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A farm survey on the presence of dioxins and dl-PCB in beef production systems in Switzerland

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In 2006, new maximum levels for the concentration of dioxins (PCDD/F) and dioxin-like PCB (dl-PCB) in food entered into force in the European Union [Regulation (EC) No 199/2006]. The Swiss Confederation decided to adopt these values from the 1 January 2009 on (RS 817.021.23). A previous appraisal showed that beef from extensive production systems in Switzerland may exceed the new maximum level of 4.5 pg WHO_{97}-TEQ·g^{-1} fat. In order to identify the reasons of the presence of dioxins (PCDD/F) and dioxin-like PCB in Swiss beef, a detailed survey was conducted on eight farms in 2008. Depending on the production system, on each farm several suckler cows and their calves or fattening bulls and heifers were selected and followed over several months. Samples of soil, milk, forages, concentrates and meat were taken and analyzed according to standard protocols. The sum of PCDD/F and dl-PCBs in soil averaged 1.4 pg WHO_{97}-TEQ·g^{-1} dry matter (DM) across all farms. The mean value found in feed samples was 0.25 pg WHO_{97}-TEQ·g^{-1} feed (88% DM), which is considerably lower than the legal maximum level of 1.25 pg WHO_{97}-TEQ·g^{-1} feed. The mean value of milk from suckler cows was 2.75 pg, and the one of milk from dairy cows was 2 pg WHO_{97}-TEQ·g^{-1} fat. Although two individual beef samples (out of 36) slightly exceeded the legal limit of 4.5 pg WHO_{97}-TEQ·g^{-1} fat, the mean value of all beef samples was 2.3 pg WHO_{97}-TEQ·g^{-1} fat. The results did not allow to establish direct relationships between the presence of contaminants in feeds and milk or beef and they showed that variation in PCDD/F and dl-PCB contamination of meat within the same farm was very high. It can be concluded that the situation in Switzerland seems not to be alarming and that no particular measures have to be taken. Nevertheless farmers should be aware that extensive production coupled with absence of delay between weaning and slaughtering may induce some risk for producing non compliant beef.
Keywords. Beef, dioxins, milk, PCDD, PCDF, dl-PCB, suckler cows, Switzerland.

1. INTRODUCTION

Dioxins cover a group of 75 polychlorinated dibenzo-p-dioxin (PCDD) congeners and 135 polychlorinated -dibenzofuran (PCDF) congeners, which are summarized under the abbreviation PCDD/F. Polychlorinated biphenyls (PCB) are a group of 209 different congeners which can be divided into two groups according to their toxicological properties. A small number exhibit toxicological properties similar to dioxins and are therefore termed dioxin-like PCB (dl-PCB). The majority does not exhibit dioxin-like toxicity but has a different toxicological profile. Each congener of PCDD/F and dl-PCB exhibits a different level of toxicity. Over all only 17 congeners of PCDD/F and 12 congeners of dl-PCB are of interest due to their toxicity. In order to be able to sum up the toxicity of these different congeners, the concept of toxic equivalency factors (TEF) has been introduced. This means that the analytical results relating to all the individual PCDD/F and dl-PCB congeners of toxicological concern are expressed in terms of a quantifiable unit, the toxic equivalent (TEQ).

In the environment, these compounds decompose very slowly and due to their liposolubility they accumulate in the food chain and represent a serious hazard for human and animal health. In 2006, new maximum levels for the concentration of PCDD/F and dl-PCB in food entered into force in the European Union [Regulation (EC) No 199/2006]. With regard to these changes, the Federal Office of Public Health, the Federal Veterinary Office and the Research Station Agroscope Liebefeld-Posieux (ALP) conducted a preliminary appraisal to assess the current level of PCDD/F and dl-PCB contamination of beef in Switzerland (BAG, 2008). The results of this appraisal showed that part of the beef samples originating from extensive production systems exceeded the new maximum level of 4.5 pg WHO_{97}-TEQ·g^{-1} fat. As the Swiss Confederation had decided to adopt this value from the 1 January 2009 on (RS 817.021.23), a subsequent study was conducted by ALP in collaboration with the Federal Office of

Public Health, the Federal Veterinary Office, the Federal Office for Agriculture and the Federal Office for the Environment to identify the reasons of these exceedances and to give advice to farmers about possible measures to respect the new regulations.

