DIOXINS IN LIVER: A REGULATORY CONUNDRUM

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Introduction

In 2002, the European Commission introduced regulatory limits for dioxins in a range of food types, including carcass meat and liver[1]. Limits were established taking into account available data and, for both meat and liver, the limits were expressed on a fat basis. The limit for liver was established on the basis of the results for a small number of samples that were available at the time, covering all animals. A survey for dioxins and PCBs in offal was carried out in the UK during 2005 and 2006, which included liver of cows, lambs, pigs, chickens and venison (mainly red deer), as well as kidney, heart and other offal-based food products. High results were reported for a significant proportion of lamb and venison liver[2]. Further investigations suggested that this was not due to poor husbandry practices or high localised contamination but is much more likely to be associated with the physiology of the animals. Subsequent data provided from the Irish Republic supports this view[3].

Materials and methods

Samples of offal, including 22 liver of lamb and 2 of venison were obtained from randomly-selected retail outlets throughout the UK between April and June 2005. An additional eight samples of venison liver from different geographical locations were obtained from a Scottish retail outlet in March 2006. The samples were analysed for the 17 dioxins and furan congeners and 12 dioxin-like PCBs assigned toxic equivalency factors by the World Health Organization by the Central Science Laboratory (CSL) using high resolution gas chromatography coupled with high or low resolution mass spectrometry. Full details of the analytical methodology[4] can be found in the analytical contractor's final report for the survey[5]. All results met published analytical quality assurance criteria[6].

Results and Discussion

A summary of results for dioxins in liver is provided in Table 1. Notably, high results were reported for the dioxin levels in 11 out of 22 samples of sheep/lamb's liver. These included nine that were above the existing EU limit of 6.0 pg WHO-TEQ/g fat[7]. A further two samples were above the EU Action Level of 4.0 pg WHO-TEQ/g fat[8]. In the case of venison, to which the regulations do not apply, both of the samples tested were significantly above 6 pg/g fat. In the light of the results for venison liver, a further eight samples were obtained.

Table 1: Summary of results for liver samples tested

Sample	Total number tested	Number over EU action level	Number over EU limit
Calf/veal	5	1	0
Chicken/poultry	14	0	0
Lamb	22	2	9
Ox	7	1	0
Pig	21	2	0
Venison*	10	0	(10)
TOTAL	**79**	**6**	**9 (19)**

* Not covered by Commission Regulation 466/2001

More detailed results, including fat content, are shown in Tables 2a (sheep/lamb) and 2b (venison). From an inspection of the data for lamb, there are several important points of note. Firstly, about half of the lamb liver samples contained very low levels of dioxin with levels in the range 0.24-1.5 pg/g and 0.03-0.12 pg/g on a fat and a fresh weight basis respectively. The dioxin contents of the remainder ranged from 2.8-25 pg/g (fat) and 0.28-1.2 pg/g (whole weight). The samples were selected at random and information is very limited. Nevertheless, it is possible that the data reflect different ages of animal. In the UK, lamb generally enters the food chain at one of three stages – spring lambs (3 months), year lambs and older animals (including those sold as mutton or halal meat). Spring lambs will have been fed predominantly on their mother's milk. Very little information is available on the dioxin content of sheep's milk, although breast milk is known to be a significant source of dioxin to human infants. Therefore, although it can be speculated that the dioxin content may be related to the age of the animal, further detailed work would need to be carried out to investigate the relationship. Also, it is apparent that there is no correlation between fat content and dioxin content. This is the case whether the dioxin concentration is expressed on a fat or a fresh weight basis. For carcass or muscle meat, because dioxin is associated with the fat present in the sample some correlation would be expected between the fat content and the whole weight dioxin concentration. Finally, the dioxin to dioxin-like PCB ratio in all of the lamb liver samples is very high, ranging from 1.2 to 11.8, with an average of 4.0. For carcass meat of most common food animals, the dioxin to dioxin-like PCB ratio is normally between 1 and 2. Similar observations can be made for venison liver, which was largely from red deer, although the dioxin and PCB levels were generally higher. This may reflect the fact that the animals are older when they enter the food chain.

Table 2a Results for lamb liver (n=22)

Fat	pg WHO-TEQ/g fat		pg WHO-TEQ/g, whole weight		Fat	pg WHO-TEQ/g fat		pg WHO-TEQ/g, whole weight	
	Dioxin	PCB	Dioxin	PCB		Dioxin	PCB	Dioxin	PCB
11.10%	0.24	0.12	0.03	0.01	7.10%	4.0	0.75	0.28	0.05
9.00%	0.35	0.26	0.03	0.02	7.50%	5.2	1.0	0.39	0.07
6.30%	0.54	0.46	0.03	0.03	5.70%	7.0	1.8	0.40	0.10
6.40%	0.65	0.42	0.04	0.03	5.20%	7.5	1.8	0.39	0.09
7.40%	0.66	0.38	0.05	0.03	4.60%	9.1	2.0	0.42	0.09
7.80%	0.92	0.50	0.07	0.04	8.30%	9.8	2.3	0.81	0.19
4.30%	0.93	0.22	0.04	0.01	5.70%	10	2.2	0.60	0.12
7.90%	0.95	0.41	0.08	0.03	6.40%	13	2.3	0.82	0.16
7.90%	1.5	0.59	0.12	0.04	5.80%	14	2.9	0.78	0.17
3.60%	1.5	0.34	0.05	0.01	4.40%	20	1.7	0.88	0.07
4.10%	2.8	1.4	0.11	0.06	4.90%	25	3.2	1.2	0.16

