How much Baltic salmon can be consumed without exceeding the tolerable safety limit ?

Henrik Rosendahl Kristiansen[1]

[1]Mobile Nutrients Ltd.

Introduction

Because Baltic salmon is a top predator preying on sprat, herring and tobis, it is very vulnerable to contamination with dioxin and PCBs. The EU safety limit (SL) for fish is 4 picogram (pg) WHO-TEQ g^{-1} fresh fish[1]. In April 2004, Danish commercial salmon fishing was banned to in the Baltic sea around Bornholm and Gotland (mainly ICES areas 25, 26)[2], because the Food Administration reported dioxin levels exceeding the intervention level of 3 pg g^{-1} fresh salmon[3]. Their report was based on data from 10 individual salmon, and 3 pooled samples, each with 10 salmon. Since dioxins are widespread in the environment, the human population face a trade off to produce sufficient food that is safe to eat and avoid eating contaminated food. The world population is increasing, and the demand for healthy food is steadily increasing. Consequently, there is a need for risk assessments, where the consequences of eating foods with different grades of contamination is evaluated. The evaluation must be based on data of high quality, and because dioxin accumulation is a slow proces, the risk assessments should consider long time periods of months and years instead of days and weeks.

The purpose of the present study is to evaluate the statistical variation of dioxin data from Baltic herring and salmon. The data are used to calculate the quantity of herring and salmon, that humans of different body weight can eat without exceeding the tolerable daily intake (TDI). (In dietary recommendations exposure from dairy products etc. must also be taken into account). A PCDD/F box model is proposed that subtract losses during cooking and postprandially.

Materials and Methods

The herring and salmon data were obtained from four sources:
The Sea Fisheries Institute (SFI) Gdynia, Poland
The National Food Administration (NFA), Uppsala, Sweden
The Danish Veterinary and Food Administration (DFFA), Soeborg, Denmark
The Government Department for Health and Consumer Protection (GDHCP), Kiel, Germany

PCB like dioxins are not included in the data.

Each fish was given a random consecutive number, which was used to estimate the running mean (X-axes in the diagrams). Data were normal distributed (Kolmogorov-Smirnov test with Lilliefors correction), and 95% confidence limits (CL) were calculated along with coefficient of variations (CV=SD mean^{-1} % 100%) (Sigma Stat 2.0, Jandel Scientific, 1995).

Tolerable daily dioxin intake (TDI_d, pg kg^{-1} day^{-1}) was recalculated to picogram (pg day^{-1}) from PD = W % TDI_d. Further, TDI of fresh salmon (TDI_{fs}) at the invention value (3 pg g^{-1} fresh weight) was calculated from TDI_{fs} = PD x IV^{-1}. See foodnote (Tab 1). PD = Picogram dioxins; W = Body weight; TDI = Tolerable Daily Intake; IV = Intervention value.

