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Chemical safety in meat industry*

Andrée Sabine[1], Jira Wolfang[1], Schwägele Fredi[1], Schwind K.-H.[1], Wagner Hubertus[1]

A b s t r a c t: Since the Second World War the consumer behaviour in developed countries changed drastically. Primarily, there was the demand for sufficient food after a period of starvation, afterwards the desire for higher quality was arising, whereas today most people ask for safe and healthy food of high quality. Therefore a united approach comprising consistent standards, sound science and robust controls is required to ensure consumers' health and maintain consumers' confidence and satisfaction. Chemical analysis along the whole food chain downstream (tracking) from primary production to the consumer and upstream (tracing) from the consumer to primary production is an important prerequisite to ensure food safety and quality. In this frame the focus of the following paper is the "chemical safety of meat and meat products" taking into account inorganic as well as organic residues and contaminants, the use of nitrite in meat products, the incidence of veterinary drugs, as well as a Failure Mode and Effect Analysis (FMEA) system assessing (prioritizing) vulnerable food chain steps to decrease or eliminate vulnerability.

Key words: *Feed; Meat; Meat products; Inorganic residues; Organic residues; Nitrite; Veterinary drugs; FMEA.*

1. Introduction

Taking consumer behaviour into consideration since the time after the Second World War in developed countries, there was primarily the demand for sufficient food, afterwards the desire for better quality in the food area and nowadays almost everybody asks for safe and healthy food of high quality. With increasing global distribution of feed, food and ingredients the different countries in our world have never been before more dependent on each other with respect to their food supply (*Wall*, 2009). A united approach with consistent standards based on sound science and robust controls is necessary to ensure consumers' health and maintain consumers' confidence.

Caused by increasing skills of analytical chemistry and forensic microbiology more and more incidents of contamination will be revealed in the food area. Some of these can be major health threats, others may be technical breaches of the legislation that are unlikely to lead to adverse health effects. Aforementioned occurrences and the spectrum of incidences between these two extremes require various approaches of risk management. Appropriate process controls, biosecurity, adequate traceability and good hygiene and manufacturing practices are the indispensable requirements for every food business.

An important role within these prerequisites to ensure food safety and quality is to be assigned to chemical analysis along the whole food chain downstream (tracking) from primary production to the consumer and upstream (tracing) from the consumer to primary production (*Schwägele*, 2005).

The following contribution is dealing with "chemical safety of meat and meat products" taking into account inorganic as well as organic residues and contaminants, the use of nitrite in meat products, veterinary drugs and an extra chapter is addressed to a Failure Mode and Effect Analysis (FMEA) system assessing (prioritizing) vulnerable food chain steps to decrease or eliminate vulnerability.

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[1] *Max Rubner-Institute, Federal Research Institute of Nutrition and Food, Analysis Division, E.-C.-Baumann-Straße 20, D-95326 Kulmbach, Germany.*

Corresponding author: Hubertus Wagner, hubertus.wagner@mri.bund.de

2. Inorganic residues and contaminants

2.1. Toxic heavy metals in domestic animals

2.1.1. Arsenic and mercury

These toxic elements are found mostly in seafood. In meat and offal they are present only in marginal concentrations, often below the limit of detection. Since the contribution of these foodstuffs to the total intake of arsenic and mercury is low they will not be dealt with in the following considerations.

2.1.2. Lead

Over the past decades, the lead (Pb) level in food has decreased significantly owing to source related efforts to reduce the emission of Pb and improvements in quality assurance of chemical analysis. Pb is present at low concentrations in most foods. Offal and molluscs may contain higher levels. Contaminations of food during processing or food production in contaminated areas are the main reasons for enhanced Pb intake via foodstuffs.

Absorption of ingested Pb may constitute a serious risk to public health. Some chronic effects of Pb poisoning are colic, constipation and anaemia. It may also induce increased blood pressure and cardiovascular disease in adults. Fetal neuro-developmental effects and reduced learning capability in children are among the most serious effects.

The Codex Alimentarius system and the EC regulations (*EC*, 2008) set the same maximum residue levels (MLs) for Pb in meat of bovine animals, sheep, pig, and poultry (0.1 mg/kg) and for edible offals of these animals (0.5 mg/kg).

2.1.3. Cadmium

Cadmium (Cd) is a heavy metal found as an environmental contaminant, both through natural occurrence and from industrial and agricultural sources. Foodstuffs are the main source of Cd exposure for the non-smoking general population. Cd absorption after dietary exposure in humans is relatively low (3–5%), but Cd is efficiently retained in the kidney and liver in the human body, with a very long biological half-life ranging from 10 to 30 years. Cd is primarily toxic to the kidney, especially to the proximal tubular cells where it accumulates over time and may cause renal dysfunction. Cd can also cause bone demineralisation, either through direct bone damage or indirectly as a result of renal dysfunction. After prolonged and/or high exposure the tubular damage may progress to decrease glomerular filtration rate, and eventually to renal failure. The International Agency for Research on Cancer has classified Cd as a human carcinogen (Group 1) on the basis of occupational studies. Newer data on human exposure to Cd in the general population have been statistically associated with increased risk of cancer such as in the lung, endometrium, bladder, and breast (*EFSA,* 2009).

Cd bioavailability, retention, and consequently toxicity are affected by several factors such as nutritional status (low body iron stores) and multiple pregnancies, preexisting health conditions or diseases (*EFSA*, 2009).

The EC regulations (*EC*, 2008) set maximum levels for Cd in meat of bovine animals, sheep, pig, and poultry as 0.05 mg/kg wet weight and for edible offal of these animals as 0.5 mg/kg for liver, and 1.0 mg/kg for kidney, respectively. In 2004, the Codex Committee on Food Additives and Contaminants decided to discontinue work on establishing maximum residue levels for Cd in livestock and poultry because the foods from these production classes were not significant contributors to Cd intake.

The Scientific Panel on Contaminants in the Food Chain (CONTAM) was asked by the European Commission to assess the risks to human health related to the presence of Cd in foodstuffs (*EFSA*, 2009). To provide an updated assessment of exposure from foodstuffs, about 140,000 data covering the period from 2003 to 2007 on Cd occurrence in various food commodities were received from 20 member states and considered by the CONTAM Panel. High Cd concentrations were detected in the following food commodities: seaweed, fish and seafood, chocolate, and foods for special dietary uses.

In the food category “meat and meat products, and offal” the fractions of samples exceeding the maximum levels (MLs) are: bovine, sheep, and goat meat 3.6%; poultry and rabbit meat-none; pork – 1.6%, liver (bovine, sheep, pig, poultry, and horse) – 3.7%, kidney (bovine, sheep, pig, poultry, and horse) – 1.0%. The corresponding median values are: 0.0050, 0.0030, 0.0050, 0.0430, 0.1520 mg/kg.

In a German food monitoring, a total of 4955 samples of domestic and foreign origins were analysed in 2007 (*Bundesamt für Verbraucherschutz und Lebensmittelsicherheit*, 2008). Beef, wild boars meat, and air cured ham were selected from the market basket among the food of animal origin. Contaminations with Cd were all below the MLs (90th percentile in mg Cd/kg: beef 0.004, wild boar 0.01, and ham 0.03). There was only one case of noncompliance (0.16 mg/kg) with the ML for Pb in beef (90th percentile in mg Pb/kg: beef 0.057, wild boar 2.56, and ham 0.029). Regarding wild boars, Pb concentrations along the bullet channel were very high (288 mg/kg). Some projectile particles were penetrating deeply into the neighbouring tissue, so that they could not always be gotten by an ample excision. The contamination levels of heavy metals generally had decreased since a similar monitoring in 2002 (*Bundesamt für Verbraucherschutz und Lebensmittelsicherheit*, 2004).

In 2003–2004, the U.S. Department of Agriculture Food Safety and Inspection Service (FSIS) conducted an exploratory assessment to determine the occurrence and levels of Cd and Pb in randomly collected samples of kidney, liver, and muscle tissues of mature chickens, boars/stags, dairy cows, and heifers (*Pagan-Rodriguez et al.,* 2007). The study found that in each production class tested, levels of Cd and Pb were higher in kidney and liver samples than in the muscle samples. None of the muscle samples contained Cd or Pb exceeding the MLs established by other countries or international organizations. There are sporadic cases in which liver samples from mature chickens and boars/stags contained elevated Cd or Pb levels; however, the 95th percentile and the mean residue levels for liver samples were below the MLs established by other countries or international organizations. In boars/stags, mature chickens, and dairy cows, the Cd levels for the 95th percentile (not for the mean) of kidney samples were above internationally accepted levels, exceeding the ML (1000 ppb) established by the EU. The results of the current and previous FSIS studies showed that the incidence (percent of positive samples) and levels of Cd in kidney, liver, and muscle did not increase between 1985 and 2004.

Waegeneers et al. (2009) investigated the effect of animal age on concentrations of Cd, Pb, As, Cu and Zn in bovine tissues (meat, kidney, and liver) sampled from animals reared in contaminated areas or reference regions in Belgium. Cd concentrations in meat samples had an increasing trend with age. In addition, a significant positive linear relation was found between animal age and renal or hepatic Cd levels. Pb concentrations in kidneys and liver also increased with age. Renal Cd concentrations were predicted for bovines at different ages by using the slope of the linear regression equation. Calculations for 2-year-old animals from reference areas showed that in this group the European maximum level of 1 mg/kg for Cd in kidneys would be exceeded in zero to 5% of cases.

