuchten Produkte waren nach 20 Tagen mikrobiologisch nicht verdorben, die sensorische Qualität hatte jedoch insgesamt deutlich abgenommen.

Schlüsselwörter: Aquakultur, Räucherforellen, Qualitätsbeurteilung, Haltbarkeit, Zusammensetzung

Introduction

Aquaculture has a long tradition in Germany. Rainbow trout and carp are the main species. Until now they are mainly produced in local farms most of which have an annual production capacity of approximately 100 t, often even less. Direct marketing has become a good source of income, especially for such small enterprises and is particularly widespread in Germany. Nearly half of the trout production is sold directly from farm to consumer, partly as fresh fish, but more and more also as value added processed product.

Altogether, over 20 000 t of portion-sized trout are raised annually throughout the country; around 42 % are sold hot-smoked. Typical products are hot smoked whole gutted fish and skin-on fillets, either vacuum-packed or unpacked.

Most rainbow trout are farmed in earthen tanks, only a small quantity in raceways, ponds or comparable rearing facilities. The differences in stocking density are considerable and can vary between 5 kg/m³ and around 50 kg/m³.

Organic farming of rainbow trout is often propagated as a lucrative alternative to conventional production. In Germany, most organic fish products are certified by the national nongovernmental certification agency Naturland (Naturland, 2002) in accordance with relevant EU legislation. Organic standards for trout require farming conditions as close as possible to nature, taking into account food safety, animal welfare and environmental sustainability. Until now the lower productivity and higher production costs prevent most producers from switching to organic production. Another contributing factor is that the regulations are often not very convincing and show only slight differences to conventional production.

There is an ongoing and contradictory discussion whether organically produced fish actually has advantages for the consumer relating to quality aspects or not. Processed products from ecologically farmed trout can have the same defects as conventionally farmed trout. This is apparent from results of tests carried out by Germany's Stiftung Warentest (monthly magazine of a consumer organisation surveying the market) on smoked and vacuum packed rainbow trout fillets in 2004. Only one of the 20 tested products was rated "very good". The only organic product in the test – at 5.45 2/100 g also the most expensive – was given one of the two "poor" quality ratings. It was spoilt by the sell-by date. Unfortunately, these findings were not an individual case and were confirmed later by other spot tests. On the other hand, a recent study on Pangasius fillets from Vietnam on the German market showed advantages in the quality of organically farmed fish (Karl et al., 2009).

To outline the quality of organically and conventionally reared rainbow trout and smoked products thereof available on the German market, two independent consecutive projects were carried out. The primary objectives of these studies were: i) to estimate the current quality status of farmed rainbow trout and smoked rainbow trout, ii) to provide useful information on the quality of their organic counterparts and iii) to answer the question if there are measurable differences between ecological and conventional products (Bundesprogramm Ökologischer Landbau, 2004, 2007).

Material and Methods

Fish

Raw rainbow trout

Fresh rainbow trout *(Oncorhynchus mykiss)* were obtained from five German fish farms in 2003. Details of the rearing conditions are given in Table 1. Data of the rearing conditions are based on the information provided by the farmers. For organic fish farming the stocking density is limited to 10 kg/m³. The fish were taken from the ponds after starving, killed by a blow on the head, immediately gutted and placed in ice in polystyrene boxes. After arrival at the institute the boxes were stored in a cold chamber at +4 °C. The quality assessment started two days after slaughtering.

TABLE 1: *Rearing conditions of raw rainbow trout*

	Rearing conditions		Sample code
Farm 1	Conventional semi-intensive	12–15 kg/m³	CoTr 1
Farm 2	Conventional extensive	2–5 kg/m³	CoTr 2
Farm 3	Conventional intensive	50–60 kg/m³	CoTr 3
Farm 4	Organic	ca. 1.3 kg/m³	OrTr 1
Farm 5	Organic	5–7 kg/m³	OrTr 2

Smoked rainbow trout

Conventionally and organically smoked rainbow trout came from two local smoke houses. Conventional rainbow trout were purchased in 2005 as whole gutted hot smoked fish placed unwrapped in polystyrene boxes. Organical trout products were bought in 2006 as vacuumpacked smoked gutted fish and as vacuum packages of two smoked rainbow trout fillets. Both were delivered in polystyrene boxes. Additionally, some of the raw organically raised trout were collected for composition analysis. All samples were stored in a cold chamber at +4 °C until analysis.

For the storage experiment fish and fillets were randomly withdrawn at each sampling date and analysed.

Chemical analyses

Proximate composition

Homogenised skinned fillets of 20 fish were taken for analyses. The water content was determined by drying at 105 °C. Fat was estimated by a modified method of Smedes (1999) and protein by the Kjeldal method (Oehlenschläger, 1997). The mineral content was determined gravimetrically after ashing at 550 °C. The salt content was obtained by titration with 0.1 n $AgNO_3$ solution after protein precipitation with Carrez I and II (Karl et al., 2002a).

Fatty acid composition

Fatty acid methyl esters (FAME) were obtained from the extracted fat by trans-esterification with potassium hydroxide (DGF, 1998). Fatty acid composition was determined according to the DGF standard method (2000). FAME analyses were performed on a Hewlett Packard 6890 gas chromatograph (Agilent Technologies, Santa Clara, USA) equipped with split injection port, auto sampler, FID and a 60-m fused silica capillary column (i. d.: 0.32 mm) coated with 0.25 µm of DB-23 (Agilent). Nitrogen carrier gas flow was adjusted to 3.2 ml/min. Injector and detector temperatures were 200 and 250 °C, respectively. Oven program: 140 °C for 5 min, programmed to 200 °C at 2 °C/min, 10 min isothermal, then with 4 °C/min to 240 °C and finally 10 min isothermal. Evaluation of chromatograms was performed with an Agilent Chem-Station. Fatty acids in the range of C14–C22:6 were determined and calculated as weight percentage (g/100 g of fatty acids).

TVB-N, DMA-N and TMA-N

TMA-N and DMA-N were determined by gas chromatography in the filtered extract of 20 g homogenised muscle flesh and 180 ml 6 % (w/v) perchloric acid (modified method according to Oetjen und Karl, 1999). The extract was also taken for the determination of total volatile basic nitrogen (TVB-N) (Commission of the European Communities, 2005).

Vitamin D, pro-vitamin D and iodine

Pooled samples of 10 fish per farm were analysed for vitamin D_3 and provitamin D_3 by HPLC with electrochemical detection (Ostermeyer and Schmidt, 2006).