2. MATERIALS AND METHODS

Based on the results of the preliminary appraisal (BAG, 2008), eight farms were selected. The farms were located in the north-western, the western and the central part of Switzerland. Six out of the eight farms were grouped by couples. The farms of a couple were located close to each other. In the previous study, one farm of each couple had presented a value above the new maximum level and the other one below. This arrangement was made in order to identify possible local sources of contamination. A further farm was selected because of its special production system. On this farm, calves were exclusively fed with milk from suckler cows, complemented with hay and cereals until slaughtering. The farms were visited once per month from April to November 2008. Depending on the production system, on each farm several suckler cows and their calves or fattening bulls and heifers were selected and samples of soil, feed, milk, and beef were taken during this period.

Soil samples were taken from the pastures and grazing areas by means of a manual bucket auger from points distributed along a transect within the farm area. The first 10 cm of the soil cores obtained were air-dried, ground with an electric mortar and homogenized. A subsample of 300 g of soil per farm was taken for subsequent analyses. On the farm where calves only consumed milk from suckler cows and cereals, no soil sample was taken, because soil was not considered as a potential source of contamination. Consequently only 7 soil samples were analyzed in this survey.

Samples of forages and other diet ingredients were taken separately, oven-dried, ground in a laboratory mill and homogenized. Subsequently samples were mixed according to the proportion of the individual diet ingredient in the total daily ration of the animals (*i.e.* only one diet sample was analyzed per farm and sampling period). Since diet composition varied during the survey period, samples were taken at monthly intervals. Overall 45 feed samples were analyzed.

Samples of milk from suckler cows were taken at monthly intervals until the calves were weaned. On the farms, where calves received milk from dairy cows or milk replacer, samples of these feeds were taken. Prior to analyses, samples of milk (500 ml) were lyophilized, ground and homogenized. All in all 59 milk samples were analyzed.

Meat samples were taken at the moment of slaughtering. For this purpose 500 g of the right hind leg were cut and immediately frozen. A total of 36 meat samples were analyzed.

All samples were sent to the laboratory of Eurofins at Hamburg (Germany) and analyses were conducted according to the Commissions regulation (EC) No 1883/2006 concerning methods of sampling and analysis for the official control of levels of dioxins and dioxin-like PCB in foodstuffs. All results given in this study are upper-bound levels.

In addition a questionnaire was developed for collecting information on farm history, production system, feeding system (*e.g.* forage production, diet composition), factors related to the calf (breed, date of birth, date of weaning, date of slaughtering, body condition score at slaughtering), factors related to the cow (breed, age, number of lactation, month of lactation), and potential local sources of contamination. A summarized description of the production and feeding systems of the selected farms is given in **table 1**.

Statistical analyses were performed considering the fact that data on PCDD/F and dl-PDB were not normally distributed. The tests used to identify significant relationships or differences were the Spearman's rank correlation, the Kruskall-Wallis-test and the Mann-Whitney-test.

3. RESULTS

The sum of PCDD/F and dl-PCB in soil varied between 0.7 and 2.0 pg WHO_{97}-TEQ·g^{-1} dry matter (DM), and no influence of the geographical location was apparent. No relationship between farms of the same couple could be found. The median value of the sum of PCDD/F and PCB was 1.4 pg WHO_{97}-TEQ·g^{-1} DM. In all samples the concentration of PCDD/F was clearly higher than the concentration of dl-PCB.