The aims of a study of *Lopez-Alonso et al.* (2007) were to evaluate toxic and essential metal concentrations in meat and offal from pigs in north-west Spain to compare these with reported metal concentrations in pigs in other countries and in cattle in this region, and to relate the observed concentrations to maximum acceptable concentrations. The concentrations of toxic metals can be considered low as the maximum admissible concentrations established by the EU were not exceeded in any sample. The 90th percentiles for muscle, liver, and kidney regarding Cd are 0.015, 0.100, 0.446, regarding Pb 0.006, 0.007, and 0.011 (mg/kg).

Due to the growing interest in organic products, *Ghidini et al.* (2005) undertook a comparison between the chemical safety of organic and conventional products. Milk and meat were the products chosen for the study. The parameters evaluated to assess chemical safety were organochlorine pesticides, polychlorinated biphenyls (PCBs), Pb, Cd, and mycotoxin contamination. Pb and Cd residues were very low (all within the EU ML) and did not differ between organic and conventional products.

2.2. Pb contamination from ammunition residues in game meat

Human consumption of wildlife killed with Pb ammunition may result in health risks associated with Pb ingestion. This hypothesis is based on published studies showing elevated blood Pb concentrations in subsistence hunter populations, retention of ammunition residues in the tissues of hunter-killed animals, and systemic, cognitive, and behavioural disorders associated with human Pb body burdens once considered safe.

The use of Pb isotope ratios has definitively identified Pb ammunition as a source of Pb exposure for First Nations people in Canada (*Tsuji et al.*, 2009), but the isotope ratios for Pb pellets and bullets were indistinguishable. Thus, Pb contaminated meat from game harvested with Pb bullets may also be contributing to the Pb body burden. There were elevated tissue Pb concentrations (up to 5726 mg/kg) in liver and muscle samples of big game harvested with Pb bullets and radiographic evidence of Pb fragments. Accordingly the tissue surrounding the wound channel should be removed and discarded, as this tissue may be contaminated by Pb bullet fragments.

The objective of *Hunt et al.* (2009) was to determine the incidence and bioavailability of Pb bullet fragments in hunter-killed venison, a widely-eaten food among hunters and their families. They radio graphed 30 eviscerated carcasses of white-tailed deer shot by hunters with standard Pb-core, copper-jacketed bullets under normal hunting conditions. All carcasses showed metal fragments and widespread fragment dispersion. They took each carcass to a separate meat processor and fluoroscopically scanned the resulting meat packages, fluoroscopy revealed metal fragments in the ground meat packages of 80% of the deer and 32% of the ground meat packages contained at least one fragment. Fragments were identified as Pb in 93% of samples. Isotope ratios of Pb in meat matched the ratios of bullets, and differed from background Pb in bone. They fed fragment-containing venison to pigs to test bioavailability; controls received venison without fragments from the same deer. Mean blood Pb concentrations in pigs peaked at a significantly higher level after 2 days following ingestion of fragment-containing venison than the controls. They concluded that people risk exposure to bioavailable Pb from bullet fragments when they eat venison from deer killed with standard Pb-based rifle bullets and processed under normal procedures.

It has also been shown that the practice of marinading game meat (quails) in vinegar increases the concentration of Pb in the edible tissues, when Pb pellets are present (*Mateo et al.,* 2006). There are trials to substitute Pb in bullets with non-toxic metals, e.g. Cu (*Knott et al*., 2009). A global review of legislation controlling the use of Pb ammunitions can be found in *Avery and Watson* (2009).

3. Organic residues and contaminants

3.1. Status survey of PCDD/Fs and PCBs in German feedstuffs, meat and meat products

The term „dioxins and dioxin-like PCBs" summarizes 29 toxicologically relevant single compounds or congeners of three classes of chlorinated compounds (polychlorinated dibenzo-*p*-dioxins = PCDDs; polychlorinated dibenzofurans = PCDFs; polychlorinated biphenyls = PCBs), which include 419 congeners in total. These undesirable 29 congeners show similarities in toxicological and chemical behaviour and include a toxic potential which can be estimated by the so called TEQ-value (*Van den Berg et al.*, 1998).

Dioxins (PCDD/Fs) and dioxin-like PCBs (dl-PCBs), inclusive six marker PCBs (PCBs 28, 52, 101, 138, 153, and 180) have different sources. The formation of the component class of PCDD/Fs for example takes place in any combustion process and results in very different levels, depending on the physical and chemical conditions, in which the combustion process occurs. Other sources for the formation of dioxins are certain industrial processes (e.g. metallurgical industry, production of chemicals) or natural processes (e.g. volcanic eruptions, forest fires). PCDD/Fs are formed as undesirable by-products from a number of human activities like accidents at chemical factories as 1976 in Seveso, Italy (*Homberger et al.,* 1979). Thereof high emissions resulted mainly with the most toxic congener 2, 3, 7, 8-TCDD as well as the contamination of a large local area. Other dioxin sources include, for example, domestic heaters, agricultural and backyard burning of household wastes.

In contrast to PCDD/Fs, the substance class of PCBs has been produced industrially between the 1930s and 1970s for a wide range of applications. Nowadays in a great number of states, inclusive the European Union PCBs are banned, but they are still in use in closed systems like electrical capacitors and are contained in paintings and sealing materials, which were produced before the 1970s. Today the release of PCBs occurs from leakages, accidental spills and illegal disposals (*Ballschmiter and Bacher*, 1996). When released into the air PCDD/Fs and PCBs can deposit locally on plants and on soil contaminating both food and feed. They can also be widely distributed by a long range transport (*Lorber et al.,* 1998). Because of their stability they are highly persistent in the environment for a long time. Dioxins and PCBs are highly lipophilic and poor soluble in water. Therefore, an intake of these compounds by the roots of feed plants is generally negligible. But a contamination of feed plants is possible with particles of dust or soil at the surface of the feed plants. In this way PCDD/Fs and PCBs can carry over from feed plants to the tissues of farmed animals where both undesirable compounds can accumulate in the fat to a greater or lesser extent.

Therefore, the Max Rubner-Institute (MRI) carried out a representative status survey programme on behalf of the German Federal Ministry of Food, Agriculture and Consumer Protection, which was coordinated by the MRI Analysis Division, located in Kulmbach (*Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz,* 2009).

The analytical work started with sample acquisition in 1994 and lasted up to 2008. In 2009 the analytical data from more than 1100 samples of animal feedstuffs, meat and meat products, hen eggs and some products thereof, dairy products, fish and fishery products were statistically evaluated.

3.1.1. PCDD/Fs and PCBs in feedstuffs

In Germany, dioxin exposure of the population ascribable to foods of animal origin is about 90% and feedstuffs are the main input source of PCDD/Fs and PCBs. Due to the so called "carry-over effects" these substances turn over from feedstuffs into foods of animal origin and accumulate. For prevention and reduction of these undesirable substances in food their reduction in feedstuff is already necessary.

Therefore, the complete status survey project started with a representative assessment of the initial situation in feedstuffs. Within this survey the levels of PCDD/Fs, dl-PCBs and marker PCBs in 206 German feed samples were analysed in the years 2004/2005 (*Schwind et al.*, 2009). The sampling plan included compound feed ($N = 115$) and roughage and succulent feed ($N = 91$) reflecting the representative feeding situation in Germany. The median content of WHO-PCB-TEQ in analysed feed samples was 0.017 ng/kg, 88% dry matter (d.m.), and consequently more than ten times 10 below the action level of 0.35 ng/kg, 88% d.m. (EC, 2006b). A differentiation between compound feed, roughage and succulent feed showed that compound feed (median 0.007 ng/kg 88% d.m.) were significantly lower contaminated with dioxin-like PCBs than roughage and succulent feed (median 0.058 ng/kg 88% d.m.). The median sum contents of the six marker PCBs were 0.16 µg/kg (88% d.m.) for compound feed and 0.56 µg/kg (88% d.m.) for roughage and succulent feed. The median of the WHO-PCDD/F-TEQ was 0.03 ng/kg (88% d.m.), the maximum level of 0.75 ng/kg (88% d.m.) was not exceeded. The median of the WHO-PCDD/F-PCB-TEQ was 0.05 ng/kg (88% d.m.) and consequently by factor of 25 below the maximum level of 1.25 ng/kg (EC, 2006a). In addition, samples of roughage and succulent feed were analysed according to their contents of ash insoluble in HCl, representing the degree of the proportion of earthy components in feed. A slight correlation was found between ash insoluble in HCl and WHO-PCDD/F-TEQ ($R^2 = 0.59$), whereas no correlation was found between ash insoluble in HCl and WHO-PCB-TEQ ($R^2 = 0.06$), (*Schwind et al.*, 2009).

3.1.2. PCDD/Fs and PCBs in meat and meat products

In a second step more than 300 representative German samples of meat and meat products were analysed for their levels of PCDD/Fs, dl-PCBs and marker PCBs. The sampling plan included different types of meat (pork, poultry meat, beef and sheep) and meat products (Bologna type sausage, raw ham, cooked liver sausage and raw sausage). For sampling the German National Nutrition Survey of the year 2004, the actual consumer behaviour and the population of the different states in Germany were taken into consideration. To get highly representative data the Federal Institute for Risk Assessment in Germany (BfR) was additionally consulted. Therefore, about 300 samples of meat and meat products were collected, which ensured a preferably high level of representativeness. (*Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz*, 2009).

3.1.2.1. dl-PCBs in meat and meat products

A total of 161 meat samples (55 pork, 49 poultry meat and 57 beef) (*Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz,* 2009) were analysed for levels of dl-PCBs (12 WHO-PCB congeners). TEQs were calculated using toxic equivalency factors (TEFs) laid down by the WHO (*Van den Berg et al.,* 1998). For non-detected congeners the upper-bound level has been used. Correspondent maximum residue levels for dl-PCBs and PCDD/Fs in meat and products thereof are given in Commission Regulation (EC) No 1881/2006 of 19 December 2006 (*EC*, 2006c).