Iodine determination was carried out in the same samples by the gas chromatographic method of Karl et al. (2001).

Dioxin and PCB determination

Dioxins were analysed according to the method described in detail by Karl et al. (2002b) and analysis of dl- and ndl-PCBs were performed according to Karl and Ruoff (2007).

Briefly, dioxin determination included fat extraction and addition of 17 ^{13}C labelled PCDD/F congeners (internal standards for correction of the results by recoveries), removal of fat by GPC and further clean up with different adsorbents (Florisil, active carbon, aluminium oxide). PCDD/Fs were determined and quantified by HRGC/HRMS (HP 5890/Finnigan MAT 95; Agilent Technologies, Santa Clara, USA/Finnigan MAT GmbH, Bremen, Germany).

PCB analysis was performed after adding a ^{13}C labelled standard mixture of twelve dl-PCB and five ndl-PCB congeners prior to fat extraction. Further clean up included separation of fat by GPC (Bio-Beads SX-3, ethyl acetate/cyclohexane 1:1 (v/v)), removal of residual fat on a Bond Elut® PCB-SPE tube (Varian, Palo Alto, USA) and fractionation on Supelclean™ ENVI-Carb™ SPE-tube (Sigma-Aldrich, St. Louis, USA) with n-hexane/toluene 99:1 (v/v) for di- and mono-ortho-PCBs and toluene for nonortho-PCBs. Determination was carried out by HRGC/MS (ndl-PCBs) and HRGC/MS-MS (dl-PCBs) using a Varian Saturn 2200 system.

The quantification of dioxins and PCBs was carried out by the isotope dilution method.

Microbiological analysis

For the enumeration of total viable count (TVC), enterobacteria and specific spoilage bacteria *(Shewanella putrefaciens)* five parallel samples of skin and tissue from five fish per sampling day were taken aseptically. Defined dilutions of homogenates were plated on Standard IIron agar and Violet Red Bile Dextrose (VRBD) agar; inoculated plates were incubated at 20 °C (Standard I-Iron agar) or at 37 °C (VRBD agar) for 48 h before counting colonies. For detection of clostridia random samples of the intestines were taken and plated on Sulfadiazine (SPS) agar.

Sensory analysis

Raw rainbow trout

Skinned fillets of five trout were placed in individual pouches and heated for 8 min in a water bath (90 °C). After treatment samples were immediately served to the panel. The sessions were carried out in a sensory laboratory with separate booths. Seven to ten trained assessors participated in the sensory profiling using a 100 point line scale with two anchor points to rate the intensity of the sensory attributes. Assessment included descriptive terms for appearance, odour, taste and texture, which were defined during previous training sessions.

Smoked rainbow trout

The assessment of smoked samples based on a set of key attributes for the description of odour, taste, texture and appearance. As for raw trout the profiles covered the range between 0 and 100. The members of the panel were the same as for the raw trout assessment.

Triangle tests were conducted to determine differences in the quality of conventionally and organically raised trout (Amtliche Sammlung, 2006).

Physical measurements

Electronic nose analysis

An electronic nose (NST 3320, Applied Sensor, Sweden) equipped with twelve metal oxide semiconductor sensors (MOS) and nine field effect sensors (FE) was used. Homogenised samples (3 g) of the rainbow trout fillets served for sensory assessment were weighted in 30 ml glass bottles and analysed with a temperature controlled autoanalyser. The characteristic signal parameters were calculated from the resulting raw data set and subjected to principal component analysis (PCA). The selection of the most relevant sensors improved the discrimination characteristics of the aroma pattern (Kroeger et al., 2004).

Colour and texture measurements, water binding ability

Colour measurements were performed using a spectral colorimeter spectro pen® (Dr. Lange, Düsseldorf, Germany) on the fillets (n = 15) as described by Schubring (2003).

Texture measurements (n = 15) were carried out as Texture Profile Analysis at 60 % strain (according to Schubring, 2004a) using a Texture Analyser TA.XT2 (Stable Micro Systems, Godalming, U.K.). Additionally, penetration force was measured using the same equipment on the homogenates prepared for colour measurement as described by Schubring (2004a). Water binding ability (WBA) was measured as expressible moisture at 75 % strain according to Schubring et al. (2003) using the above mentioned texture analyser. Finally, the suitability of DSC for species identification was considered. The measurements were performed using a Perkin-Elmer DSC 7 device equipped with a Perkin-Elmer Intra cooler II and Pyris software (Perkin Elmer, Überlingen, Germany). The fish samples (15–30 mg) were weighted (± 0.1 mg) into 60 µl stainless steel pans (LVC 0319-0218; Perkin Elmer) and sealed. At least triple samples were heated from 10 to 95 °C at a scanning rate of 10 °C/min with an empty sealed pan as reference (Schubring, 2004b).

Results

Raw rainbow trout

Biological parameters

The biological parameters are given in Table 2. The rainbow trout looked healthy and were typically pigmented. They had comparable lengths, but differed, however, distinctly in their individual weights which reflected the individual farming conditions. The condition factor is commonly used to measure the length-weight relationship of the fish. Extensive conventional farming resulted in smaller fish with lower condition factor (CoTr 2) compared to the organically raised fish (OrTr 2) whereas the trout of the intensive farming (CoTr 3) were comparable to OrTr 1. From these divergent results it can be concluded that the physical condition and the condition factor of the fish were mainly influenced by the type of feed and the feeding conditions; the rearing density was less important.

Proximate composition and vitamins

The fat content of the rainbow trout from different farms differed considerably (Tab. 3). Generally, an amount of about 5 % is aimed to get a delicate texture after processing steps like frying or smoking. Only rainbow trout from conventional semi-intensive or intensive farming reached this target approximately. Fish with the lowest condition factor (OrTr 2/CoTr 2) had the lowest fat and highest water content. The protein content of 18.5–20.2% was independent from the rearing conditions.

Iodine and vitamin D_3 must be assimilated by the diet. The content in aquacultured fish depends on the added amount in the feeding stuff (Tab. 3). In contrast to iodine vitamins are normally supplemented. The provitamin D_3 (also called 7-dehydrocholesterol) is transformed by an UV-mediated photochemical reaction to previtamin D_3 which then thermally equilibrates into vitamin D_3. About 100 g fillet with 40 to 110 mg vitamin D_3/kg supplied the recommended daily intake of 5 mg of this vitamin for adults (WHO, 2004a). As expected, farmed trout products are minor contributors to the optimal iodine nutrition for humans. A portion of 100 g covers only 10 % of the recommended daily intake of 150–200 mg per person (WHO, 2004b).