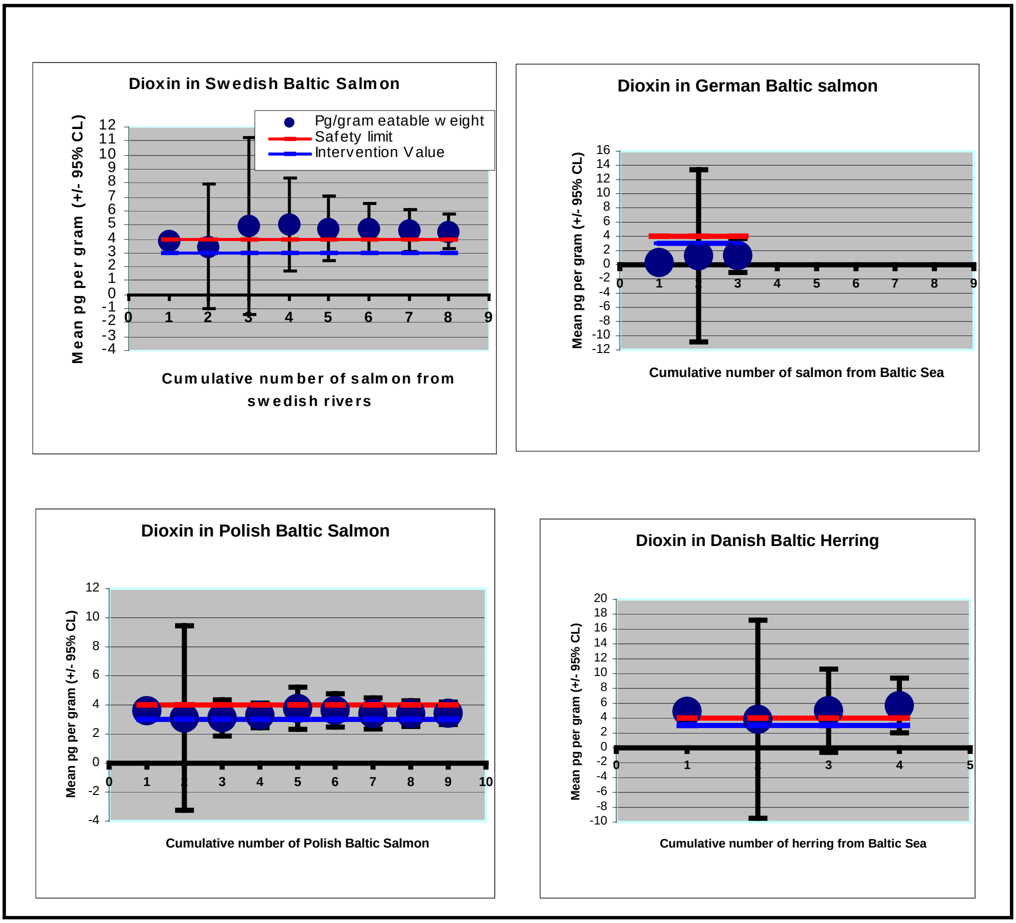
Results and Discussion

Data are given as mean pg PCDD/F WHO-TEQ g^{-1} fresh salmon ! 95% CL [range] (coefficient of variation). Dioxin in 8 swedish salmon exceeded the IV (4.5 ! 1.3 [3.1-7.8] (12%). Among 9 Polish salmon, 6 exceeded the IV (3.4 ! 0.8 [2.1-5.7] (7%). The 3 German salmon fell below the IV (1.3 ! 2.4 [0.3-2.2] (60%), whereas 3 out of 4 Danish herring exceeded the IV (5.7 ! 3.7) [2.8-7.8] (16%).

One problem with the comparisons is that the exact sample locations were not specified. The reason behind the very small sample sizes is probably the high cost to run GC-MS analysis[4]. The samples are not considered representative for the Baltic fishing area.

The interpretations would be easier if the analysis always were presented with the name of the laboratory and the type of authorisation. A major aspect affecting the results is whether fat containing tissue (skin) was removed before analysis. According to the NFA, more than half of the dioxins occur in the skin. The method of fat extraction should also follow the data. It has been shown in ring tests that there is a huge variation between laboratories[5]. If surveillance dioxin data exceed the IV, it should be recommended to repeat the analysis at least in one other independent laboratory in a double blind approach (only sample number is known by the parties).

The running means (Figs 1, 2, 3 and 4) is a tool to estimate the sample size, when the mean is robust and the CL is small. In Swedish salmon there was no doubth that means exceeded IV, but a sample size of 6-8 was necessary to narrow CL´s. Polish salmon is an interesting case, where the final mean is below the SL and above the IV. It is a matter of interpretation, whether the lot is acceptable or non-compliant with the SL. The German salmon is even more interesting, because individual salmon are below IV, but because the variation is high, the 95% CL exceed the IV, and approximate the SL. In such a border situation, it is important to clarify the EC Directive 2004/44/EC[6] , that "the taking into account of the measurement uncertainty can be done by calculating the expanded uncertainty, using a coverage factor of 2, which gives a level of confidence of approximately 95%". In statistical terms this mean that 2 % standard error approximate 95% CL. However, this was only the case when means were based on at least 6 salmon.



The tolerable daily intake (TDI), established by WHO, is 1-4 picogram g^{-1} day^{-1} through the life span of humans[7]. It was assumed that the two boundary figures correspond to a minimum and a maximum value. The relative TDI interval is then recalculated to pg dioxins day^{-1} at body weights of 25, 50, 75 and 100 kg, respectively (Tab 1). The absolute TDI´s for children and adults vary between 25 and 400 pg.