In the daily rations, the concentration of PCDD/F did not vary between the production systems. By contrast, the dietary concentration of PCB and the sum of PCDD/F and dl-PCB was clearly lower ($P < 0.01$) in intensive systems than in extensive systems (**Figure 1**). The median value of the sum of PCDD/F and dl-PCB was 0.25 pg WHO_{97}-TEQ·g^{-1} of diet (88% DM). Concentrations of PCDD/F and dl-PCB in grass samples did not vary much and no effects of the location or relationships between farms of the same couple could be seen. Contrary to the soil samples, in feed the concentration of PCDD/F was lower than the concentration of dl-PCB.

The sum of PCDD/F and dl-PCB in individual milk samples ranged from 1.1 to 7.9 pg WHO_{97}-TEQ·g^{-1} fat and varied heavily within farm (**Figure 2**).

Table 1. Summarized description of the production and feeding systems of the selected farms.

Farm No	Denomination	Production intensity	Age at weaning (months)	Age at slaughtering (months)	Feeding	Concentration in soil (pg WHO_{97}-TEQ·g^{-1} DM)	
						PCDD/F	PCB
1	Cattle intensive	Intensive	3	16-19	Milk from dairy cows, milk replacer, silage, hay, concentrate	0.67	0.25
2	Cattle intensive	Intensive	4	15-22	Milk from dairy cows, milk replacer, silage, hay, concentrate	1.11	0.41
3	Calves semi-intensive	Semi-intensive	5-6	5-6	Mainly milk from suckler cows, small amounts of hay and cereals	ND	ND
4	Cattle extensive	Extensive	9	20-29	Milk from suckler cows, pasture, silage, hay	0.60	0.34
5	Cattle extensive and calves from suckler cows on pasture*	Extensive	7-10	10-21	Milk from suckler cows, pasture, silage, hay	1.33	0.49
6	Calves from suckler cows on pasture	Extensive	10	10	Milk from suckler cows, pasture, silage, hay	0.51	0.19
7	Calves from suckler cows on pasture	Extensive	10	10	Milk from suckler cows, pasture, silage, hay	1.22	0.75
8	Calves from suckler cows on pasture	Extensive	10	10	Milk from suckler cows, pasture, silage, hay	1.49	0.37

* This farm had two production systems. Some animals were slaughtered directly after weaning at 10 months and the others were weaned at 7 months and finished on pasture, silage and hay for 8 to 14 months; ND: not determined.

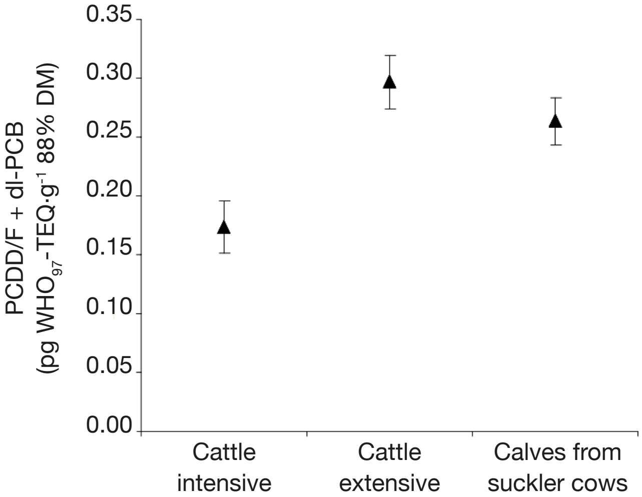

Figure 1. Sum of PCDD/F and dl-PCB (median and standard deviation) in the daily ration depending on the production system (cattle intensive, n = 9; cattle extensive, n = 11; calves from suckler cows on pasture, n = 18).

Despite this large within-farm variation a certain effect of the cow type could be observed. Milk from dairy cows showed a lower ($P < 0.05$) concentration of PCDD/F and dl-PCB than milk from suckler cows (2.00 *vs* 2.75 pg WHO_{97}-TEQ·g^{-1} fat). Number or month of lactation had no effect ($P > 0.05$) on the contamination with PCDD/F and dl-PCB.