TABLE 2: *Biological data of raw rainbow trout (average value of n = 20 for each farm)*

Sample code		Length (cm)	Weight (g)	Weight after gutting (g)	Weight loss (%)	Condition factor* (g/cm³)
	Conventional					
CoTr 1	semi-intensive	33.0	475	423	11.0	1.32
CoTr 2	extensive	31.0	307	287	7.0	1.01
CoTr 3	intensive	32.7	389	350	10.0	1.14
	Organic					
OrTr 1		33.0	401	347	13.0	1.15
OrTr 2		32.2	330	303	8.1	1.03

* This parameter expresses the condition of a fish and was determined from the observed total weight and length: condition factor = weight (g)/(length (cm))³ x 100.

TABLE 3: *Proximate composition of raw rainbow trout (n = 20)*

		CoTr 1 semi-intensive	CoTr 2 extensive	CoTr 3 intensive	OrTr 1	OrTr 2
Lipid (%)	x ± s	4.7±0.8	2.1±0.4	4.2±1.0	3.6±0.6	1.7±0.3
	range	3.5–6.1	1.6–3.0	2.5–6.6	2.2–4.7	0.8–2.3
Water (%)	x ± s	74.2±0.9	77.7±0.7	75.4±1.3	76.7±0.6	79.0±0.5
	range	72.4–75.4	76.6–78.8	73.1–77.9	75.8–78.0	78.3–79.3
Protein (%)	x ± s	20.2±0.4	19.9±0.5	19.3±0.5	19.7±0.5	18.5±0.5
	range	19.2–20.7	18.9–20.7	18.6–20.1	18.8–21.0	17.6–19.4
Mineral content (%)	x ± s	1.3±0.1	1.3±0.1	1.3±0.1	1.31±0.1	1.2±0.05
	range	1.1–1.4	1.2–1.6	1.1–1.4	1.2–1.5	1.1–1.3
Vitamin D_3 (µg/kg)	x	40	110	110	80	80
Provitamin D_3 (µg/kg)	x	340	130	270	120	220
Iodine (µg/kg)	x	<200	<200	<200	<200	<200

Lipid, water, protein, mineral content: mean value (x) Å} standard deviation (s) in g/100 g edible portion. Vitamin D_3, provitamin D_3 and iodine: average of pooled samples of 10 fish/farm.

TABLE 4: *Selected fatty acid contents of raw rainbow trout (n = 10) in g/100 g edible portion*

	CoTr 1	CoTr 2	CoTr 3	OrTr 1	OrTr 2
Stearic acid	3.15	3.24	3.10	2.39	1.80
Linoleic acid	7.64	8.13	12.05	10.28	11.00
cis-11-Eicosenoic acid	5.15	4.43	6.30	11.15	7.72
Eicosapentaenoic acid (EPA)	8.14	7.89	6.54	6.10	5.24
Docosahexaenoic acid (DHA)	16.69	19.85	14.35	14.89	29.76

Fatty acid pattern

The fatty acid composition of fish muscle is directly influenced by the feed. The fatty acid pattern of the different rainbow trout samples was as expected (Tab. 4). Conventionally and organically farmed fish showed only small differences. For most of the individual fatty acids the ranges overlapped and did not allow a clear assignment of the origin. Physiologically, both farming conditions had the same valuation.

Some differences were found between the conventionally farmed rainbow trout and OrTr 1 from organic aquaculture in the content of three fatty acids: cis-11-eicosenoic acid, eicosapentaenoic acid and linoleic acid. The latter is attributed to the presence of vegetable oil in the organic diet. The contents of linoleic and cis-11-eicosenoic acid increased while stearic acid decreased in comparison to conventionally farmed rainbow trout. On the other hand, OrTr 2 had a higher content of docosahexaenoic acid.

Undesired compounds: dioxins and PCBs
Polychlorinated dibenzo-p-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs) (collectively referred to as dioxins) and polychlorinated biphenyls (PCBs) including dioxin-like PCBs (dl-PCBs) and non-dioxin-like PCBs (ndl-PCBs) accumulate in the fatty tissue of animals and humans. Over 90% of human exposure to these compounds results from the consumption of food of animal origin like milk, meat, eggs and fish.

The European Commission established maximum levels for dioxins and dioxin-like PCBs in foodstuffs (Commission Regulation, 2006). This regulation entered into force on 4th of November 2006. For the muscle flesh of fish and fishery products the maximum level has been set to 4 ng WHO-PCDD/F-TEQ/kg wet weight (w. w.) and to 8 ng WHO-TEQ/kg w. w. for the sum of WHO-PCDD/FTEQ and WHO- PCB-TEQ (WHO-TEQ).

Fish accumulate dioxins and PCBs from the surrounding environment and from their diet (Loonen et al., 1993; Wu et al., 2001). For rainbow trout as for other aquaculture fish the contaminant levels in the muscle meat depend on the concentrations in the fish feed (Karl et al., 2003). The main source for dioxin, dl-PCB and ndl-PCB (indicator PCB) contamination is discussed to be fish oil and fish meal, coming from wild fish stocks from northern European and southern American fishing grounds (European Commission, 2000).

Fish meal and oil for organic trout diet shall come from sustainable fishery or from by-products, trimmings or other left overs from the production of fish for human consumption and the fish meal and oil amount of the feed should be substituted as much as possible by vegetable material.

Differences in feeding ingredients between organical and conventional feed should result in different contaminant levels of the lipophilic dioxins and PCBs. Thus, pooled samples from each farm were analysed (Tab. 5). Rainbow trout from both rearing forms had very low contamination levels of dioxins, dl-PCBs and ndl-PCBs. The dioxins, total WHO-TEQ and indicator PCB concentrations were far below the maximum levels. Differences between organically and conventionally farmed fish could not be deduced from the data.

Microbiological analysis
In general, the microbiological quality of all tested trout after two days storage on ice was excellent. Detected TVC on the skin varied from 10^2 to 10^3 cfu/cm^2 depending on the different farms. On skin of all rainbow trout only very low numbers (10^1–10^2 cfu/cm^2) of specific spoiling bacteria were found. All samples of trout tissue were sterile as expected. Neither on the skin nor in the tissue enterobacteria could be detected. The random samples of intestines were free of clostridia. No differences could be detected between conventionally or organically farmed rainbow trout concerning the microbiological results.