The median content of WHO-PCB-TEQ in beef samples was 0.9 ng/kg fat and consequently in the range of the action level of 1.0 ng/kg fat. Subdividing the analysed beef samples in beef ($N = 44$) and veal ($N = 13$), it was shown that the contents of dl-PCBs in veal (median: 0.23 ng WHO-PCB-TEQ/kg fat) were significantly lower than in beef (median: 1.08 ng WHO-PCB-TEQ/kg fat) (*Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz*, 2009). For veal, with the exception of one extreme value, all samples were below the action level of 1 ng/kg fat. For beef about 50% of the analysed samples exceeded the action level (*EC*, 2006b). An explanation for this fact could be the different age of slaughtering for calves and cattle. Calves (in Germany) were slaughtered at the age of about 6 months; cattle at the age of about 20 months. The uptake and deposition of these undesirable compounds in ruminants and their tissues seem to be age-related. In poultry meat a median content of WHO-PCB-TEQ was determined, which was more than by a factor of 10 below the action level of 1.5 ng/kg fat. For pork the determined results for the median content of WHO-PCB-TEQ were in a similar manner more than six fold below the action level in force.

In meat products the WHO-PCB-TEQ ranged from 0.06 ng/kg fat for raw ham to 0.13 ng/kg fat for raw sausages (salami). The WHO-PCB-TEQ in meat and meat products was dominated by PCB 118, PCB 126 and PCB 156, which together contributed in a range between 87% (for pork) and 96% (for beef) to the WHO-PCB-TEQ. The congeners PCB 114, PCB 123, PCB 157, and PCB 189 were only detected in very small amounts compared to the other mono-ortho PCBs.

3.1.2.2. PCDD/Fs in meat and meat products

In total, 169 samples of different types of meat (pork, poultry meat, beef and sheep) were analysed according to their contents of the 17 WHO-PCDD/Fs (*Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz,* 2009). The median contents of WHO-PCDD/F-TEQ ranged from 0.09 ng/kg fat (pork), 0.11 ng/kg fat (poultry), 0.19 ng/kg fat (lamb) up to 0.24 ng/kg fat (beef) and were significantly below their maximum levels. Meat of the ruminants beef and sheep (lamb) showed significant higher median PCDD/F levels than meat of poultry or pork. This might be again attributed to the different ages of slaughtering for pork (about 6 months), poultry (about 3 months), lamb (about 6 months), and beef (about 20 months). Maximum contents (without outliers and extreme values) were in the range of 0.2 ng WHO-PCDD/F-TEQ/kg fat for pork and poultry meat and about 1 ng/kg fat. The EU maximum residue levels (MRLs) for pork (1 ng WHO-PCDD/F-TEQ/kg fat), poultry meat (2 ng WHO-PCDD/F-TEQ/kg fat) and beef (3 ng WHO-PCDD/F-TEQ/kg fat) were not exceeded in all three types of meat (EC, 2006c). The 5 analysed sheep (lamb) samples showed a median of 0.2 ng WHO-PCDD/F-TEQ/kg fat which were in the range of beef. The WHO-PCDD/F-TEQ of veal (median 0.1 ng/kg fat) was significantly lower than that of beef (median 0.35 ng/kg fat). In comparison to an earlier survey conducted 10 years ago, especially for beef and poultry meat significant decreases of the PCDD/F-contents were observed.

In the investigated meat products (Bologna type sausage, raw ham, raw sausage, cooked liver sausage) the median WHO-PCDD/F-TEQ levels varied from 0.05 ng/kg fat (Bologna type sausage) to 0.09 ng/kg fat (cooked liver sausage). The maximum contents (without outliers and extreme values) were in the range of 0.2 ng/kg fat. Because the analysed meat products were mainly produced from pork and consequently a maximum residue WHO-PCDD/F-TEQ level of 1 ng/kg fat has to be used, the median contents were at least by a factor of 10 below the maximum residue level (MRL). No exceeding of the MRL for the WHO-PCDD/F-TEQ was observed.

3.1.3. Marker PCBs in meat and meat products

The EU intends to regulate marker PCBs in food on the basis of sum contents of the six marker PCBs (*DG Sanco*, 2008). Actually for meat and meat products the following MRLs for the sum contents of six marker PCBs are discussed: 50 µg/kg fat for bovine animals and sheep, 30 µg/kg fat for poultry and 15 µg/kg fat for pork.

The sum contents of the 6 marker PCBs on median basis in meat increased from pork (1.41 µg/kg fat), poultry meat (1.73 µg/kg fat) to beef (5.33 µg/kg fat). These levels are from 3 to 10 times below the actual discussed MRLs by the Commission of the European Union (http://www.bmu.de/files/english/pdf/application/pdf/non_dioxin_like_pcbs_090728_bf.pdf). In the analysed samples for pork, five extreme values were above the proposed maximum level of 15 µg/kg fat. For poultry meat only one exceeded the disputed MRL of 30 µg/kg fat and for beef one of them exceeded the discussed MRL of 30 µg/kg fat (*Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz*, 2009). In meat products medians of sum contents of six marker PCBs for Bologna type sausage, raw ham, raw sausage (salami) and cooked liver sausage were in the range of 1 to 3 µg/kg fat. Maximum levels (without outliers and extreme values) for Bologna type sausage and raw ham were in the range of 3 to 4 µg/kg fat, for raw sausage and cooked liver sausage from 7 to 8 µg/kg fat. Because the analysed meat products were produced mainly with pork, a MRL of 15 µg/kg fat for the sum of the six marker PCBs has to be applied. Consequently, the proposed MRLs would be exceeded in the bologna type sausage, raw ham and cooked liver sausage.

3.1.4. Uptake of PCDD/Fs and dl-PCBs from meat and meat products

On the basis of the determined data for PCDD/Fs and PCBs in German meat and meat, products the Analysis Division of the MRI assessed that an adult consumer with 70 kg body weight with the consumption of meat and meat products takes up about 3% of the tolerable weekly intake (TWI), which was set to 14 pg WHO-PCDD/F-PCB-TEQ/kg body weight by the Scientific Committee on Food (*SCF*, 2001).

3.2. Polycyclic aromatic hydrocarbons (PAH) in smoked meat products

Smoking is one of the oldest technologies for conservation of meat and meat products and is defined as the process of penetration in meat products of volatiles resulting from thermal destruction of wood (*Toth*, 1983). It is assumed that in Germany 60% of meat products are smoked (*Frede*, 2006). As a non-desired consequence of smoking, polycyclic aromatic hydrocarbons (PAH) are generated during the incomplete combustion of wood. About 660 different compounds belong to PAH group (*Sanders and Wise*, 1997). Some representatives show carcinogenic properties (*IARC*, 2009). The best known carcinogenic PAH compound is benzo[a]pyrene (BaP), which has been used as a leading substance until now.

In the European Union, a maximum level of 5 µg/kg benzo[a]pyrene (BaP) in smoked meats and smoked meat products exists (*EC*, 2006c). Furthermore, the European Commission (EC, 2005a) recommended that the member states should investigate not only the contents of BaP in smoked meat products, but also other PAH seen as carcinogenic by SCF. These 15 PAH compounds are: benzo[a]anthracene (BaA), chrysene (CHR), cyclopenta[c,d]pyrene (CPP), 5-methylchrysene (5-MC), benzo[b]fluoranthene (BbF), benzo[k]fluoranthene (BkF), benzo[j]fluoranthene (BjF), BaP, dibenzo[a,h]anthracene (DhA), indeno[c,d]pyrene (IcP), benzo[g,h,i]perylene (BgP), dibenzo[a,l]pyrene (DlP), dibenzo[a,e]pyrene (DeP), dibenzo[a,i]pyrene (DiP) and dibenzo[a,h]pyrene (DhP). In particular, DlP has been in the spotlight of scientific interest recently, because toxicological investigations indicated that DlP probably has a much stronger carcinogenic potential than BaP (*Higginbotham et al*., 1993, (*Luch et al*., 1994) and (*Schober et al.,* 2006). The European Food Safety Authority (EFSA) additionally recommends the analysis of benzo[c]fluorene (BcL), which was assessed to be relevant by the Joint FAO/WHO Experts Committee on Food Additives (*JECFA*, 2005), consequently all in all 15 + 1 PAH are classified as priority in the EU.

In order to analyse these 15 + 1 EU priority PAH in smoked meat products at the MRI Kulmbach an analytical method was developed (*Jira,* 2004a; *Jira et al*., 2008), which included accelerated solvent extraction (ASE), gel permeation chromatography, solid phase extraction (SPE) with silica gel and a quantification by gas chromatography/high resolution mass spectrometry (GC/HRMS). Therefore, a semipolar GC column with 50% polyphenylsiloxane was used, which enables a chromatographic separation and consequently an identification and quantification of all 15 + 1 EU priority PAH with the exception of a separation of CHR and triphenylene (TP). Consequently with the help of this method only the sum of contents of CHR + TP can be determined. A disadvantage of this method is the long runtime of 72 min. Therefore a Fast-GC/HRMS method for the quantification of the 15 + 1 EU priority PAH with a runtime of only 25 min, using a TR-50 ms column (10 m × 0.1 mm × 0.1 µm) was developed (*Ziegenhals et al.,* 2008).