In meat, the concentrations of PCDD/F and dl-PCB varied considerably between and within farms. The sum of PCDD/F and dl-PCB of individual samples ranged from 0.76 to 5.7 pg WHO_{97}-TEQ·g^{-1} fat. Meat from intensively managed cattle (farms No 1 and 2) showed lower ($P < 0.01$) levels of contamination than meat from all other production systems (**Figure 3**). Despite the relatively intensive production system on farm No 3 (calves semi-intensive), the meat produced on this farm presented similar levels of contamination as the meat produced in extensive systems (cattle extensive and calves from suckler cows on pasture, farms No 4-8). Overall two individual meat samples (out of 36) slightly exceeded the legal limit of 4.5 pg WHO_{97}-TEQ·g^{-1} fat for the sum of PCDD/F and dl-PCB. The median value of all meat samples was 2.3 pg WHO_{97}-TEQ·g^{-1} fat. The duration of the period between weaning and slaughtering had a significant effect on the contamination with PCDD/F and dl-PCB (**Figure 4**). Meat from animals which consumed milk from suckler cows until slaughtering showed considerably higher levels ($P < 0.05$) of contamination than meat from animals which had

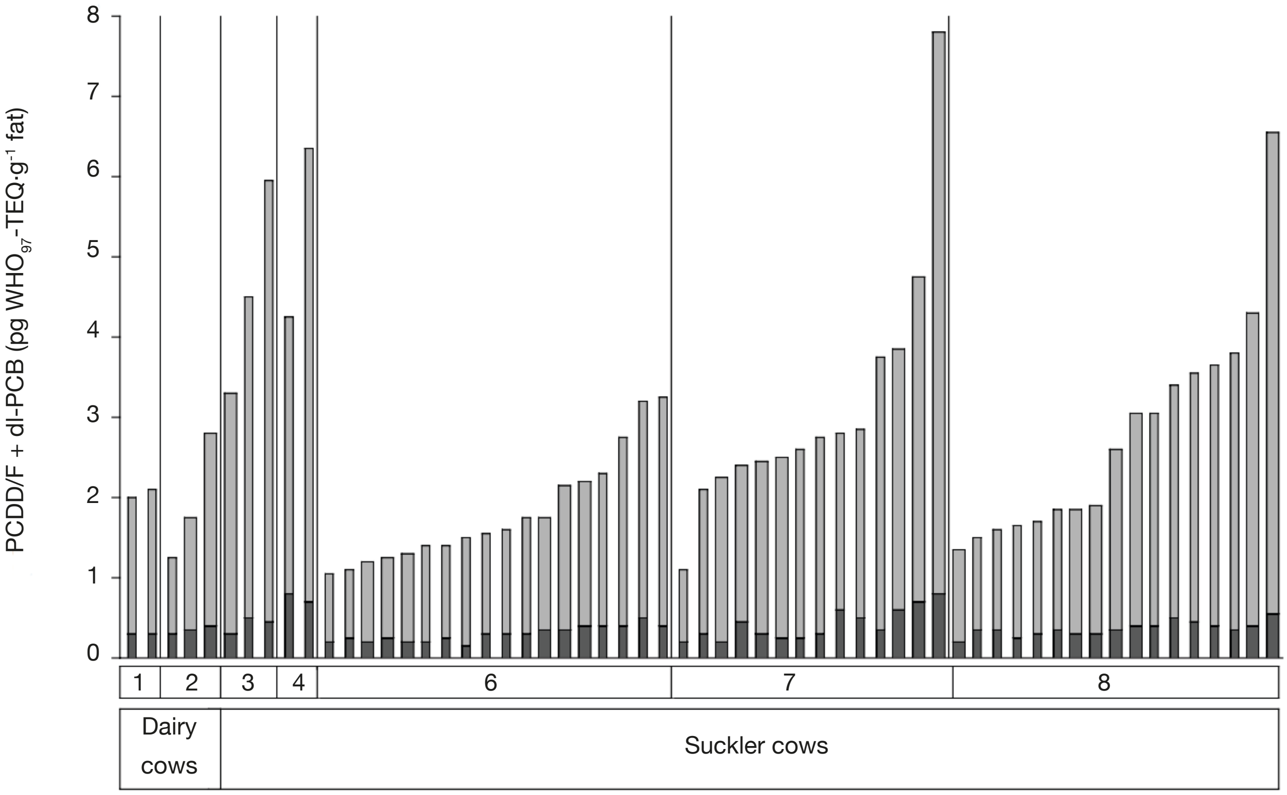

Figure 2. Concentration of PCDD/F (■) and dl-PCB (■) in milk for each farm (individual values).