Sensory assessment
Cooked rainbow trout fillets had an elastic and slightly fibrous texture and a typical somewhat sweet taste. Scores for fresh odour were high. Quality differences between rainbow trout from the different farms were small. Only samples from the semi-intensive farm (CoTr 1) were rated lower due to a slight muddy-earthy flavour (geosmine), an attribute which can appear in freshwater fish without sufficient starving (Fig. 1).

In a triangle test eight judges could not identify the different raising forms. In both triangle combinations of CoTr 2 / OrTr 1 and CoTr 3 / OrTr 1 only seven of 24 deci-

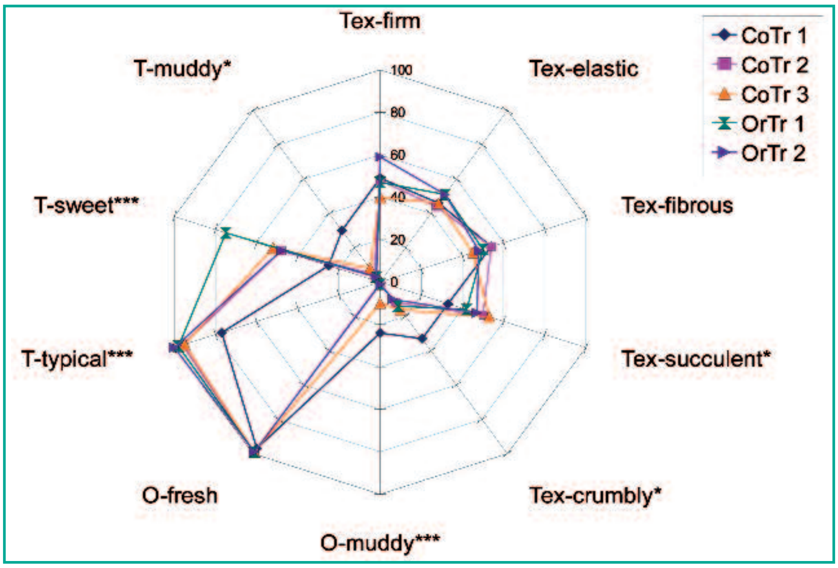


FIGURE 1: *Comparison of the main sensory profiles of differently raised rainbow trout (Tex = texture, O = odour, T = taste). Significance level for differences: * p<0.05; ** p<0.01; *** p<0.001.*

TABLE 5: *Dioxins, dl-PCBs and ndl-PCBs in pooled muscle meat samples of 10 rainbow trout per farm*

	Dioxin	dl-PCB (ng WHO-TEQ/kg w. w.)	∑ WHO-TEQ	PCB 52	PCB 101	PCB 138 (µg/kg w. w.)	PCB 153	PCB 180
Maximum level	4	–	8	80	80	100	100	80
CoTr 1	0.145	0.476	0.621	0.285	0.700	1.066	1.261	0.387
CoTr 2	0.134	0.260	0.394	0.175	0.386	0.640	0.843	0.224
CoTr 3	0.124	0.661	0.785	0.361	0.651	0.828	1.409	0.376
OrTr 1	0.141	0.310	0.451	0.328	0.505	0.774	0.901	0.245
OrTr 2	0.188	0.359	0.547	0.321	0.634	1.235	1.109	0.376

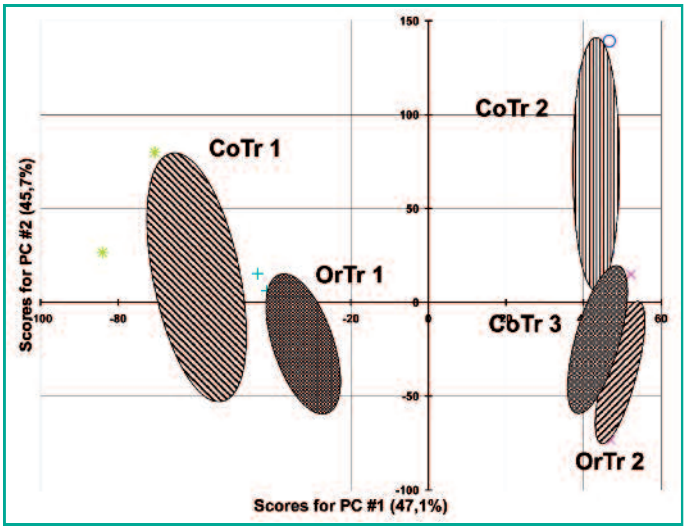


FIGURE 2: *Score plot of a principal component analysis (PCA) with rainbow trout from five different farms.*

sions (3 x 8) identified the correct sample by choice. So, the results fall below the confidence level of 95 % and the question "is there a difference between ecological and conventional rainbow trout?" must be negated. The test was done without CoTr 1 which could be identified to easily by its muddy flavour.

Electronic nose measurements

The technique was developed to support the sensory evaluation for the prediction of quality. A number of applications in the food industry have been reported, but standardised methods do not exist yet and a stable correlation between sensory data and electronic nose responses still represents a problem.

The raising conditions in Germany's small trout farms are very specific, concerning the environmental conditions like water habitat and feeding. So, it could be speculated that this resulted also in different aroma patterns of the fish.

The responses from the electronic nose were evaluated with principal component analysis (PCA) and are shown in Figure 2. In all cases the measured attributes deviated from each other. This means that the electronic nose has found differences. Yet, the validity of the collected data was limited. Of course, it must be considered that the panel also did not find remarkable varieties as well, except for CoTr 1 which the sensory panel described as slightly muddy-earthy. This flavour attribute is the most frequent problem in farmed fish and can appear in fish from muddy rearing facilities which were not starved long enough before slaughtering. Figure 2 shows that the score plot discriminated CoTr 1 from OrTr 2, CoTr 2 and CoTr 3, but only marginal from OrTr 1. The individual composition of the volatile compounds made it difficult to predict undesired sensory characteristics reliably.

In summary, the volatile compounds analysed by electronic nose were not useful to describe the quality attributes of raw fish or to distinguish ecologically and conventionally raised trout. Differences were only observed between different farms.

Colour and texture

Colour measurements were performed on intact and homogenised raw fillets (Fig. 3). When conventionally and organically farmed rainbow trout were compared it became obvious that colour attributes (L*, a*, b*) of the homogenates varied significantly ($p<0.05$) between all samples as shown for redness (Fig. 3, right). This can be traced back to varying feed compositions, which were obviously different in all farms. The redness of CoTr 1 (fillet) was significantly higher, probably as consequence of an astaxanthine containing nutrition (Fig. 3, left). The colouration of the flesh with pigmenting feed additives is forbidden in organic salmonid fish. Therefore, ecologically farmed rainbow trout had only low a* values.