In order to investigate the contents of the 15 + 1 EU priority PAH in representative samples of smoked meat products in Germany, a total of 113 samples of smoked meat products (raw sausages $N = 25$; raw ham $N = 23$; cooked ham $N = 17$; frankfurter-type sausages, $N = 23$ and liver sausages, $N = 25$ were analysed (*Jira,* 2010). These samples originated from different states in Germany, considering populations in the single states. The median BaP contents of the analysed sampled was 0.03 µg/kg and consequently more by a factor of 100 below the maximum level of 5 µg/kg. The P 95 was 0.14 µg/kg and maximum value was 0.43 µg/kg, which was still more than a factor of 10 below the maximum level. The highest PAH contents were observed for BcL and CHR + TP which were the only PAH compounds with median contents above 0.1 µg/kg. Dibenzpyrenes (DeP, DhP, DiP and DlP) were observed only in a few samples. In the most samples contents of dibenzpyrenes were below the limit of detection (LOD) of 0.01 µg/kg. EFSA concluded that BaP is not a suitable indicator for the occurrence of PAH in food and assessed that the sum content of the four PAH compounds BaP, CHR, BaA and BbF („PAH4") is the most suitable indicator of PAH in food (EFSA, 2008). The median contents of „PAH4" were 0.28 µg/kg, P 95 was 1.19 µg/kg and maximum value was 2.46 µg/kg. Because of the above mentioned coelution of CHR and TP also "PAH4" includes contents of TP. The median of the sum content of 15 + 1 EU priority PAH was 0.64 µg/kg, P 95 was 2.58 µg/kg and the maximum value was 5.47 µg/kg. The highest BaP levels were detected in raw ham and frankfurter-type sausages with median concentrations of about 0.05 µg/kg. The highest content of BaP was detected in a frankfurter-type sausage (about 0.4 µg/kg). The lowest BaP content was detected in cooked ham (median: 0.01 µg/kg). The median content of BaP was 0.02 µg/kg for raw sausages and 0.03 µg/kg for liver sausages. The highest „PAH4" levels were observed in frankfurter-type sausages. Within this group of hot smoked meat products median "PAH4" contents of 0.6 µg/kg were observed. The median "PAH4" contents of raw ham and liver sausages were both in the range of 0.3 µg/kg. Raw sausages had a median of 0.2 µg/kg. The lowest „PAH4" levels were observed in cooked ham (median: 0.1 µg/kg). The results of this study analysing representative samples of German smoked meat products clearly demonstrated that the production of smoked meat products with BaP levels below 1 µg/kg is possible without any problems. These findings are in accordance with other studies, which were performed in other European countries like Spain (*Falcon et al*., 1999; *Falco et al*., 2003; *Fontcuberta et al*., 2006), Italy (*Roda et al*., 1999; *Purcaro et al*., 2009), Denmark (*Duedahl-Olesen et al.,* 2006), Ireland (*FSAI, Food Safety Authority of Ireland*, 2006) and Estonia (*Rei-*

nik et al., 2007) in the last 10 years. BaP contents in smoked meat and meat products reported in these studies were less than 0.5 µg/kg.

Considering the genotoxic and carcinogenic properties of several PAH compounds SCF recommended that the PAH contents in smoked meat products should be as low as reasonably achievable (ALARA), (*SCF*, 2002). Actually, the Codex Alimentarius Commission (*CAC,* 2008) works on a draft for a "Code of Practice for the Reduction of Contamination of Food with Polycyclic Aromatic Hydrocarbons (PAH) from Smoking and Direct Drying Processes" with the objective of lowering PAH contents in foods (e.g. smoked meat products). The unreasonably high BaP maximum level of 5 µg/kg is in conflict with efforts to reduce PAH contents in smoked meat products. Therefore lowering the maximum level for BaP from 5 µg/kg to 1 µg/kg seems to be advisable. The observed correlation coefficient between the sum content of the 15 + 1 EU priority PAH and BaP of $R = 0.90$ is an indicator for the suitability of BaP as a marker substance for PAH in smoked meat products. A better correlation coefficient of $R = 0.99$ for the sum content („PAH4") is based on the relatively high contribution of "PAH4" to the sum content of the 15 + 1 EU priority PAH of 42% (median). A substantial disadvantage of using „PAH4" instead of BaP as a marker substance for PAH in food surveillance is the insufficient chromatographic separation of CHR and TP, which is only feasible with a time-consuming GC temperature programme running more than one hour (*Jira et al*., 2008), which is not suitable for routine measurements. In contrast to a sufficient gaschromatographic separation of BaP, also the separation of CHR and CPP respectively BbF, BjF and BkF appears problematic. Furthermore an important disadvantage of using „PAH4" as an indicator of PAH in food is that PAH compounds with very different carcinogenic potential are summed up to a total content without weighting. A very different carcinogenic potential of these four PAH compounds was not only established by the International Agency for Research on Cancer (IARC, 2009), but also by other researchers (*Bostrom et al.*, 2002; *Nisbet and LaGoy*, 1992), who assessed a toxicological potential for BbF, BaA and CHR, which was more than by a factor of 10 lower as observed for BaP. Because within the presented study a median contribution of only 10% of BaP to "PAH4" was determined, this sum content is dominated in PAH compounds with lower toxicological relevance. In order to evaluate the suitability of BaP as a marker in addition to representative samples also suspicious samples of smoked meat products should be analysed for the contents of 15 + 1 EU priority PAH compounds.

In spite of relatively low contents of PAH in smoked meat products in Europe there are still possibilities to lower PAH contents by improving smoking technologies. By analysing cold smoked meat products from Serbia (traditional and industrial smoking) a dependency of PAH contents and smoking time was found. On the other hand, lower PAH contents were observed for industrial smoked meat products in comparison to conventionally smoked products (*Djinovic et al*., 2008a., 2008b., 2008c). Because PAH are adsorbed by the surface of meat and do not penetrate significantly into the inside of smoked meat products (*Jira et al*., 2006) the surface/mass ratio is significantly influencing PAH contents in smoked meat products. Nevertheless, within the mentioned study differences in PAH contents in different types of meat (beef and pork ham) were found for samples with similar surface/mass ratio, indicating different adsorption capacities of the surface for different types of meat products (*Djinovic et al*., 2008a, 2008b, 2008c). In a research project at the MRI Kulmbach starting in the year 2010 the influences of different parameters of smoking, like smoke generation temperature, oxygen content, smoking time, type of casing and wood and fat content on the PAH contents for emulsified sausages and raw sausages will be systematically investigated. The results of this study will be an important tool in order to achieve a further reduction of PAH in smoked meat products.

3.3 Mycotoxins

Application of modern agricultural practices and the presence of a legislatively regulated food processing and marketing system have reduced the mycotoxin exposure in the populations of the developed world very effectively. As *Milićević* (2009) states in a review, the health risks from mycotoxins for populations in developing regions however are higher orders of magnitude.

4. The use of nitrite in meat products

In the European Union the use of nitrite and nitrate in meat products is regulated (*EC*, 2006a, 2006b , 2006c, 2006d). Within this directive the use of nitrates is limited in non-heated meat products to 150 mg (ingoing amount must be calculated as sodium nitrite)/kg, but with several exemptions, and nitrite up to 100 mg, respectively, 150 mg nitrite (ingoing amount)/kg in all meat products, again with a number of exemptions (*Honikel*, 2008). In contrast to a former regulation in Germany (Nitrit-Pökelsalz-Gesetz; nitrite pickling salt (NPS) law), which only allowed the use of nitrite in meat products in premixes with table salt and was limiting the nitrite content to 0.6%, the percentage of nitrite in NPS is not limited in the EU since 1995.

At MRI Kulmbach in the time between 2000 and 2006 a total of 336 meat products (189 emulsified sausages, 41 cooked sausages, 51 raw sausages, 29 raw hams, 8 cooked hams and 18 cooked cured products) were analysed with respect to their contents of nitrite and nitrate (*Dederer*, 2007) by an enzymatic methodology (*Arneth and Herold*, 1988). Limits of detection (LOD) of this analytical method were 0.2 mg/kg for nitrite and 0.1 mg/kg for nitrate. Median contents in the analysed meat products were 27 mg/kg for nitrate and 11 mg/kg for nitrite. The highest observed levels (without a few outliers and extreme values) were below 100 mg/kg for nitrate and in the range of 50 mg/kg for nitrite. Assuming an estimated addition of 80 to 100 mg nitrite/kg only about 11 to 14% of the added nitrite will be found in the cured meat product.

Nitrite shows both positive and negative effects. Positive effects of the addition of nitrite curing salt in meat products are reddening (*Wirth*, 1991), formation of a curing flavour (Fischer et al., 2005), antioxidative effects (*Arneth*, 2001) and antimicrobial effects (*Lücke*, 2003; *Kabisch et al*., 2008), whereas the latter is not to be discussed within this paper.

An important aspect of the addition of nitrite curing salt to meat products is the formation of stable red colour, which is developed in a number of complicated reaction steps until NO-myoglobin (Fe^{2+}) is formed (*Honikel*, 2008). By heating the NO-myoglobin the protein moiety is denatured, but the red NO-porphyrin ring system still exists and is found in meat products heated to 120° C. An advantage for the consumer is that this heat stable red colour will change on bacterial spoilage, consequently the consumers recognize spoilage by a change of the colour. A second advantage is the formation of a curing flavour. The role of nitrite in the formation of this characteristic flavour is not completely understood until now. There are several evidences that the curing flavour is not caused by a single chemical compound or substance classes, but rather by a combination of many different compounds. It is assumed that compounds which are formed by binding nitrite with proteins or fats, have valuable contribution to the formation of a curing flavour (*Jira*, 2004b). The third and probably the most relevant advantage is the antioxidative effect of nitrite. This effect consists in an oxidation to nitrate, on the other hand a stable complex between heme-bond iron and nitrite is formed, which inhibits the release of iron ions. Consequently, free iron ions (Fe^{2+}) are not available for the initiation of lipid peroxidation (LPO). In addition nitrite is able to form a complex with free iron ions. It is also assumed that nitrite is able to stabilize polyunsaturated fatty acids forming nitro–nitroso derivatives (*Freybler et al.*, 1993). As a consequence cell membranes are protected against lipid peroxidation and the stability of the cured meat product during storage is raised. The antioxidative effect of nitrite is not only limited to an inhibition of LPO. The addition of nitrite to meat products also leads to lower contents of harmful cholesterol oxides (*Arneth and Münch*, 2002). Furthermore nitrite can form different compounds like S-nitrosocysteine (*Shahidi*, 1992), which show antioxidative properties.

