Changes of the Iodine Content in Fish during Household Preparation and Smoking

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Summary

The influence of various household preparations on the iodine content of fish has been studied. Thawing of deep frozen fillets reduced the iodine content about 10 %, losses during steaming of fish balls were in the same range and frying did not change the iodine content significantly. Large variations of the iodine content have been found in fish fingers within and between different packages, depending on the fish species and on the amount of dark muscle of the fish core.

The influence of hot smoking was studied on ocean perch portions and herring fillets.

No change in iodine content was observed.

Zusammenfassung

Es wurden die Veränderungen der Iodgehalte während der haushaltsmäßigen Zubereitung von Fischen untersucht. Während des Auftauens von Fischfilets ging ca. 10 % des Jodgehaltes mit dem Auftauwasser verloren. Etwa die gleiche Menge an Iod trat beim Dämpfen aus. Beim Braten wurden dagegen keine Gehaltsänderungen festgestellt.

Fischstäbchen zeigten große Schwankungen in ihren Iodgehalten. Dies galt sowohl innerhalb einer Haushaltspackung als auch für Stäbchen aus unterschiedlichen Packungen. Die Gehalte hingen von der Fischart und vom Anteil der dunklen Muskulatur im Fischanteil ab.

Der Einfluss des Heißräucherns wurde an Rotbarschstücken und Heringsfilets untersucht. Durch den Räucherprozess wurden die Gehalte nicht verändert. Das Iod verblieb im Muskelfleisch.

Keywords: Iodine content, fish products, household preparation, steaming, frying, thawing, smoking, fish fingers, dark muscle / Iodgehalt, Fischereierzeugnisse, haushaltsmäßige Zubereitung, Dämpfen, Braten, Auftauen, Räuchern, Fischstäbchen, dunkle Muskulatur

1 Introduction

Iodine is an essential trace element of great importance in human nutrition. The element is an integral part of the thyroid hormones and iodine deficiency leads to endemic goiter (enlarged thyroid) and other iodine deficiency disorders[1,2]. The recommended daily allowance of dietary iodine is 180–200 µg for adults[3], > 100 µg for children and the daily intake during pregnancy should be at least 230 µg iodine. The main iodine supply occurs via nutrition and marine sea food is the only natural source containing relatively large amounts of iodine. However, the iodine content of marine fish depends on the species and can vary considerably. *Julshamn* et al.[4] measured the iodine content in various fish species off the coast of Norway and from the North Sea. They found a great variation between different individuals of the same species as well as between different fish species. The results for haddock e. g. varied between 0.6 and 9.2 mg iodine/kg wet weight (w.w.), but a correlation to the fishing ground was not found. This corresponds well to our recent finding that the iodine concentration in the muscle of fishes of the same size and even from the same catch can vary considerably[5]. *Julshamn* and coworkers[4] discussed the variety of different species of prey as possible explanation for the large differences of iodine within the same species. Fish absorb iodine both from the seawater and the feed and cod is feeding on more than 250 different species. *Yu* et al.[6] found different transfer rates of ^{131}I administrated to water for tilapia and common carp due to different physiologies and metabolic rates of the species.

Also other factors influence the measured iodine content of fish. We found an iodine gradient within the muscle of marine fishes decreasing from the skin to the internal part of the fillet[7]. *Eckhoff* and *Maage*[8] reported high iodine concentrations in the skin of East African fishes, the iodine content of the skin can be more than ten times of the muscle tissue.

Consequently a direct comparison of literature data is only possible when the sampling procedure was similar and the same part of fish was taken for analysis.

Most investigations studied the iodine content in raw fish[9], however in Germany fish is either consumed processed (smoked, marinated, canned) or heated (cooked, fried,

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baked). Few older studies exist on the influence of household preparation and processing on the iodine content in marine fish species[10–14] and rather inconsistent results have been reported.
Manthey[10] found an increase of iodine after cooking and frying of saithe portions, whereas *Montag* and *Grote*[11] reported a considerable decrease in the iodine content after household preparation of plaice and haddock. The contradictory findings could result from the large variation of iodine content in individuals of the same species. All authors used different fishes or fish portions for the analysis of the raw and processed products.
The aim of this study was to reinvestigate the influence of household preparation and smoking on the iodine content of fish and fishery products by excluding the possible bias due to variations of the iodine content of the raw material. Additionally the variation of the iodine content in commercially processed fish fingers was studied in detail.