The texture of the thermally untreated fillets of both types of farmed fish was compared by instrumental Texture Profile Analysis. The hardness (Fig. 4, left) of OrTr 2 was significantly higher ($p<0.05$). The same was found for the texture parameter chewiness. This was possibly due to differences found in the proximate composition (Tab. 3) indicating that OrTr 2 had the lowest fat content. The panel rating confirmed these findings. In contrast, the samples did not differ in cohesiveness, springiness and adhesiveness.

The resistance against penetration of small cylinders into homogenised muscle was highest for CoTr 2 and OrTr 2, which were both comparable, and was followed by CoTr 3 and OrTr 1, which did not differ. The lowest value was found for CoTr 1. All differences were significant ($p<0.05$). The water binding ability (WBA) was highest for CoTr 2 ($p<0.05$). All other samples did not differ in WBA ($p>0.05$).

The DSC pattern taken on fish muscle indicates the extent of protein denaturation. Furthermore, it is possible to distinguish fresh fish of different species by means of

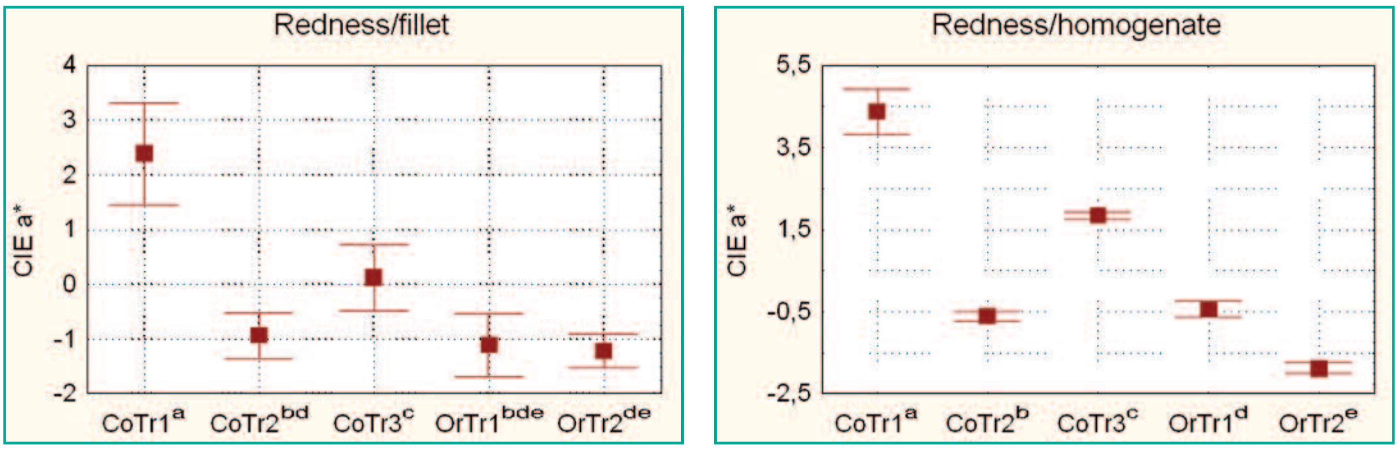
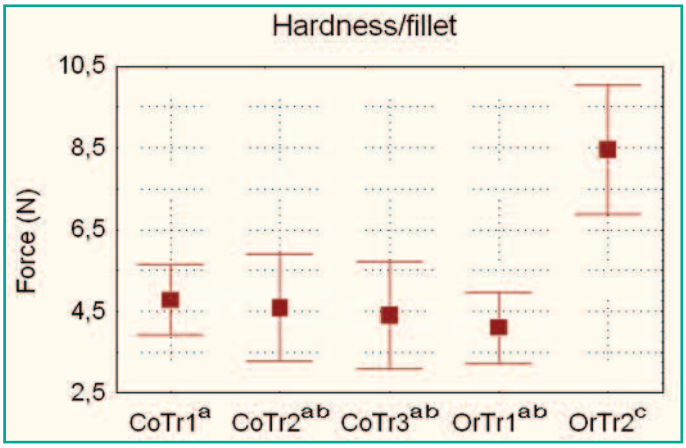


FIGURE 3: *CIE Lab a* values taken on fillet (left) and homogenate (right) of thermally untreated organically and conventionally farmed rainbow trout.*



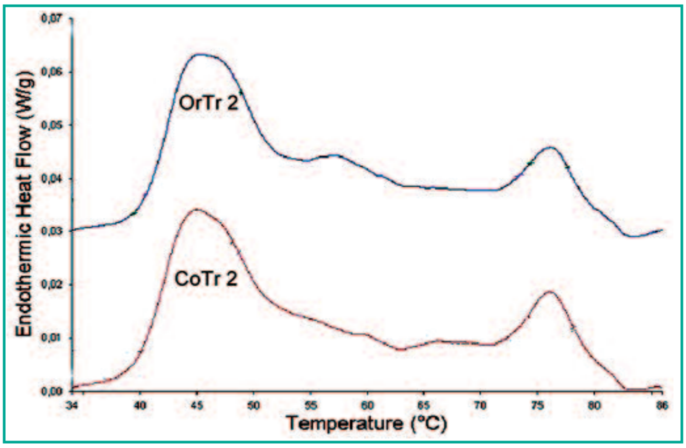


FIGURE 4: *Hardness (left) and DSC curves (right) measured on fillets of thermally untreated organically and conventionally farmed rainbow trout.*

TABLE 6: *Proximate composition of smoked rainbow trout (mean value ± standard deviation in g/100 g edible portion) of 5 fish from retail*

	Conventionally smoked trout (2005)	Organically smoked trout (2006) raw	smoked*
Lipid (%)	6.5 ± 0.2	6.4 ± 1.6	7,1 ± 1.2
Water (%)	70.8 ± 0.3	73.8 ± 1.2	65.9 ± 1.7
Protein (%)	21.4 ± 0.4	19.1 ± 0.5	24.7 ± 0.9
Ash (%)	1.8 ± 0.1	1.1 ± 0.1	2.4 ± 0.3
NaCl (%)	0.84 ± 0.1	0.1 ± 0.01	1.6 ± 0.2

* vacuum-packed.

their DSC curves. However, it was impossible to differentiate between organically and conventionally farmed rainbow trout using this measuring technique (Fig. 4, right). Both major peaks seen in the curves were dedicated to myosin (T_{max} ~45 °C) and actin (T_{max} ~77 °C). Small peaks between the major ones belong to sarcoplasmic and connective tissue proteins (Schubring, 2004b).