As an undesirable consequence of curing with nitrite, the formation of N-nitrosamines (NA) is discussed. This discussion started in the 1970s in USA after the detection of NA in fried bacon (*Fiddler et al*., 1978). N-Nitrosamines are formed by a nitrosation of secondary amines. Primary amines can be nitrosated too, but these products are not stable and decompose to the corresponding alcohols. A nitrosation of tertiary amines is not possible. The chemistry of nitrosation is very complicated and shows a dependency on the pH, the basicity of the secondary amine and temperature (*Mirvish*, 1975; *Ward and Coates*, 1987). At low pH the formation of nitrosating agents like protonated nitrous acid ($H_2NO_2^+$), nitrogen trioxide (N_2O_3) or nitrosyl halogenides (NOX) is stimulated, whereas the concentration of non protonated amine is decreasing. Therefore lightly basic amines like morpholine (pKa = 8.7) are nitrosated more rapidly than strongly basic amines like dimethylamine (pKa = 10.7). The commonly occurring N-nitrosamines in food are the volatile substances N-nitrosodimethylamine (NDMA), -piperidine (NPIP), -pyrrolidine (NPYR), -thiazolidine (NTHZ) and the non-volatile compounds N-nitrososarcosine (NSAR), -hydroxyproline (NHPRO), -proline (NPRO) and -thiazolidine-4-carboxylic acid (NTCA) (*Tricker*, 1997). Within this group of NA the International Agency for Research on Cancer (*IARC*, 1987) classified NDMA in group 2A and NPIP, NPYR and NSAR in group 2B. NDMA is the most frequently detected carcinogen in meat products. For the formation of NDMA dimethylamine is necessary, which can be formed by decomposition of lecithine, sarcosine, creatine and creatinine. The formation of NPIP requires piperidine, which can result from an alkaline hydrolysis of piperine, an important ingredient of pepper. The detection of

NPYR is primarily restricted to bacon, a roasted and cured meat product. During the production of bacon temperatures in meat products are often higher than 150° C, which leads to an anhydrous product and a decarboxylation of the amino acid proline forming pyrrolidine and finally to high NPYR concentrations. In a recent study (*Drabik-Markiewicz et al.,* 2009), investigating the role of proline in NA formation during heating of cured meat, it was demonstrated that the influence of proline on the NPYR contents was larger compared to the added amounts of sodium nitrite. Other investigations showed an increase of NPYR contents in meat products in correlation with an increase of biogenic amines (*Bulushi et al.*, 2009; *Warthesen et al*., 1975). Therefore, an alternative formation of pyrrolidine originating from ring closure of the biogenic amines putrescine, spermin or spermidin was assumed. Besides the formation of NA by curing meat products with nitrite also NA containing elastic rubber nettings can contaminate the edible parts of meat products (*Fiddler et al*., 1998; *Helmick and Fiddler*, 1994).

In meat products the most relevant NA are NDMA, NPIP and NPYR. A formation of these NA is only possible under following conditions:

1) Secondary amines must be present. In fresh meat no or only very low amounts of secondary amines are present. Potential precursors of secondary amines, like creatine and creatinine and the free amino acids proline and hydroxyproline and some decarboxylation products, are present, which can lead to a formation of secondary amines during ageing and fermentation of meat products.

2) pH must be low enough (< 5.5) to form nitrosating agents. This only applies for fermented sausages.

3) At high temperatures (> 130° C; formation of NPYR) or long storage at room temperature (NDMA, NPYR). This only applies for grilling, roasting and the production of raw sausages.

There are no really alternatives to nitrite until now and especially the antioxidative and curing flavour forming effects of nitrite is not possible to be substituted by other additives (*Lücke*, 2003). The negative aspects of the use of nitrite in meat products can be relativised as follows (*Drabik-Markiewicz et al*., 2009): processing technology involving good manufacturing practices and the widespread use of ascorbate which will lower the NA contents in meat products (*Tannenbaum et al*., 1991). Furthermore only 7% of the ingested food derives from food and thirdly the nitrate/nitrite content of vegetables far exceeds that of meat products (*Honikel*, 2008).

Recently vegetal-based extracts were used instead of NPS for curing meat products (*Nochemfood*, 2010). This procedure possibly contains the risk of using higher amounts of nitrite extracted by the vegetables in comparison to the amounts of nitrite added to the meat product if NPS is used. Furthermore an extraction of further residues and contaminants from the vegetables and, as a consequence, higher contamination levels of the meat product can not be excluded.

5. Veterinary Drugs

Exceedingly relevant with respect to safety of food of animal origin are residues of veterinary drugs. The use of veterinary drugs within the European Union is regulated by means of the Council Regulation (*EEC*, 1990) No. 2377/90 describing a procedure for the establishment of MRLs for veterinary medicinal products in foodstuff of animal origin including meat, fish, eggs and honey. Its annexes present substances, for which MRLs have been established (Annex I), substances, for which it is not considered necessary to establish MRLs (Annex II), substances with provisional, temporary MRLs (Annex III) and substances, which are not allowed to be used in food producing species (Annex IV). While Council Directive (*EC*, 1996b) No. 96/23/EC defines measures to monitor certain substances and residues thereof in live animals and animal products it divides veterinary drugs into two groups: group A covering prohibited substances in compliance with the Annex IV of the Council Regulation (EEC) No. 2377/90 and group B containing agents, in compliance with Annexes I and III of the Council Regulation (EEC) No. 2377/90 (Table 1).

Commission Decision 2002/657/EC (EC, 2002a) establishes criteria and procedures for the validation of analytical methods for detection of residues. For substances according to Annex IV of the Commission Regulation (EEC) No. 2377/90 Commission Decision 2003/181/EC (*EC*, 2003a) defines minimum required performance limits (MRPLs) for the determination of their residues in food of animal origin.

The prohibition of the use of growth promoting substances, such as hormones or ß-agonists, is regulated by Council Directives No. 96/22/EC (*EC*, 1996a) and 2003/74/EC (*EC,* 2003b). Since January, 1st 2006, according to Regulation (EC) No. 1831/2003 (*EC*, 2003c), the use of antibiotic growth promoting substances as additives for use in animal nutrition is forbidden. However, coccidiostats and histomonostats, antibiotics intended to kill or inhibit protozoa, are still authorised for use as feed

Table 1. EU legislation on veterinary drugs
Tabela 1. EU zakoni o veterinarskim lekovima

(EEC) No. 2377/90			
Annex II/*Aneks II*	**Annex I/*Aneks I***	**Annex III/*Aneks III***	**Annex IV/*Aneks IV***
Includes substances, for which it is not considered necessary to establish MRLs/ *Uključuje supstance za koje se smatra da nije potrebno utvrđivati MDK*	Includes substances, for which MRLs have been established/ *Uključuje supstance za koje su utvrđene MDK*	Includes substances, for which provisional MRLs have been established/ *Uključuje supstance za koje su utvrđene privremeni MDK*	Includes substances, for which no MRLs could be established; administration prohibited; „zero tolerance"/ *Uključuje supstance za koje se ne utvrđuju MDK; njihova primena je zabranjena "nula tolerancija"*
	Group B/*Grupa B*		Group A/*Grupa A*
	96/23/EC		

additives in accordance with Regulation (EC) No. 1831/2003. Despite the requirements set for feed business operators in regulation No (EC) 183/2005 (*EC*, 2005b), it is generally acknowledged that under practical conditions during the production of mixed feeds, a certain percentage of a feed batch remains in the production circuit and these unavoidable residual amounts can contaminate subsequent feed batches. Therefore MRLs for these substances in animal feed for non-target animals are established by the Commission Directive 2009/8/EC (*EC*, 2009a) amending Annex I to Directive 2002/32/EC (*EC*, 2002b). The occurrence of carry-over of coccidiostats and histomonostats in non-target feed may result in the presence of residues of these substances in food products of animal origin. Consequently the European Commission set MRLs for the presence of coccidiostats or histomonostats in the respective foods of animal origin by means of Commission Regulation (EC) No. 124/2009 (*EC*, 2009b).

The generic term „veterinary drugs" comprises a broad variety of classes of chemical compounds. Among them are antibiotics such as aminoglycosides, ß-lactams, macrolides and lincosamides, quinolones, sulfonamides and tetracyclines, antiparasitic agents like antihelmintics or coccidiostats, stilbens, ß-agonists, amphenicols, nitrofurans, nitroimidazoles, carbamates, pyrethroids and sedatives etc. This list is certainly not exhaustive. Nevertheless it gives an impression how manifold this area and consequently how enormously complex the analytical challenge is.