These TDI_d estimates was further recalculated to salmon TDI_{fs}´s using the intervention value of 3 pg g^{-1}, when the Danish government decided to intervene and ban commercial Baltic salmon fishing[2]. It appears (Tab 1), that a 25 kg child safely can eat 8-33 g, whereas adults from 75-100 kg can eat 25-133 gram. However, since dioxins from other foods may constitute a significant part of the dioxin budget, this must be included in dietary recommendations. It is interesting to notice that the maximum TDI for a child of 25 kg corresponds to the minimum TDI for a 100 kg adult. The TDI_{fs} was recalculated to weeks, months and years, because dioxin accumulate in the body over long time periods (Tab 2). Salmon is delicacy, and it is reasonable to assume that most people eat much less than these figures (Tab 2).

According to DFFA, dioxins enter the danes through fat fish (44%), dairy products (40%), meat (13%) and eggs (3%). Consequently, dioxin intake from fish exemplified with salmon (Tab 2) should be reduced accordingly. However, as shown in the box model this is balanced by preprandial and postprandial losses. The input data are probably so variable that even controlled clinical trials will give very different results.

Table 1: TDI_d at different body weights. TDI_{sf} of salmon with 3 pg dioxins g^{-1} (The intervention value, IV)

	TDI_d		TDI_{sf}	
Body weight (W)	1 pg kg^{-1} day^{-1}	4 pg kg^{-1} day^{-1}	1 pg kg^{-1} day^{-1}	4 pg kg^{-1} day^{-1}
Kg	Picogram dioxins (PD)[1]		Gram fresh salmon (TDI_{fs})[2]	
25	25	100	8	33
50	50	200	17	67
75	75	300	25	100
100	100	400	33	133

PD[1] = W % TDI_d; example: 25 kg % 4 pg kg^{-1} day^{-1} = 100 pg dioxin day^{-1}
$TDI_{fs}{}^{2}$ = PD % IV^{-1}; example: 100 pg % (3 pg g^{-1} fresh salmon)$^{-1}$ = 33.3 g fresh salmon day^{-1}

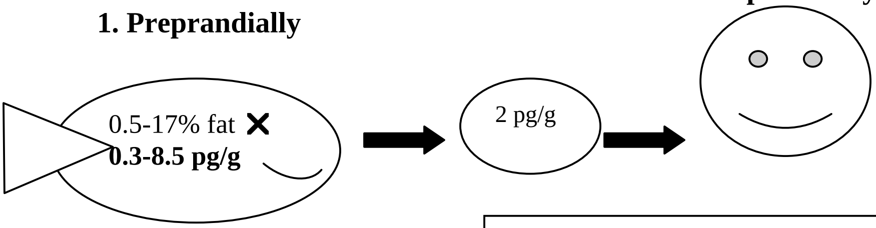
Table 2: Tolerable intake of Baltic salmon with 3 pg dioxins g^{-1} (IV), and at 100% excess (2x IV) for man of 75 kg body weight.

Period	3 pg g^{-1} (IV)		6 pg g^{-1} (2 % IV)	
	Min	Max	Min	Max
	g fresh salmon			
Day	25	100	12.5	50
Week	175	700	87.5	350
Month	750	3000	375	1500
Year	9125	36500	4562.5	18250
Year	9 kg	37 kg	4.5 kg	18.5 kg

Box model - PCDD/F in salmon

1. Preprandially

2. Postprandially



Cooking

Frying (50%)

Skin removal (50%)

Fresh salmon (8 pg/g)

Petroske *et al.* (1998)
Zabik & Zabik (1999)
Rose *et al.* (2001)
Schecter *et al.* (1998)