Smoked rainbow trout

Proximate composition

The composition of the edible part of commercially available hot smoked rainbow trout from both raising forms was in the expected range (Tab. 6). Additionally, data of the organic raw material are presented. The comparison of the raw and smoked meat allowed an estimation of changes in composition caused by the smoking process.

The organically farmed rainbow trout had a much higher fat content of 6.4 % compared to the one analysed in 2003 (Tab. 3). However, the fat content of both smoked trout products still covered the normal range for this product type in Germany. The salt content was generally typical and ranged between 0.8 % and 1.6 %. The differences could be attributed to different fish sizes and salting conditions. The considerable water loss during the smoking process of the organic rainbow trout was unusual and indicated a too long stay in the smoking kiln. On the other hand, the high water loss explained the higher protein and fat content of the product.

Microbiological analysis

No bacteria were found on whole gutted unwrapped rainbow trout at the beginning of the storage trial. Vacuum-packed products were examined after five days for the first time. TVC were not detectable either on the skin or in the in the muscle tissue of whole fish. On the skin of vacuum-packed fillets counts were below 100 cfu/cm^2.

Sensory assessment

Conventional smoked rainbow trout were judged as whole gutted unwrapped fish, which is the traditional distribution form. Organical fish is normally offered vacuum-packed. The results of the quality assessment did not reveal distinct quality differences. All products fulfilled the quality demands. The averages of the scores for the main attributes were close together. Flavour attributes were mainly influenced by the individual smoking conditions of the processors. The conventionally raised rainbow trout were smoked in a Altona type kiln, which normally results in a more intensive smoke flavour. Thus, the ecological rainbow trout smoked in an electrical kiln were judged as slightly less aromatic. Their texture was also rated dryer which corresponded to the lower water content.

Electronic nose measurements

Odorous mixtures generated by equivalent sources will also provide rather similar patterns. Data from all smoked samples were pooled together and analysed with PCA. The intensive smoke flavour dominated and masked individual quality attributes of the initial raw material. As a result the data reflected the different smoking techniques and spread out in a long elliptical cluster with some overlapping. A further differentiation was not possible.

Colour and texture

The colour of smoked fish depends on the quantity and composition of the smoke components which penetrated the surface. The results of the measurements were already published elsewhere (Schubring, 2006). Briefly, colour measurement revealed remarkable differences in lightness. Smoked rainbow trout originating from conventionally farmed fish had higher L* values than organically farmed trout. This difference in L* was already found when colour measurements were taken on the raw material (L* = 32.0 vs 28.8 for conventionally and organically farmed trout, respectively). However, during chilled storage differences were equalized. The a* and b* values were not significantly influenced by farming and did not change remarkably during chill storage.

TABLE 7: *TVC, enterobacteria, Shewanella putrefaciens and clostridia at the end of storage at +2 to +4 °C*

	Product	Storage time	Bacteria on Skin	Bacteria in tissue
Conventionally produced smoked rainbow trout	Whole trout	21 d	n. d.	n. d.
Organically produced smoked rainbow trout	Vacuum-packed whole fish	21 d	TVC: max 10^4 cfu/cm^2	n. d.
	Vacuum-packed fillets	21 d	TVC: max 10^6 cfu/cm^2	TVC: max 10^6 cfu/g[(b)]
			Shewanella putrefaciens: max $5x10^4$ cfu/cm^2[(a)]	

Samples of 5 fish or packages. [(a)]: count in 2 samples; [(b)]: count in 3 samples; n. d.: not detected.

Storage behaviour of smoked products

Especially for product categories with a relatively short shelf life like vacuum-packed smoked products recommendations are often too long. So, the purpose of the following investigations was to find out the storage behaviour of hot smoked rainbow trout under correct storage conditions. The fish was stored in a refrigerated room adjusted to +2 to +4 °C up to 24 days.

TVB-N, TMA-N and DMA-N in smoked trout

TVB-N in smoked trout remained almost constant between 17.2 and 22.5 mg/100 g. DMA-N and TMA-N were below the limit of detection. Therefore, these parameters were not suitable for the determination of quality deterioration during storage.

Microbiological changes in smoked trout

In conventional whole smoked rainbow trout without packaging no TVC, enterobacteria, *Shewanella putrefaciens* or clostridia could be detected after 21 days storage at +2 to +4 °C (Tab. 7). Also, in vacuum-packed, whole organically produced and smoked fish no bacteria were found in the tissue samples, whereas on the skin TVC started with less than 100 cfu/cm^2 on day 5 and increased very slowly with one outlier on day 18 ($1x10^5$ cfu/cm^2) up to $1x10^4$ cfu/cm^2 after 21 days. *Shewanella putrefaciens,* enterobacteria or clostridia could not be detected on skin samples during the storage experiment.

In contrast to these findings the TVC on skin samples of ecological smoked and vacuum packed fillets varied very distinctly during storage time. This could be explained as a result of filleting as additional processing step. TVC grew from about 100 cfu/cm^2 at the beginning up to $1x10^6$ cfu/cm^2 after 21 days. *Shewanella putrefaciens* were first detected on two of five samples on day 21 with $2x10^3$ cfu/cm^2 and $5x10^4$ cfu/cm^2, respectively. In tissue samples the TVC levels varied between individual fillets. In some fillets no bacterial counts were determined. After storage for 21 days in three of five parallels $4x10^4$, $1x10^5$ and $1x10^6$ cfu/g were found. None of the samples contained enterobacteria or clostridia.

It can be summarised that all investigated samples were of good or very good microbiological quality, but it was evident that in conventional rainbow trout TVC were detected less frequently and at lower rates as compared to organically produced trout. Enterobacteria were only found in fillets from organic farms. Yet, these satisfactory results cannot be generalized as independent market tests regularly reveal. Further investigations on two randomly chosen smoked and vacuum-packed retail products gave the following results. Ecological rainbow trout fillets were moulded and had high bacterial counts of up to $8.7x10^5$ cfu/g muscle tissue one day before the expiration date. Conventional whole rainbow trout with a remaining maturity of 14 days had a TVC of more than 10^8 cfu/g muscle tissue.