2 Material and Methods

2.1 Fish samples

Cod was used as raw material for studying the influence of household preparations. The fish was caught in the western Baltic Sea in September 1999 by the research ship W. Herwig III. Size and weight of the fishes were measured immediately after catch; the fishes were filleted and deep frozen for further experiments.
Consumer packages of deep frozen fish fingers from Alaska pollock (*Theragra chalcogramma*) and hake were bought at local retail shops.
Thawed, gutted and beheaded Ocean perch (*Sebastes* sp.), caught by our research ship, was used for the smoking experiments.

2.2 Household preparation

Thawing

Three cod were filleted on board of the research ship directly after catch, the skin was removed and each the left and right fillets were deep frozen in a blast freezer at –40 °C. Fillets from each fish were thawed separately at room temperature in two plastic bags. From one bag the drip water was decanted carefully, the weight was determined and iodine content was analysed both in drip and remaining fillet. The content of the other bag was homogenised completely and analysed for iodine.

Steaming

Approximately 3 kg of thawed cod fillets were pooled and homogenised and 5 samples were taken for iodine analysis of the raw material. Six 300 g meat balls were formed and sealed in plastic bags. A thermocouple was inserted into one ball and all bags were heated together at 90 °C in a water bath (core temperature 70 °C, cooking time 13 min).

Frying

Another batch of thawed cod fillets were homogenised and meat balls of 150 g were formed. 5 balls were analysed raw and 5 balls were fried in an open frying pan, covered by a thin layer of vegetable oil. Frying temperature was approximately 150 °C, frying time was 5 min at each side. The core temperature reached 70 °C. The balls were removed, weighed and placed in plastic bags for further analysis.

2.3 Smoking

Ocean perch

10 gutted and beheaded ocean perch were thawed and cut in the middle vertically to the backbone to yield 2 cutlets, one front and one tail part. Alternately one part was analysed raw and the other was hot smoked.
Smoking included salting of the cutlets for 1 h in 10 % (w/w) brine, the ratio brine: fish was 1 : 1. The salted cutlets were stored over night in a refrigerated room and hot smoked in a smoking kiln with external smoke generator. The core temperature was 60 °C.

Herring

About 20 kg fresh butterfly fillets of herring were bought at the local fish market. All fillets were salted for 10 min in 6 % (w/w) brine, the ratio brine: fish was 1 : 1. After salting, ten butterfly fillets were divided in left and right fillet and one part was smoked and the other analysed without further treatment. To obtain realistic smoking conditions, the 10 marked fillets were smoked together with the rest of salted butterfly fillets. The core temperature reached 60 °C.

2.4 Analytical methods

Iodine determination

Iodine content was analysed according to the method described in detail by *Karl* et al.[7]. Briefly the homogenised sample is completely oxidised in a basic solution of peroxidisulfate.
The resulting iodate is reduced to iodide by addition of sodium sulfite. The iodide is oxidised to iodine and derivatised with pentane-3-one[15] in the presence of acid to form 2-iodo-pentane-3-one and measured by gas chromatography using ECD-detection.

Lipid and water determination

The lipid content of the homogenised tissue samples was determined by a modified *Bligh* and *Dyer* method[16]. The water content was determined gravimetrically after 12 h at 105 °C.

Drip loss

The drip loss was determined gravimetrically after decanting the drip water.

3 Results and Discussion

3.1 Household preparations

Thawing

In 2003 over 32 % of the fish consumed in Germany was sold deep frozen and fishes and fillets are often thawed before kitchen preparation. Thawing of fish results in thaw-drip loss, the amount depends on frozen storage temperature, the degree of protein denaturation and other factors[17]. The drip consists not only of tissue water but also of water solubles like peptides, amino acids and minerals. Our interest focused on the question if the iodine content of the fillets is influenced by the thawing process. To follow the changes of the iodine content, right and left fillets from three fishes were analysed after thawing, respectively. One fillet was measured together with the drip and the other fillet and drip separately. The mean drip loss of six fillets was 7.3 % and the drip had slightly higher iodine concentrations as the fillets (Tab. 1). This indicates that the iodine is mainly dissolved in the water phase of the fillets. Similar findings have been reported by *Harrison* et al.[18], who found that iodine in fish fillets is mainly present in a soluble form. The data allow also the calculation of the relative amount of iodine loss due to thawing. On average 8.3 % of the total iodine of the frozen fillet was found in the thaw-drip (Fig. 1).