For the explanation of the farm numbers, see **table 1.**

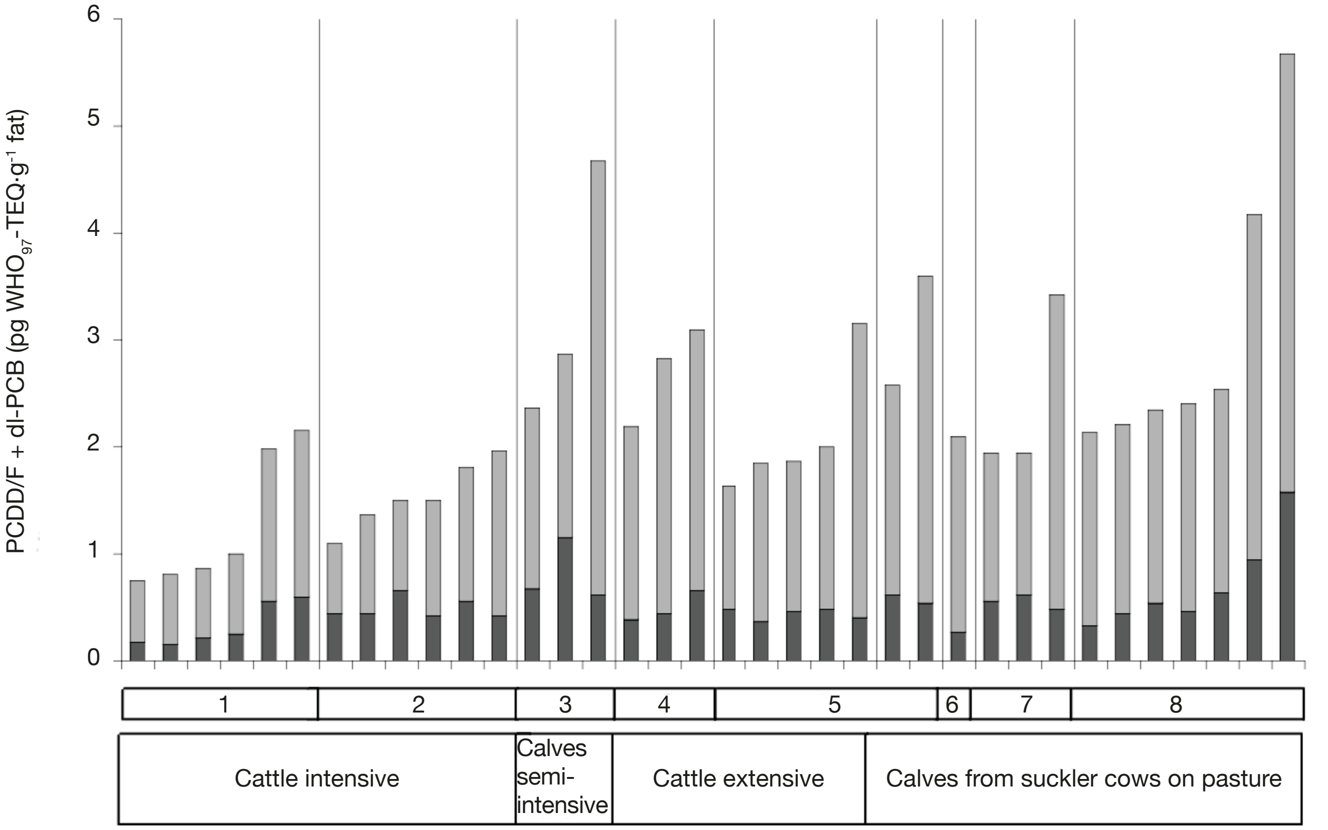

Figure 3. Concentration of PCDD/F (■) and dl-PCB (■) in beef for each farm grouped by production system (individual values).

For the explanation of the farm numbers, see **table 1.**

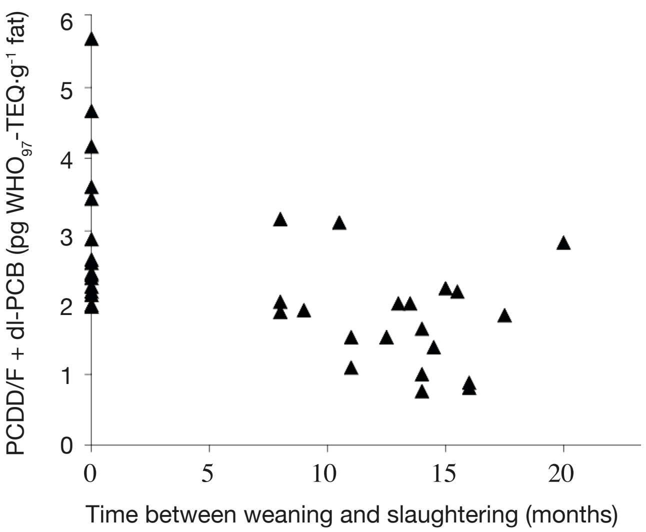

Figure 4. Sum of PCDD/F and dl-PCB in beef dependent on the period between weaning and slaughtering (n = 36).

been weaned several months before slaughtering. No effect ($P > 0.05$) of breed or number of lactation of the mother on the contamination with PCDD/F and dl-PCB was found.

4. DISCUSSION

One objective of this study was to identify possible local sources of contamination. Therefore farms which were located close to each other and had presented contrasting levels of contamination in the previous study were grouped by couples. The present study did not confirm the previous results and no systematic difference or relationship between farms of the same couple could be identified. Within-farm variation in the concentration of PCDD/F and dl-PCB in milk and meat was considerable and in part even higher than differences between farms. Furthermore contamination of soil samples was not influenced by the geographical location and had no apparent effect on the contamination of feed, milk or meat. No important local sources of PCDD/F or dl-PCB could be identified. Thus the grouping by couples resulted to be inappropriate and was not further considered in the interpretation of the results.