Sensory changes in smoked trout

The quality of the freshly smoked products was excellent. During storage quality decreased remarkably (Fig. 5 and 6). Smoked whole rainbow trout stored for nine days were distinctly inferior to their fresh equivalents (Fig. 5). At day 13 the texture had deteriorated substantially and some of the ratings halved. The skin was dried out and wrinkled. The tissue of the belly flaps had become soft and the residual flesh dry. Provided a good manufacturing practice and an optimal cold storage good product quality is restricted to about ten days.

Commercial ecological trout are sold as vacuum-packed product and were judged as such (Fig. 6). Such packaging is an effective tool for maintaining quality for a longer period. The desired components did not deteriorate until day 14. Then, the typical flavour changed and the taste became distinctly sour and partly bitter as well. Differences between whole and filleted trout were insignificant over the whole storage time. Texture parameters remained nearly stable up to day 18, after that the muscle flesh was rated considerably harder or less soft. None of the products was deteriorated after 21 days of +4 °C storage.

Conclusions

The quality of fish is a very complex interaction of various parameters related to nutritional, sensorial, microbiologi-

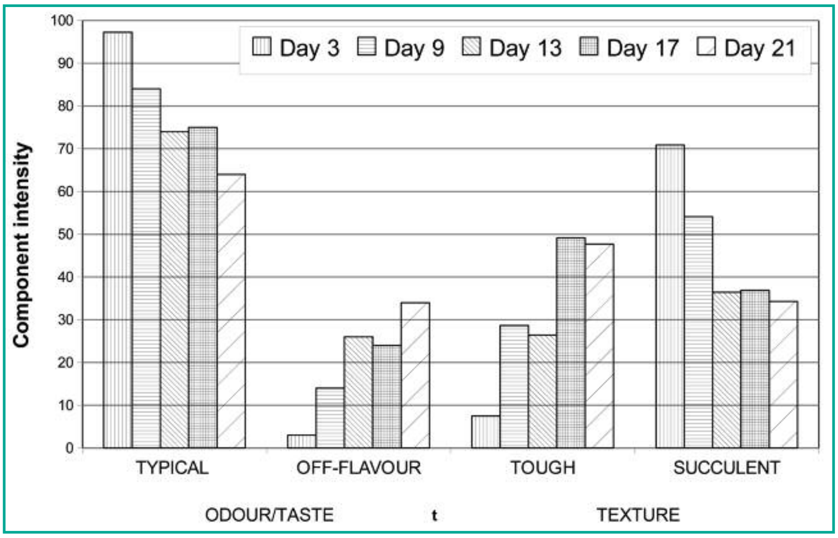


FIGURE 5: *Changes of main quality attributes of smoked conventional rainbow trout stored unwrapped at +2 to +4 °C.*

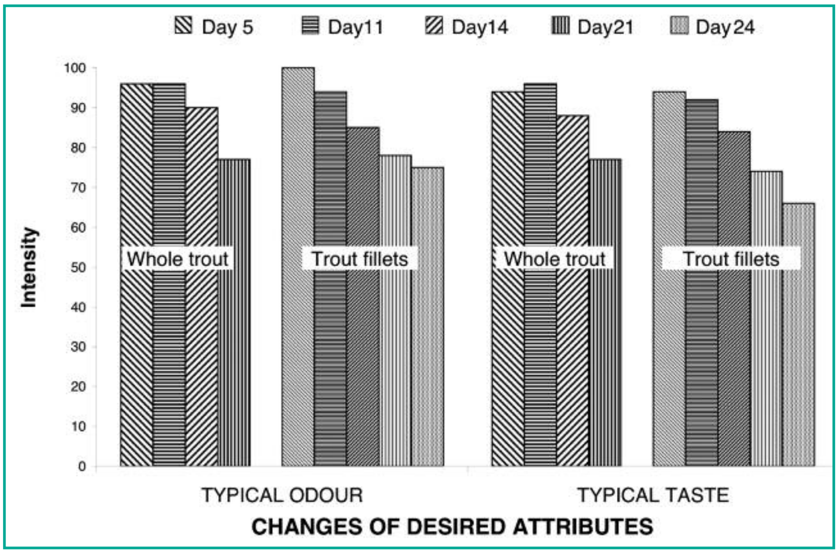


FIGURE 6: *Changes of main quality attributes of smoked and vacuum-packed ecological rainbow trout and fillets stored at +2 to +4 °C.*

cal, biochemical and physicochemical characteristics. The rearing conditions, the manufacturing processes and the storage period before consumption are factors which affect the quality of fish in aquaculture and derived products.

Farmed rainbow trout is a nutritious and healthy food source. It is low in pollution because the feed components are controlled. The study provided reasonable estimates of texture and colour. The results of the electronic nose were not satisfactory, whereas, as expected, sensory evaluation has been found to be useful for the quality description.

Comparing conventionally and ecologically farmed rainbow trout, it was not possible to identify any quality advantages for one of the rearing conditions. With regard to the meat quality, residues of environmental contaminants and microbiological parameters the conventionally farmed rainbow trout obtained the same good results as their organic counterparts.

The convenience aspects of food as well as the specifications of the retail markets have led to an increasing demand for products with extended shelf life. As highly perishable foodstuff proper handling of rainbow trout as raw material and of its products in all processing phases like continuous cooling with ice or storing in a cold room below +4 °C is an inevitable basis for a safe product. Raising the temperature just a few degrees could cause microbial growth including pathogens.

The responsibility of determining the shelf life of a food, and thus its best-before date lies with the manufacturer. Especially for product categories with a relatively short shelf life like vacuum-packed smoked products recommendations are often too long. In our storage experiment vacuum-packed samples had a shelf life with good quality up to 14–16 days. After this period chemical, biochemical or microbiological processes decreased the sensory quality. There are no generally binding legal regulations regarding shelf life of such products. As it is well known that particularly vacuum-packing can cause food safety hazards to the consumer, the shelf life should be limited to 14 days. Rainbow trout without packaging should be sold at the latest ten days after smoking. This should be good commercial practice to fulfil the consumer expectations to a high quality product.

References

Bundesprogramm Ökologischer Landbau (2004): Qualitätsvergleich von Regenbogenforellen aus konventioneller und ökologisch zertifizierter Aufzucht als Voraussetzung für eine Verbesserung der Wettbewerbsfähigkeit von Bioforellen. http://orgprints.org/4004/.