Typical preparations of fish in German households are cooking of whole gutted fish in salted water, steaming of fillets or whole gutted fish in a glass mould in an oven and frying of battered or unbattered fillets and fish fingers in a pan.

Steaming

Changes of iodine content during household cooking were studied as model experiment with fish balls made from a large batch of thawed cod fillets. This experimental design guaranteed identical iodine content of the raw material. To prove the homogeneity 5 samples were taken randomly from the minced batch and analysed for iodine. The iodine content was very uniform: 9560 ± 150 µg I/kg (w.w.), having a coefficient of variation of less than 2 %. The iodine content was significantly higher compared to the fillets used in the drip experiments. The results show again the great variation which can be obtained between different individuals of the same species and emphasis the importance to check the homogeneity of the starting material.

Now six fish balls were formed and sealed in plastic bags. After heating in a water bath at 90 °C five fish balls were allowed to cool to room temperature in the sealed bags and carefully opened to decant the separated water. The one used for temperature measurement was discarded. Weights of the drip and the cooked minced balls were determined and the iodine contents of drip and cooked balls were analysed, respectively. The average liquid loss during steaming in a plastic bag was 9.8 % (Tab. 2).

The iodine loss during steaming corresponds with the drip loss. On average 8.7 % of the initial iodine content of the raw mince was found in the separated drip liquid. These model experiments showed that during steaming of fish over 90 % of the iodine retained in the heated product. The iodine loss of whole fillets should be even less because mincing of fillets disrupts the structure which leads to a larger release of water[19]. Steaming in a plastic bag simulates the heating of fish in a glass mould e.g. on a vegetable bed. In this case the released liquid becomes a part of the meal will be consumed as well. Therefore the loss of iodine due to steaming of fish can be estimated as minor.

Frying

Changes of iodine during frying were also studied on minced portions of cod fillets. Another batch was homogenised and minced portions of 150 g were formed. 5 portions were fried in an open frying pan and the other part was analysed raw. When the core temperature reached 70 °C, the fried portions were removed from the frying pan, weighed and analysed for fat-, water- and iodine content.

Tab. 1 Iodine (in µg I/kg w.w.) concentrations in fillets and drip of thawed Baltic cod

Fish	Fillet 1 + Drip1	Fillet 2	Drip 2
1	3880	3890	4980
2	4000	4020	4180
3	2580	2260	2620

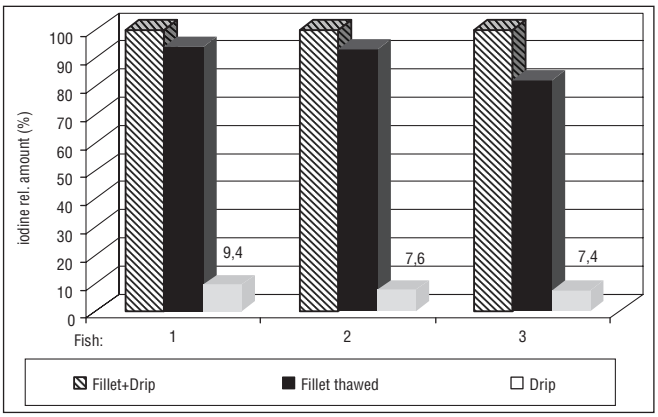

Fig. 1 Relative amount of iodine in fillet and thaw-drip of Baltic cod

Tab. 2 Changes [x ± s] of iodine content in minced fish balls during steaming (n = 5)

	Raw mince	Cooked mince	Drip
Weight [g]	300.7 ± 0.4	269.4 ± 1.7	29.4 ± 1.4
Iodine content [µg/kg]	9760 ± 150	9860 ± 560	8490 ± 900
Mass balance [%]	100	90.2	9.8
Rel. amount of iodine [µg]	9760	8870	850

Tab. 3 Changes (mean) in minced cod fillet portions during frying (n = 5)

	Raw mince	Fried mince
Weight [g]	150	130 ± 2
Fat content [%]	0.8	4.6
Iodine content [µg/kg]	5570 ± 40	6580 ± 210
Mass balance [%]	100	86.6
Rel. amount of iodine [µg]	5570 ± 40	5680 ± 110

During frying some fat was taken up by the mince and water evaporated. The average weight loss was 13.4 %. The fat content increased from 0.8 % to 4.6 % and the loss of water was approximately 15 %.