There is a need for sensitive, selective and reliable analytical methods to detect and monitor veterinary drugs. The scientific literature provides an overwhelming amount of information (*Sanders*, 2007). Even in the field of sample preparation a multitude of methods is available and applicable depending on sample selection or matrix and the target residue (*Kinsella et al*., 2009). Antimicrobial residues and compounds with hormonal activity can be screened by using rapid immunochemical methods, such as radio immunoassays (RIA), enzyme-linked immunosorbent assays (ELISA) or microbial growth inhibition assays (*Bovee and Pikkemaat*, 2009). The recent developments in ultra performance liquid chromatography (UPLC) with fast switching MS/MS and UPLC coupled with full-scan high resolution accurate mass analysers based on time-of-flight (TOF) or orbital trap technologies triggered the development of selective targeted approaches as well as multi-analyte and even multi-class detection methods (*Le Bizec et al*., 2009). Even the „omic" technologies such as transcriptomics, proteomics and metabolomics are used for the screening for veterinary drug-treated or non-treated situations (*Riedmaier et al*., 2009). Given the enormous amount of information acquired, the data handling and analysis becomes more and more important.

A reliable estimation of the contamination of meat and especially meat products with veterinary drugs is difficult. The Annual Report of The Rapid Alert System for Food and Feed (*Rapid Alert System for Food and Feed, RASFF*, 2007) specifies notifications due to the presence of metabolites of the prohibited nitrofurans for meat other than poultry. Also chloramphenicol was found in this category as well as the presence of unauthorised substances, namely the presence of phenbutazone and oxyphenylbutazone. For poultry, one notification on the presence of chloramphenicol and one for sulphachloropyrazine was recorded. According to the RASFF there is a downward trend for notifications on residues in poultry meat. This proved to be true also in the Annual Report of The Rapid Alert System for Food and Feed (*Rapid Alert System for Food and Feed, RASFF*, 2008). However, it seems to be obvious that nitrofurane metabolites are still the most notified hazards even if the majority appears with regard to crustaceans. Looking at the Annual Report of the *Federal Office of Consumer Protection Food Safety, Germany* (2008) with regard to the National Residue Control Plan it stands out that coccidiostats, namely lasalocid was found in beef and pork liver as well as in broiler meat with contents well above the MRLs. Despite the approval of „unavoidable carry-over of coccidiostats or histomonostats in non-target feed" (Commission Directive 2009/8/EC) and the therefore established MRLs in food resulting from the unavoidable carry-over of these substances there still seems to be a need for a certain amount of action.

6. Failure Mode and Effect Analysis (FMEA)

Risk assessment according to the Codex Alimentarius Commission is a scientific evaluation of known or potential adverse health effects resulting from exposure to food borne hazardous agents. The process consists of four steps: (i) hazard identification, (ii) hazard characterisation, (iii) exposure assessment and (iv) risk characterisation. (CAC/GL 62, 2007, Working Principles for risk analysis for food safety for application by governments). Risk assessment is mostly directed towards the safety of the end product and consumer protection. During hazard identification the most significant hazards for the end product are identified and addressed within the scope of risk assessment or using a HACCP-plan. In most HACCP-plans a qualitative approach is used. By using a quantitative approach to risk assessment the hazard analysis can result in a very powerful tool for managing risks. Control measures can be validated and resources can be allocated to minimize the occurrence of hazards, i.e. contaminants at single production steps as well as in the end product.

One of the methods applicable for quantitative risk assessment is the Failure Mode and Effect Analysis (FMEA). FMEA is a systematic process meant for reliability analysis. It is a tool to assure product quality. It improves operational performance of the production cycles and reduces their overall risk level. The FMEA methodology was developed and implemented for the first time in 1949 by the United States Army. In the 1970s its application field extended to general manufacturing. Today the FMEA method is mainly applied in industrial production of machinery and electronic components, but also in food industry (*Scipioni et al*, 2002). Recently it has been used within the industrial processing of snails (*Arvanitoyannis and Varzakas*, 2009a), common octopus (*Arvanitoyannis and Varzakas*, 2009b) and ready to eat vegetables (*Varzakas and Arvanitoyannis*, 2009). The EU-Project *ΣChain* (2006) developed a modified FMEA procedure to identify, assess and address vulnerabilities in food production chains such as poultry meat. A clear and specific understanding and description of the products and processes is a mandatory prerequisite for any FMEA application. Thus the poultry meat production chain was exemplarily mapped. Flow charts were designed to identify the single steps in the chain. Following the consideration that a substantial number of contaminants may enter the poultry meat production chain via the feed chain, the latter was mapped, too.

Vulnerability within the EU-Project ΣChain was defined as a weakness in the system that can result in harm to the system or its operations, especially when this weakness is exploited by a hostile person or organisation or when it is present in conjunction with particular events or circumstances. This definition was applied to the poultry meat production chain, in relation to contamination with agents, hazardous to human health. Vulnerability was understood as lack of traceability whereas the implementation of this traceability was understood as a combination of:

- The documentation accompanying the product
- Appropriate physical and electronic tags including the information about their application
- Identification of relevant contaminants
- Occurrence and dynamics of contaminants
- Analytical methods to detect relevant contaminants including information about appropriateness and application

Vulnerabilities identified were rated according to three criteria, severity (Sev), likelihood (Lik) (of occurrence) and detectability (D). Severity is the rating of the hazard associated with the vulnerability, in the sense of damage to public health and is rated from 1 (no effect) to 10 (immediate effects and/or serious effect on health). The likelihood of occurrence indicates the frequency of a vulnerability event happening. Likelihood of occurrence is rated from 1 (will not occur) to 5 (occurs on a frequent basis). Detectability or likelihood of detection/recognition refers to whether the vulnerability or event happening will be noticed or detected giving the current control measures whereas a rating of 1 was understood as „likely" and 3 as „unlikely" to be detected.

For each potentially vulnerable chain step a Vulnerability Priority Number (VPN) was calculated: VPN = Severity × Likelihood × Detectability.

Thus a prioritisation of vulnerabilities or vulnerable chain steps, respectively, was achieved. The higher the VPN the higher the priority for addressing the vulnerability.

The identified and prioritized potential vulnerable chain steps were addressed by identifying a set of control measures to reduce or even eliminate the vulnerability (reduce the VPN).

Likelihood of occurrence and detectability are understood to be possibly influenced by control measures. Namely the likelihood of occurrence can be decreased as the detectability can be increased by suitable measures.

It must be kept in mind that vulnerable chains steps and their ranking must be identified and estimated respectively for each individual food business operator and product and a given time. The ranking needs revision and update regularly. It is not possible to create a generic ranking of vulnerabilities for the production of poultry meat. The [Table 2] and [Table 3] illustrate the process of calculation for a few steps in a given part of the poultry meat production chain. These examples have been selected for illustration purposes only.

Table 2. Example for vulnerability assessment in the poultry feed chain
Tabela 2. Primeri ocene ugroženosti u lancu ishrane živine

No. of potentially vulnerable chain step/ ***Broj koraka u lancu koji potencijalno su ugroženi***	**Description of chain step/** ***Opis koraka u lancu***	**Potential failure (contaminant name or tag/documentation failure)/** ***Potencijalna greška (naziv kontaminenta ili greška u oznakama/ dokumentaciji)***	**Cause of failure/** ***Uzrok greške***	**Current control measures in place/** ***Trenutno postojeće kontrolne mere***	**Sev[a]**	**Lik[b]**	**D[c]**	**VPN[d]**
9.01	Delivery of raw materials (feed chain)/ *Isporuka sirovina (lanac hrane)*	PCDD/DF	Contaminated feed additives/ *Kontaminirani aditivi*	In-house testing; 1–6 samples/ year; end product Official control – residues/ *Interna kontrola; 1-6 uzoraka godišnje; krajnji proizvod, Službena kontrola – rezidue*	8	3	2	48
9.09–9.19	Feed chain from “dosing minor components” to “bulk storage”/ *Lanac hrane od „doziranja manjih komponenti“ do „skladišta većih količina“*	Coccidiostats/ *Kokcidiostatici*	Cross contamination in subsequent feed batches/ *Unakrsna kontaminacija u uzastopnim šaržama hrane*	In house: determination of degree of carry-over/biennial Official feed control- residues/ *Interno: kontrola nivoa prenosa/dvaput godišnje; Službena kontrola hraniva - rezidue*	1	5	2	10

[a] Severity/*jačina*
[b] Likelihood/*verovatnost*
[c] Detectability/*detektibilnost*
[d] Vulnerability Priority Number/*prioritetni broj sa aspekta ugroženosti*

Table 3. Example for addressing vulnerabilities in the poultry feed chain putting into place new control measures
Tabela 3. Primer rešavanja pitanja ugroženosti u lancu hrane za živinu, uspostavljanjem kontrolnih mera

No. of potentially vulnerable chain step/ ***Broj koraka u lancu koji su potencijalno ugroženi***	**Description of chain step/** ***Opis koraka u lancu***	**Potential failure (contaminant)/** ***Potencijalna greška (kontaminent)***	**Cause of failure/** ***Uzrok greške***	**New control measures that could be put into place/** ***Nove konrolne mere koje mogu biti uvedene***	**Sev[a]**	**Lik[b]**	**D[c]**	**VPN[d]**
9.01	Delivery of raw materials (feed chain)/ *Isporuka sirovina (lanac hrane*)	PCDD/DF	Contaminated feed additives/ *Kontaminirani aditivi*	Test of each batch of feed additives at delivery/ *Testiranje svake šarže aditiva pri isporuci*	8	1	1	8
9.09–9.19	Feed chain from “dosing minor components” to “bulk storage”/ *Lanac hrane od „doziranja manjih komponenti“ do „skladišta većih količina“*	Coccidiostats/ *Kokcidiostatici*	Cross contamination in subsequent feed batches/ *Unakrsna kontaminacija u uzastopnim šaržama hrane*	Separate production lines for medicated feed/feed for non-target animals/ *Odvojene linije za proizvodnju medicinirane hrane/hrane za ne-ciljne životinje*	1	1	2	2

[a] Severity/*jačina*
[b] Likelihood/*verovatnost*
[c] Detectability/*detektabilnost*
[d] Vulnerability Priority Number/*prioritetni broj sa aspekta ugroženosti*

7. Conclusion

With changing consumer behaviour over a period of more than six decades since the Second World War and constantly increasing consumer demands with respect to quality and safety food analytical chemical methods experienced simultaneously a wide ranging improvement with respect to sensibility, accuracy, rapidness and reliability. In consideration of this expeditious development in analytical chemistry especially meat and meat products could benefit a lot concerning quality and safety. Nevertheless, in terms of risk assessment there exists the liability of chemical analysts in interaction with toxicologists to decide, if possible, on reasonable MRLs for legislation. In addition, the presented Failure Mode and Effect Analysis (FMEA) system can be an effective means assessing (prioritizing) vulnerable chain steps in the production of meat products to decrease or eliminate vulnerability.