Bundesprogramm Ökologischer Landbau (2007): Untersuchungen zur Qualitätsveränderung bei der Verarbeitung und Lagerung von ausgewählten Erzeugnissen aus Bioforellen und konventionell erzeugten Forellen als Voraussetzung für die Erstellung einer Handlungsanweisung für handwerkliche Forellenzuchtbetriebe. http://orgprints.org/14277/.

Commission of the European Communities (2005): Commission regulation (EC) No 2074/2005 of 5 December 2005 laying down implementing measures for certain products under Regulation (EC) No 853/2004 of the European Parliament and of the Council and for the organisation of official controls under Regulation (EC) No 854/2004 of the European Parliament and of the Council and Regulation (EC) No 882/2004 of the European Parliament and of the Council, derogating from Regulation (EC) No 852/2004 of the European Parliament and of the Council and amending Regulations (EC) No 853/2004 and (EC) No 854/2004. Off J EU L338: 27–59.

Commission Regulation (2006): Commission Regulation (EC) No 1881/2006 of 19 December 2006 setting maximum levels for certain contaminants in foodstuffs. Off J EU L 364: 5–24.

DGF (1998): DGF-Einheitsmethode C-VI-11d. Fettsäuremethylester (Alkalische Umesterung). Wissenschaftliche Verlagsgesellschaft mbH, Stuttgart, Germany.

DGF (2000): DGF-Einheitsmethode C-VI-10a. Gaschromatographie: Analyse der Fettsäuren und Fettsäureverteilung. Wissenschaftliche Verlagsgesellschaft mbH, Stuttgart, Germany.

European Commission (2000): Opinion of the Scientific Committee on Animal Nutrition on the dioxin contamination of feedingstuffs and their contribution to the contamination of food of animal origin. http://europa.eu.int/comm/food/fs/sc/scan/outcome_en.html.

Karl H, Münkner W, Krause S, Bagge I (2001): Determination, spatial variation and distribution of iodine in fish. Dtsch Lebensmitt Rundsch 97: 89–96.

Karl H, Äkesson G, Etienne M, Huidobro A, Luten J, Mendes R, Tejada M, Oehlenschläger J (2002a): WEFTA interlaboratory comparison on salt determination in fishery products. J Aquat Food Prod Technol 11: 215–228.

Karl H, Ruoff U, Blüthgen A (2002b): Levels of dioxin in fish and fishery products on the German market. Chemosphere 49: 765–773.

Karl H, Kuhlmann H, Ruoff U (2003): Transfer of PCDDs and PCDFs into the edible parts of farmed rainbow trout, *Oncorhynchus mykiss* (Walbaum), via feed. Aquac Res 34: 1009–1014.

Karl H, Ruoff U (2007): Dioxins, dioxin-like PCBs and chloroorganic contaminants in herring, *Clupea harengus,* from different fishing grounds of the Baltic Sea. Chemosphere 67: 90–95.

Karl H, Lehmann I, Rehbein H, Schubring R (2009): Composition and quality attributes of conventionally and organically farmed Pangasius fillets on the German market. Int J Food Sci Technol, doi: 10.1111/j.1365–2621.2009.02103X.

Kroeger M, Manthey M, Tejada M (2004): Physical measurements. In: Kent M, Knöchel R, Barr UK, Tejada M, Nunes L, Oehlenschläger J (eds.), Sequid. A new method for measurement of the quality of seafood. Shaker Verlag, Aachen, Germany, 65–74.

Amtliche Sammlung (2006): Amtliche Sammlung von Untersuchungsverfahren nach § 64 LFGB. Sensorische Prüfverfahren, Dreiecksprüfung L 00.90-7.

Loonen H, Tonkes M, Parsons JR, Govers HAJ (1993): Relative contributions of water and food to the bioaccumulation of a mixture of polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans in guppies. Sci Total Environ Suppl: 491–498.

Naturland (2002): Naturland Richtlinien für die Ökologische Aquakultur. Naturland – Verband für naturgemäßen Landbau e. V., Kleinhaderner Weg 1, 82166 Gräfelfing, Germany. http://www.naturland.de.

Oehlenschläger J (1997): WEFTA interlaboratory comparison on nitrogen determination by Kjeldahl digestion in fishery products and standard substances. Inf Fischwirt 44: 31–37.

Oetjen K, Karl H (1999): Improvement of gas chromatographic determination methods of volatile amines in fish and fishery products. Dtsch Lebensmitt Rundsch 95: 403–407.

Ostermeyer U, Schmidt T (2006): Vitamin D and provitamin D in fish. Eur Food Res Technol 222: 403–413.

Schubring R (2003): Colour measurement on skin during storage of wet and frozen fish. In: Luten J, Oehlenschläger J, Olafsdottir G (eds.), Quality of fish from catch to consumer: labelling, monitoring & traceability. Wageningen Academic Publishers, Wageningen, The Netherlands, 251–263.

Schubring R, Meyer C, Schlüter O, Boguslawski S, Knorr D (2003): Impact of high pressure assisted thawing on the quality of fillets from various fish species. Innov Food Sci Emerg Techn 4: 257–267.

Schubring R (2004a): Instrumental colour, texture, water holding and DSC measurements on frozen cod fillets *(Gadus morhua)* during long term storage at different temperatures. Dtsch Lebensmitt Rundsch 100: 247–254.

Schubring R (2004b): Differential scanning calorimetric (DSC) measurements on the roe of rainbow trout *(Oncorhynchus mykiss):* Influence of maturation and technological treatment. Thermochim Acta 415: 89–98.

Schubring R (2006): Veränderungen der Farbe und thermischen Stabilität der Muskelproteine von Räucherforellen während der Kühllagerung. Inf Fischereiforsch 53: 52–58.

Smedes, F (1999): Determination of total lipid using non-chlorinated solvents. Analyst 124: 1711–1718.

WHO (2004a): Dietary recommendations / Nutritional requirements. http://libdoc.who.int/publications/2004/9241546123_chap3.pdf.

WHO (2004b): Dietary recommendations/Nutritional requirements. http://libdoc.who.int/publications/2004/9241546123_ chap16.pdf.

Wu WZ, Schramm KW, Xu Y, Kettrup A (2001): Accumulation and partition of polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/F) in the muscle and liver of fish. Chemosphere 43: 633–641.

Address for correspondence:
Monika Manthey-Karl
Max Rubner-Institute, Federal Research Institute of Nutrition and Food, Department of Safety and Quality of Milk and Fish Products
Palmaille 9, 22767 Hamburg, Germany
monika.manthey@mri.bund.de