The absolute iodine content per g product increased from 5570 µg iodine/kg w.w. to 6580 µg/kg w.w. due to the evaporation of water. When taking the weight changes into account, the relative amount of iodine in the raw and fried minced portions kept nearly constant. The frying in hot fat (oil) obviously closed the surface of the meat balls very rapidly and prevented a loss of iodine containing drip, so that all iodine remained in the fried portions.

Our finding correspond with the results of *Manthey*[10], who found a 12 % increase of iodine per g product after frying of fishburgers compared to the raw material.

Fish fingers

One of the most popular deep frozen fish products in Germany are fish fingers. Today they are mainly produced from Alaska pollock (*Theragra chalcogramma*) and from various hake species (*Merluccius* spp.). Data on the iodine content of these products and possible changes during household preparation are not available. To collect information, commercially available fish fingers from several consumer packages were analysed raw and fried, respectively. Additionally the distribution of iodine between batter and fish core was studied on raw Alaska pollock fish fingers. The frying was done in an open pan according to the recommendations given on the packages. The results are summarised in table 4.

The iodine content in ten different fish fingers made from Alaska pollock, which have been taken from one 300 g consumer package varied considerably. The mean iodine content of package No. 1 was 308 µg/kg w.w., ranging between 203 and 550 µg/kg w.w.

The same large variation was found, when fish fingers of a second package (No. 4) from the same producer were analysed after separation into fish core and corresponding batter. The iodine content of the fish meat ranged between 250 and 849 µg/kg w.w., with a mean value of 530 µg iodine/kg w.w. and a coefficient of variation of 40 %.

The iodine content of the batter was more homogenous, the coefficient of variation was only 26 %. The repeated analysis of other 10 fish cores from a third package (No. 3) yielded a mean iodine content of 413 µg/kg w.w. with a coefficient of variation of 34 %.

The iodine content of the Alaska pollock raw material is obviously very inconsistent, leading to large variations not only within a package but also between packages. After frying we found iodine concentrations which were in the range of the raw material. The mean concentration of ten fried fish fingers was 417 µg I/kg product (w.w.). Due to the large variations found in the raw material and in the fried product, it was not possible to derive further conclusions from the frying experiments with Alaska pollock fish fingers.

The iodine content in fish fingers made from South American hake was lower and did not vary as much. The mean concentration in the raw fish fingers was 134 µg iodine/kg w.w. and in the fish core of a second package an average of 183 µg/kg w.w. was found.

Distribution of iodine in dark and light fish muscle

Visual inspection of the fish core of Alaska pollock fish fingers revealed different proportions of dark muscle in the meat which probably is related to the production process of fish fingers. Fish fingers are cut of quick frozen fillet blocks from Alaska pollock, where the fillets of various fishes have been mixed and pressed together to form a block. This results in a irregular position of the fillets within the block. All fillets contain approximately the same amount of dark muscle, therefore fish fingers produced from these blocks must yield varying amounts of dark muscle.

Our interest focused on the question if the different amounts of the dark muscle could be responsible for the observed variation of the iodine content in Alaska pollock fish fingers.

Tab. 4 Iodine content in fish fingers from consumer packages (n = 10 fish fingers)

Product	Package No	Species		Weight [g]	Water [%]	iodine [µg/kg]
Whole fish fingers	1	AP	raw	31.2 ± 1.1	62.1 ± 0.8	308 ± 112
Whole fish fingers	2	AP	fried	30.9 ± 1.4	52.3 ± 1.9	417 ± 188
Fish core	3	AP	raw	16.1 ± 0.9	76.8 ± 1.3	431 ± 148
Fish core	4	AP	raw	17.8 ± 1.1	81.1 ± 0.6	530 ± 210
Batter	4	AP	raw	n d	n d	232 ± 60
Whole fish fingers	5	H	raw	30.6 ± 1.6	64.0 ± 1.1	134 ± 11
Fish core	6	H	raw	18.3 ± 1.3	n d	183 ± 62

AP: Alaska pollock; H: Hake; n d: not determined

The dark and light muscle part of the fish core of Alaska pollock fish fingers were carefully separated and analysed. The iodine content of the dark muscle was three times as much as the light muscle (Tab. 5). This finding indicates a possible relation between amount of dark muscle and the iodine content of fish fingers. To verify the results of different iodine concentrations in light and dark muscle meat, fillets from saithe (*Pollachius virens*) and mackerel *(Scomber scombrus*) were studied as well. The fishes were filleted and the dark and light muscle of one fillet was analysed separately and the other fillet as whole. The results are given in Table 5.

The amount of dark muscle of the mackerel and saithe fillets was approximately 20 %[20] and the iodine content was again significantly higher compared to the light muscle.