References

Arneth W., Münch S., 2002. Contents of cholesteroloxides in heated meat produtcs — 2. Possibility of technological influence. Fleischwirtschaft 82, 87–91.

Arneth W., Herold B., 1988. Nitrate nitrite determination in sausages after enzymatic reduction. Fleischwirtschaft 68, 761–764.

Arneth W., 2001. Chemistry of curing meat flavour. Fleischwirtschaft 81, 85–87.

Arvanitoyannis I. S., Varzakas T. H., 2009a. Application of Failure Mode and Effect Analysis (FMEA) and cause and effect analysis in conjunction with ISO 22000 to a snails (Helix aspersa) processing plant; a case study. Critical Reviews in Food Science and Nutrition 49, 607–625.

Arvanitoyannis I. S., Varzakas T. H., 2009b. Application of Failure Mode and Effect Analysis (FMEA) and cause and effect analysis for industrial processing of common octopus (Octopus vulgaris) — Part II. International Journal of Food Science and Technology 44, 79–92.

Avery D., Watson R.T., 2009. Regulation of lead-based ammunition around the world. In: R.T. Watson, M. Fuller, M. Pokras, Hunt W.G., Editors, Ingestion of lead from spent ammunition: Implications for wildlife and humans, The Peregrine Fund, Boise, Idaho, USA .

Ballschmiter K., Bacher R., 1996. Dioxine, VCH, Weinheim.

Bostrom C. E., Gerde P., Hanberg A., Jernstrom B., Johansson C., Kyrklund T., 2002. Cancer risk assessment, indicators, and guidelines for polycyclic aromatic hydrocarbons in the ambient air. Environmental Health Perspectives 110, 451–488.

Bovee T. F. H., Pikkemaat M. G., 2009. Bioactivity-based screening of antibiotics and hormones. Journal of Chromatography A 1216, 8035–8050.

Bulushi I. A., Poole S., Deeth H., Dykes G., 2009. Biogenic amines in fish: Roles in intoxication, spoilage, and nitrosamine formation — A review, Critical Reviews in Food Science and Nutrition 49, 369–377.

Bundesamt für Verbraucherschutz und Lebensmittelsicherheit, 2004. Lebensmittel-monitoring Bericht 2002. http://www.bvl.bund.de.

Bundesamt für Verbraucherschutz und Lebensmittelsicherheit, 2008. Berichte zur Lebensmittelsicherheit 2007, Lebensmittel-Monitoring, BVL-Reporte Band 3, 1, Birkhäuser Verlag, Basel ISBN 978-3-7643-8912-3. http://www.bvl.bund.de.

Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz, 2009. Statuserhebung zu Dioxinen und PCB in Futter- und vom Tier stammenden Lebensmitteln. Angewandte Wissenschaft Heft 522, Verlagsgesellschaft W.E. Weinmann e.K. or pdf-file. available at http://www.bmelv.de/cae/servlet/contentblob/793196/publicationFile/44180/Heft522.pdf.

CAC/GL 62, 2007. Working principles for risk analysis for food safety for application by governments.

CAC, Codex Alimentarius Commission, 2008. Proposed draft code of practice for the reduction of contamination of food with polycyclic aromatic hydrocarbons (PAH) from smoking and direct drying processes ftp://ftp.fao.org/codex/alinorm08/al31_41e.pdf (2008).

Dederer I., 2007. Personal communication.

Sanco D. G., 2008. Working document — Non dioxin like PCBs http://www.bmu.de/files/english/pdf/application/pdf/non_dioxin_like_pcbs_090728_bf.pdf

Djinovic J., Popovic A., Jira, W., 2008a. Polycyclic aromatic hydrocarbons (PAHs) in traditional and industrial smoked beef and pork ham from Serbia, European Food Research and Technology 227, 1191–1198.

Djinovic J., Popovic A., W. Jira, ., 2008b. Polycyclic aromatic hydrocarbons (PAHs) in different types of smoked meat products from Serbia. Meat Science, 80, 449–456.

Djinovic J., Popovic A., Spiric A., Turubatovic L., Jira W., 2008c. 16 EU prioritetnih policiklicnih aromaticnih ugljovodonika (PAH jedinjenja) u dimu drveta i dimljenoj prsuti. Tehnologija mesa, 49, 181−184.

Drabik-Markiewicz G., Van den Maagdenberg K., De Mey E., Deprez S., Kowalska T., Paelinck, H., 2009. Role of proline and hydroxyproline in N-nitrosamine formation during heating in cured meat, Meat Science, 81, 479–486.

Duedahl-Olesen L., White S., Binderup M. L., 2006. Polycyclic aromatic hydrocarbons (PAH) in Danish smoked fish and meat products, Polycyclic Aromatic Compounds 26, 163–184.

EC, 2009a. Commission Directive 2009/8/EC of 10 February 2009 amending Annex I to Directive 2002/32/EC of the European Parliament and of the Council as regards maximum levels of unavoidable carry-over of coccidiostats or histomonostats in non-target feed (text with EEA relevance). Official Journal of the European Union L 40, 19–25.

EC, 2009b. Commission Regulation 124/2009/EC of 10 February 2009 setting maximum levels for the presence of coccidiostats or histomonostats in food resulting from the unavoidable carry-over of these substances in non-target feed (text with EEA relevance). Official Journal of the European Union L 40, 7–11.

EC, 2008. Commission Regulation 629/2008/EC of 2 July 2008 setting maximum levels for certain contaminants in foodstuffs, Official Journal of the European Union L 173, 6.

EC, 2006a. Commission Directive 2006/13/EC of 3 February 2006 amending Annexes I and II to Directive 2002/32/EC of the European Parliament and of the Council on undesirable substances in animal feed as regards dioxins and dioxinlike PCBs, Official Journal of the European Union L32, 44–53.

EC, 2006b. Commission Recommendation 2006/88/EC of 6 February 2006 on the reduction of the presence of dioxins, furans and PCBs in feedingstuffs and foodstuffs, Official Journal of the European Union L42, 26–28.

EC, 2006c. Commission Regulation 1881/2006/EC of 19 December 2006 setting maximum levels for certain contaminants in foodstuffs L364, 5–24.

EC, 2006d. Directive 2006/52/EC of the European Parliament and of the Council of 5 July 2006 amending Directive 95/2/EC on food additives other than colours and sweeteners and Directive 95/35/EC on sweeteners for use in foodstuffs, Official Journal of the European Union L 204 of 26.7.2006.

EC, 2005a. Commission Recommendation 2005/208/EC of 4 February 2005 on the further investigation into the levels of polycyclic aromatic hydrocarbons in certain foods, Official Journal of the European Union L 34, 43–45.

EC, 2005b. Regulation 183/2005/EC of the European Parliament and of the Council of 12 January 2005 laying down requirements for feed hygiene (text with EEA relevance), Official Journal of the European Union L 35, 1–22.

EC, 2003. Commission Decision 2003/181/EC amending Decision 2002/657/EC as regards the setting of minimum required performance limits (MRPLs) for certain residues in food of animal origin (text with EEA relevance) (notified under document number C(2003) 764), Official Journal of the European Union L 71, 17–18.

EC, 2003b. Directive 2003/74/EC of the European Parliament and of the Council amending Council Directive 96/22/EC concerning the prohibition on the use in stock farming of certain substances having a hormonal or thyrostatic action and of beta-agonists, Official Journal of the European Union L 28, 45–50.

EC, 2003c. Regulation 1831/2003/EC of the European Parliament and of the Council on additives for use in animal nutrition, Official Journal of the European Union L 268, 29–43.

EC, 2002a. Commission Decision 2002/657/EC implementing Council Directive 96/23/EC concerning the performance of analytical methods and the interpretation of results (Text with EEA relevance) (notified under document number C (2002) 3044), Official Journal of the European Union L 221, 8–36.

EC, 2002b. Directive 2002/32/EC of the European Parliament and of the Council of 7 May 2002 on undesirable substances in animal feed, Official Journal of the European Union L 140, 10–22.

EC, 1996a. Council Directive 96/22/EC concerning the prohibition on the use in stock farming of certain substances having a hormonal or thyrostatic action and of ß-agonists, and repealing Directives 81/602/EEC, 88/146/EEC and 88/299/EEC, Official Journal of the European Union L 125, 3–9.

EC, 1996b. Council Directive 96/23/EC on measures to monitor certain substances and residues thereof in live animals and animal products and repealing Directives 85/358/EEC and 86/469/EEC and Decisions 89/187/EEC and 91/664/EEC, Official Journal of the European Union L 125, 10–32.

EEC, 1990. Council Regulation 2377/90/EEC laying down a community procedure for the establishment of maximum residue limits of veterinary medicinal products in foodstuffs of animal origin. Official Journal of the European Union, L224, 1–8.

EFSA, 2009. Scientific Opinion of the Panel on Contaminants in the Food Chain on a request from the European Commission on cadmium in food. The EFSA Journal 980, 1–139.