4.1. Feed

The composition of the daily rations varied according to the production system of the farms. On the extensively managed farms, between May and October 2008, fresh forage represented the most important diet ingredient (approximately 90% of DM). By contrast, on the intensively managed farms, animals only received silage or hay, and the forage proportion in the daily ration was much lower than on the extensively managed farms. As shown in previous studies (André et al., 2003; Czub et al., 2004; Rychen et al., 2008), fresh forage is the most important source of PCDD/F and dl-PCB for ruminants. This suggests that the considerably higher PCDD/F and dl-PCB contamination of the daily rations on extensively managed farms mainly resulted from the higher proportion of fresh forage in the diet.

4.2. Milk

Excretion of milk fat is an important way of elimination of PCDD/F and dl-PCB from the body (Perry et al., 1981). In cattle, a significant proportion of dl-PCB and PCDD/F consumed with the forage is transferred to the milk fat (Ruoff et al., 2007). In general, suckler cows produce clearly less milk and excrete less milk fat than dairy cows. On the other hand the amounts of PCDD/F and dl-PCB to be excreted per day, are similar or even higher in suckler cows, due to the higher proportion of roughages in the diet. Consequently, these substances are more diluted in milk from dairy cows than in milk from suckler cows. This relation was confirmed by the observations made in the present study.