3. Postabsorption

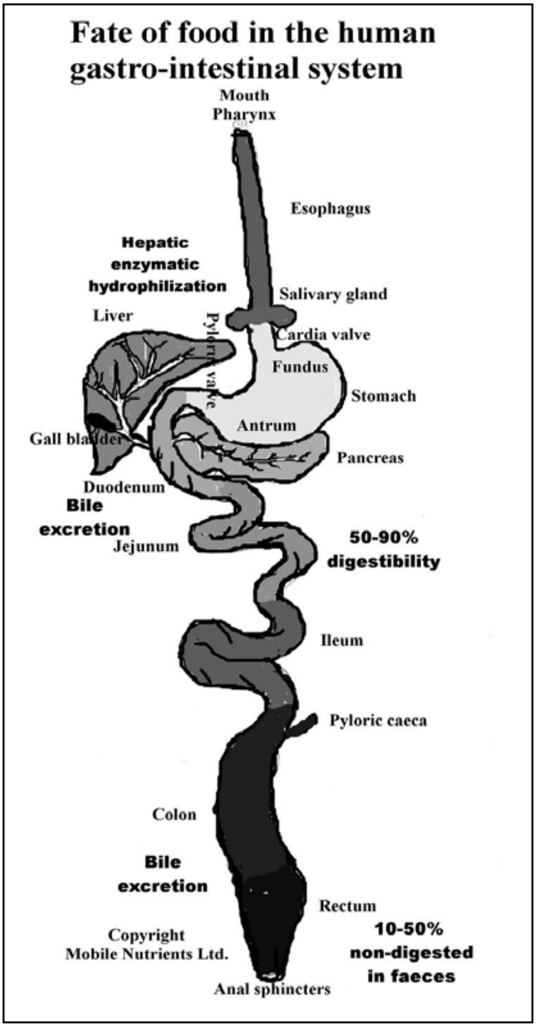
Transport in lymphatic chylomicrons
1 h residence time in blood

74-81% deposition in liver and fat tissues as dioxin-lipoprotein complexes (VLDL, LDL, HDL)

Dioxin Ah-receptor binding

Liver enzymes convert dioxins to partly water soluble metabolites. Excretion through bile.

T_{50} (2,3,7,8 – TCDD) is 5.5-11 yr



JECFA (2001)

The SL shall be reviewed for the first time by 31 dec. 2004 in the light of the new data on the presence of dioxins and dioxin-like PCBs, in particular with a view to the inclusion of dioxin-like levels[1].

Box model

The human exposure to PCBs depend on the factors outlined in the PCDD/F box model. Skin removal and cooking can reduce the fat, and thus the dioxin content of fish substantially[8,9,10,11].

The body has two mechanisms, whereby dioxin load of the body may be reduced. The first is selective absorption, where 10-50% of dioxins has been reported to be non-absorbed and pass through the gastro-intestinal system. The second is two enzyme systems in the liver that convert dioxins to partly soluble compounds, which can be excreted in the bile, transported to the *duodenum* and excreted along with the non-absorbed dioxins through the rectum[12]. Consequently the postfrying and postprandial effects must be taken into consideration.

Conclusion

Dioxin surveillance is important, but sample size and data quality must be substantially improved, when data interpretation can close a fishing area. Intervention values are relative units, which should be recalculated to absolute dietary recommendations in communications with the public. The risk assessments need more clinical data to support the pre-clinical animal studies. Dioxins are everywhere, and it is important to know how the body get rid of them.

Acknowledgements

To the governmental bodies for the public available data.

References

1 Official Journal of the EC (2001). Council Regulation No. 2375/2001 of 29 Nov.
2 Danish Ministry of Food, Fisheries and Agriculture (2004). Departmental order banning fisheries and salmon catch in the Baltic sea, and prohibition against sale of salmon caught in the Baltic sea. Departmental order No. 0, 6 April 2004.
3 Official Journal of the EC (2002) L67, 69-73. Commission Recommendation of 4 march, 2002 (notified under document number C(2002), 836.
4 US EPA (1999) Method 1613. Tetra- through octa-chlorinated dioxins and furans by isotope dilution HRGC/HRMS. 86 pp. US Environmental Protection Agency.
5 Lindstrom, G., Hang, L. S, Nicolaisen, T. & Dybing, E. (2002) Chemosphere 47, 139.
6 Official Journal of the EU (2004) 47, L113, 17-18. Commission Directive of 13 april 2004.
7 Van Leeuwen, F. X. R., Feeley, M., Schrenk, D., Larsen, J. C., Farland, W. & Yonnes, M. (2000) Chemosphere 40, 1095.
8 Petroske, E., Zarylskie, R. G. & Feil, V. J. (1998) J. Agric Food Chem. 46(8), 3280.
9 Zabik, M. E. & Zabik, M. J. (1999) Adv. Exp. Med. Biol. 459, 213.
10 Rose, M., Thorpe, S., Kelly, M., Harrison, N. & Startin, J. (2001) Chemosphere 43 (4-7),861.
11 Schecter, A., Dellarco, M., Papke, O. & Olson, J. (1998) Chemosphere 37 (9-12), 1723.
12 JECFA (2001) Joint FAO/WHO Expert Committee on food additives. Fifty-seventh meeting, Rome, 5-14 June 2001. Food and Agriculture Organization of the United Nations and World Health Organization.