The theoretical iodine content of the whole fillet calculated from the iodine content of each compartment, taken the relative amount of light and dark muscle into account, corresponded well with the measured iodine content of the other fillet.

The results showed that the dark muscle of the three species analysed, contained approximately three times more iodine than the light muscle.

The reason for the specific accumulation of iodine in the dark muscle is to our knowledge still unknown.

Tab. 5 Iodine content in light and dark muscle (Iodine in µg/kg w. w., weight in %)

	Whole fillet		Light muscle		Dark muscle	
	Measured	Calculated				
	Iodine	Iodine	Iodine	Weight	Iodine	Weight
Fish core AP	–	–	530	–	1550	–
Mackerel	438	427	310	79.6	885	20.4
Mackerel	330	386	294	79.1	738	20.9
Saithe	380	348	268	78.0	631	22.0

Tab. 6 Changes during smoking of ocean perch and herring fillets

	Raw	Smoked	Change [%]
Ocean perch (n = 9)	mean and range		
Weight [g]	160 105–229	137 92–197	–13.3 –10.7–(–16.5)
Iodine content [µg/kg w.w.] Rel. amount of iodine [µg]	330 227–422 326	421 310–546 364[a)]	+ 29.5 10.4–47.2 + 11.9
Herring fillets (n = 10)			
Iodine content [µg/kg w. w.]	757[b)] 636–1063	871 697–1434	+ 14.4 –1.3–34.9

[a)] considering weight losses during smoking; [b)] raw salted fillet

3.2 Smoking

Hot smoked fishery products have a long tradition on the German market and a variety of different fish species are used as raw material. The smoking process includes salting and heating of fish to a core temperature of 60 °C under application of freshly developed wood smoke. Changes of iodine content during smoking were followed for two typical products- hot smoked ocean perch portions and hot smoked herring fillets. To overcome the problem of different iodine content in raw and smoked samples, gutted and beheaded ocean perch were divided into two similar portions, one was analysed raw and the other smoked, respectively.

In case of herring, skin-on butterfly fillets were used. The fillets were salted and then divided into right and left fillet. One was smoked and the other was analysed without further treatment.

For ocean perch the weight loss during hot smoking (including salting and smoking) was followed. On average a reduction of 13.3 % was observed (Tab. 6).

The absolute iodine content per gram ocean perch portion increased considerably during smoking from initially 330 µg I/kg w. w. to 421 µg/kg, being an increase of approx. 30 %.

The true retention of nutrients can be calculated when the weight loss is taken into account[21]. Based on this calculation, the smoked ocean perch portions contained about 12 % more iodine than the corresponding raw material. This indicates that some additional iodine had been taken up during the smoking process. Wood smoke does not deliberate any iodine, thus the iodine uptake must have occurred during the salting step.

This was supported by a second trial with herring. This time the iodine content was compared between salted and smoked herring fillets and the increase per gram product was only 14 %. Considering a same weight loss for herring fillets as for ocean perch, all iodine remained in the herring fillets and no additional iodine was taken up (Tab. 6). Therefore, the noticed additional uptake in smoked ocean perch portions could only be attributed to the salting step due to some iodine in the salt applied as all other smoking conditions were similar.

The results show that no significant reduction of the initial iodine content occurs during smoking of fish.

4 Conclusions

Typical German household preparations of fish like thawing, steaming and frying have been studied with respect to possible changes of the iodine content. The iodine loss during thawing of deep frozen fish corresponds to the drip loss and is moderate, over 90 % remained in the flesh. During steaming of fish at 90 °C some iodine gets lost with the drip water, but again over 90 % remained in the cooked flesh.

Frying of fish prevented any iodine loss and the iodine concentration of the final product increased due to evaporation of some water.

It can be concluded that normal household handling to prepare a fish meals has no or only minor effect on the valuable iodine concentration of the original fish.

The smoking process has a positive effect on the iodine content. Smoked fish products can contain 10–20 % more iodine compared to the corresponding raw material because of weight losses during processing. The iodine content could even been increased if iodine enriched salt would be applied in the process.

The results furthermore demonstrate that the iodine contents of fish fingers depend on the fish species and the amount of dark muscle of the fish core. Dark muscle of fillets contains more iodine then the corresponding white flesh.

Consequently the commercially often applied procedure of deep skinning of fish to produce a more white and sometimes more stable deep frozen product will reduce the iodine content of the original raw material.

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