Table 2b Results for venison liver (n=10)

Fat	pg WHO-TEQ/g fat		pg WHO-TEQ/g, whole weight	
	Dioxin	PCB	Dioxin	PCB
2.6%	109	50	2.8	1.3
3.8%	98	22	3.7	0.83
3.7%	92	19	3.4	0.71
4.0%	64	14	2.6	0.56
4.1%	45	17	1.9	0.69
3.3%	32	17	1.0	0.54
3.4%	24	5.9	0.8	0.20
4.5%	24	7.2	1.1	0.32
3.7%	20	5.4	0.74	0.19
4.1%	13	3.7	0.53	0.15

While exceeding the existing regulatory limit was naturally of concern, the most important considerations were, firstly, to assess the risk to consumers and, secondly, to determine whether the limit had been set in an appropriate manner in view of the proportion of lamb liver samples close to or above that limit. In addition, it was essential to consider the implication for consumers of venison liver, for which results as high as 160 pg WHO-TEQ per gram had been reported on a fat basis. Intake estimates based on the samples containing the highest concentrations of dioxin and dioxin-like PCBs are shown in Table 3. The data show the effect that the consumption of one or two 100g portions of liver weekly has on the average daily intake for an adult when taking into account exposure from the rest of the diet. What these figures indicate is that consumption of lamb's liver is likely to have very little impact on overall dietary exposure to dioxins. In the case of venison liver, for which the highest whole weight total TEQ concentrations are similar to those of oily fish, frequent consumption could lead to an exceedence of the Tolerable Daily Intake of 2.0pg WHO-TEQ/kg bodyweight[9].

The possibility that high results were due to high levels of localised contamination was ruled out because not only were the samples obtained from a wide range of UK sources but also there were significant differences in the individual congener profiles. Sheep and deer in the UK are usually reared in an extensive manner, which limits the opportunity to control dioxin exposure through feed. They will, however, be exposed to the low levels of dioxins and PCBs that are to be found in most rural areas.

Table 3 Intake estimates, pg WHO-TEQ/ kg BW.day

Intake from non-offal part of the diet = 0.8	Lamb					Venison		
Concentration in liver (pg WHO-TEQ/g whole weight)	1.4	1.00	0.98	0.95	0.72	4.56	4.14	3.12
Average daily intake from one weekly 100g portion of liver	0.3	0.24	0.2	0.2	0.17	1.1	1.0	0.7
Total daily intake	1.2	1.1	1.1	1.1	1.0	1.9	1.8	1.6
Average daily intake from two weekly portions of liver	0.7	0.48	0.5	0.5	0.34	2.2	2.0	1.5
Total daily intake	1.5	1.3	1.3	1.3	1.2	3.0	2.8	2.3

In order to gain a better understanding of the results, discussions were held with experts in animal physiology who made a number of suggestions. The liver is a target organ for dioxins and PCBs. Dioxins are known to bind to aryl hydrocarbon receptor sites on proteins and these are largely present in the liver. Increased exposure would be expected to lead to the generation of greater amounts of these proteins. It is also known that dioxins tend to bind more strongly than PCBs. Furthermore, ruminants in particular, which include sheep and deer, do not produce large amounts of fat in the liver, which means that the system for transporting dioxins and PCBs from the liver is limited and is likely to favour the less strongly bound PCBs. This would account for the higher dioxin to PCB ratio found in the liver and also why higher levels would be expected in older animals. It also explains the lack of a relationship between fat content and dioxin content. On the other hand, it does mean that, because the analytical method involves extracting the dioxins and PCBs present in the sample into the fat phase, they will be concentrated and a sample containing a lower level of fat may therefore show a higher fat-based concentration.

In light of these results, it is apparent that the existing limits of 6.0 pg WHO-TEQ/g fat for dioxins and 12.0 pg/g fat for dioxins plus dioxin-like PCBs may need to be revised. On the basis of available data, it should be possible to set limits for lamb's liver expressed on a whole weight basis that continue to provide an adequate level of consumer protection. In the case of venison liver, it might be necessary to provide advice to consumers to limit consumption. However, it is of note that UK consumer advice already recommends that all liver consumption should be limited in order to avoid the excessive intake of vitamin A[10], which has been associated with possible foetal damage and also brittle bones in the elderly.

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