Compared to other feeds, milk from suckler cows presented relatively high levels of contamination. Thus large consumption of milk from such cows, particularly when they are grazing on extensively managed pastures, may lead to an accumulation of these contaminants in the body fat of calves.

4.3. Meat

The results of this study showed, that the contamination with PCDD/F and dl-PCB may vary heavily from one animal to another within the same farm. On one farm, where cattle were extensively managed, the sum of PCDD/F and dl-PCB ranged from 2.1 to 5.7 pg WHO_{97}-TEQ·g^{-1} fat. Nevertheless, it was evident that animals which consumed milk from suckler cows until slaughtering were more contaminated than animals which were weaned several months before slaughtering.

During gestation, PCDD/F and dl-PCB present in body tissues of the cow may be transferred directly to the fetus. After birth, these contaminants are transferred via milk to the new born and suckling calf (Peterson et al., 1983; Hirako, 2008). Consequently young bovines may be more contaminated than older ones. The contamination may be particularly high, when milk from suckler cows represents the main component in the diet of calves. In the present study this was the case in the semi-intensive system, where calves were fed mainly with milk from suckler cows and some hay and cereals until slaughtering. These animals showed higher levels of contamination than animals which received milk from dairy cows and were weaned several months before slaughtering.

Independent of the production system, younger animals tended to be more contaminated than older ones. Furthermore the level of contamination was reduced, when animals were weaned several months before slaughtering. This indicates that the amounts of PCDD/F and dl-PCB which had been accumulated during milk consumption were diluted by increasing the amount of body fat. This is in good agreement with Peterson et al. (1983) who showed that calf meat is more contaminated during the suckling period than after weaning.

4.4. Effect of the production system

In summary, these results showed that the meat with the lowest contamination level was found in the intensive cattle production system. In this system, animals received feed with low levels of PCDD/F and dl-PCB (milk replacer or milk from dairy cows, silage, hay and concentrates). This agrees well with the observation made in the previous study (BAG, 2008). In the extensive cattle production system, the level of contamination was slightly higher but still clearly below the legal maximum level. Although these animals consumed milk from suckler cows with high levels of dl-PCB, the time period between weaning and slaughtering was apparently long enough to result in a dilution of these contaminants in the body. This is supported by the results of the calves from suckler cows on pasture. These animals consumed milk from suckler cows until slaughtering, which resulted in the highest rate of contamination.

5. CONCLUSION

The results of this study did not allow the identification of specific factors or local sources of contamination with PCDD/F and dl-PCB. Nevertheless they gave certain indications about why meat samples originating from certain production systems may exceeded the maximum level of 4.5 pg WHO_{97}-TEQ·g^{-1} fat. On average, meat samples from extensive productions systems showed a higher contamination (2.7 pg WHO_{97}-TEQ·g^{-1} fat) compared to samples from intensive systems (1.4 pg WHO_{97}-TEQ·g^{-1} fat). Furthermore, meat from animals that were fed with milk from suckler cows until slaughtering was more contaminated than meat from animals that had been weaned several months before slaughtering. Although two individual beef samples (out of 36) exceeded the legal maximum level, the mean value of all beef samples was 2.3 pg WHO_{97}-TEQ·g^{-1} fat. The results did not allow to establish direct relationships between the presence of contaminants in feeds and milk or beef and they showed that variation in PCDD/F and dl-PCB contamination of meat within the same farm was very high. Therefore, no conclusion about an entire farm should be made based on the analysis of a single beef sample. It can be concluded that the situation in Switzerland seems not to be alarming and that no particular measures have to be taken. Nevertheless farmers should be aware that extensive production coupled with absence of delay between weaning and slaughtering may induce some risk for producing non compliant beef.

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