EFSA, 2008. Scientific Opinion of the Panel on Contaminants in the Food Chain on a request from the European Commission on polycyclic aromatic hydrocarbons in food. EFSA Journal 724, 1–114.

Falco G., Domingo J.L., Llobet J.M.,Teixido A., Casas C. , Muller L., 2003. Polycyclic aromatic hydrocarbons in foods: Human exposure through the diet in Catalonia, Spain, Journal of Food Protection, 66, 2325–2331.

Falcon M.S.G., Amigo S.G., Yusty M.A.L, Lozano, J.S., 1999. Determination of benzo[a]pyrene in some Spanish commercial smoked products by HPLC-FL. Food Additives and Contaminants 16, 9–14.

Federal Office of Consumer Protection Food Safety, Germany, 2008. Annual report (2008) regarding the national residue control plan. Available at: http://www.bvl.bund.de/cln_027/nn_493680/DE/01__Lebensmittel/01__Sicherheit__Kontrollen/04__NRKP/01__berichte__nrkp/03__NRKP__ErgaenzendeDokumente__2008/nrkp__bericht__2008.html#doc1330186bodyText3.

Fiddler W., Pensabene J.W., Piotrowski E. G., Phillips J. G., Keating J., Mergens, W. J., Newmark H. L., 1978. Inhibition of formation of volatile nitrosamines in fried bacon by use of cure-solubilized alpha-tocopherol. Journal of Agricultural and Food Chemistry 26, 653–656.

Fiddler W., Pensabene J. W., Gates R. A., Adam R., 1998. Nitrosamine formation in processed hams as related to reformulated elastic rubber netting. Journal of Food Science 63, 276–278.

Fischer A., Bristle A., Gehring U., Herrmann K., Gibis M., 2005. Reddening of emulsion type sausage without nitrite curing salt — Part 1: Colour, colour stabilisation, nitrite and nitrate concentrations, sensory properties. Fleischwirtschaft 85, 110–115.

Fontcuberta M., Arques J. F., Martinez M., Suarez A., Villalbi J. R., Centrich F., 2006. Polycyclic aromatic hydrocarbons in food samples collected in Barcelona, Spain, Journal of Food Protection 69, 2024–2028.

Frede W., 2006. Taschenbuch für Lebensmittelchemiker, Springer Verlag, Berlin, 505.

Freybler L. A., Gray J. I., Asghar A., Booren A. M., Pearson A. M., Buckley D. J., 1993. Nitrite stabilization of lipids in cured pork. Meat Science, 33, 85–96.

FSAI, Food Safety Authority of Ireland, 2006. Investigation into levels of polycyclic aromatic hydrocarbons (PAH) in food on the Irish market http://www.fsai.ie/uploadedFiles/Monitoring_and_Enforcement/Monitoring/Surveillance/PAH_levels.pdf

Ghidini S., Zanardi E., Battaglia A., Varisco G., Ferretti E., Campanini G., Chizzolini R., 2005. Comparison of contaminant and residue levels in organic and conventional milk and meat products from Northern Italy. Food Additives and Contaminants, 22, 9–14.

Helmick J. S., Fiddler W., 1994. Thermal decomposition of the rubber vulcanization agent zinc dibenzyldithiocarbamate, and its potential role in nitrosamine formation in hams processed in elastic nettings. Journal of Agricultural and Food Chemistry, 42, 2541–2544.

Higginbotham S., Ramakrishna N. V. S., Johansson S. L., Rogan E. G., Cavalieri E. L., 1993. Tumor-initiating activity and carcinogenicity of dibenzo[a, l]pyrene versus 7, 12-dimethylbenz[a]anthracene and benzo[a]pyrene at low-doses in mouse skin. Carcinogenesis 14, 875–878.

Homberger E., Reggiani G., Sambeth J., Wipf H., 1979. The Seveso Accident: Its nature, extent and consequences. The Annals of Occupational Hygiene, 22, 327–370.

Honikel K.O., 2008. The use and control of nitrate and nitrite for the processing of meat products. Meat Science, 78, 68–76.

Hunt W.G., Watson R.T., Oaks J.L., Parish C.N., Burnham K.K., Tucker R.L., Belthoff J.R., Hart G., 2009. Lead bullet fragments in venison from rifle-killed deer:

Potential for human dietary exposure. PLoS ONE 4, Art. No. e5330.

IARC, 1987. IARC monographs on the evaluation of carcinogenic risks to humans overall evaluations of carcinogenity. An updating of IARC monographs, 1–42, 7.

IARC, 2009. http://monographs.iarc.fr/ENG/Classification/index.php.

JECFA, 2005. Summary and conclusion of the joint FAO/WHO Expert Committee on Food Additives. 64th Meeting, Rome, 8 – 17 February 2005, JECFA/64/SC.

Jira W., 2010. Polycyclic aromatic hydrocarbons in German smoked meat products, European Food Research and Technology 230, 447–455.

Jira W., Ziegenhals K., Speer K., 2008. Gas chromatography--mass spectrometry (GC-MS) method for the determination of 16 European priority polycyclic aromatic hydrocarbons in smoked meat products and edible oils. Food Additives and Contaminants, 25, 704–713.

Jira W., Ziegenhals K., K. Speer, 2006. Values don't justify high maximum levels: PAH in smoked meat products according to the new EU standards. Fleischwirtschaft International, 4, 11–17.

Jira W., 2004a. A GC/MS method for the determination of carcinogenic polycyclic aromatic hydrocarbons (PAH) in smoked meat products and liquid smokes. European Food Research and Technology, 218, 208–212.

Jira W., 2004b. Chemical reactions of curing and smoking — Part 1: Curing. Fleischwirtschaft 84, 235–239.

Kabisch J., Scheuer R., Roedel W., Gareis M., 2008. Influence on the microbial effect of sodium nitrite in raw fermented sausage. Mitteilungsblatt der Fleischforschung Kulmbach 47, 99–105.

Kinsella B., O'Mahony J., Malone E., Moloney M., Cantwell H., Furey A., Danaher M., Le Bizec B., Pinel G., Antignac J.-P., 2009. Options for veterinary drug analysis using mass spectrometry. Journal of Chromatography A, 1216, 8016–8034.

Knott J., Gilbert J., Green R. E., Hoccom D. G., 2009. Comparison of the lethality of lead and copper bullets in deer control operations to reduce incidental lead poisoning; field trials in England and Scotland. Conservation Evidence, 6, 71–78.

Le Bizec B., Pinel G., Antignac J. P., 2009. Options for veterinary drug analysis using mass spectrometry. Journal of Chromatography A, 1216, 8016–8034.

Lopez-Alonso M., Miranda M., Castillo C., Hernandez J., Garcia-Vaquero M., Benedito J. L., 2007. Toxic and essential metals in liver, kidney and muscle of pigs at slaughter in Galicia, north-west Spain, Food Additives and Contaminants, 24, 943–954.

Lorber M., Pinsky P., Gehring P., Braverman C., Winters D., Sovocool W., 1998. Relationships between dioxins in soil, air, ash, and emissions from a municipal solid waste incinerator emitting large amounts of dioxins. Chemosphere, 37, 2173–2197.

Luch A., Glatt H., Platt K.L., Oesch F. Seidel A., 1994. Synthesis and mutagenicity of the diastereomeric fjord-region 11, 12-dihydrodiol 13, 14-epoxides of dibenzo[a, l]pyrene. Carcinogenesis, 15, 2507–2516.

Luecke F.K., 2003. Use of nitrite and nitrate in the processing of meat from organic production — Benefits and risks, Fleischwirtschaft, 83, 138–142.

Mateo R., Rodriguez-de la Cruz M., Vidal D., Reglero M., Camero P., 2006. Transfer of lead from shot pellets to game meat during cooking, Science of the Total Environment 372, 480–485.

Milićević D., 2009. Mycotoxins in the food chain – old problems and new solutions. Technologija mesa 50, 99–111.

Mirvish S. S., 1975. Formation of N-nitroso compounds: Chemistry, kinetics and in vivo occurrence. Toxicology and Applied Pharmacology 31, 325–351.

Nisbet I.C.T., LaGoy, P.K., 1992. Toxic equivalency factors (TEFs) for polycyclic aromatic hydrocarbons (PAHs). Regulatory Toxicology and Pharmacology 16, 290–300. Nochemfood, 2010. http://www.nochemfood.eu

Pagan-Rodriguez D., O'Keefe M., Deyrup C., Zervos P., Walker H., Thaler A., 2007. Cadmium and lead residue control in a hazard analysis and critical control point (HACCP) environment. Journal of Agricultural and Food Chemistry, 55, 1638–1642.

Purcaro G., Moret S., Conte L. 2009. Optimisation of microwave assisted extraction (MAE) for polycyclic aromatic hydrocarbon (PAH) determination in smoked meat. Meat Science 81, 275–280.

Rapid Alert System for Food and Feed (RASFF), 2007. Annual report. Available at: http://ec.europa.eu/food/food/rapidalert/report2007_en.pdf.

Rapid Alert System for Food and Feed (RASFF), 2008. Annual report (2008) Available at: http://ec.europa.eu/food/food/rapidalert/report2008_en.pdf.

Reinik M., Tamme T., Roasto M., Juhkam K., Tenno T., Kiis A., 2007. Polycyclic aromatic hydrocarbons (PAHs) in meat products and estimated PAH intake by children and the general population in Estonia. Food Additives and Contaminants, 24, 429–437.

Riedmaier I., Becker C., Pfaffl M.W., Meyer H.H.D., 2009. The use of omic technologies for biomarker development to trace functions of anabolic agents. Journal of Chromatography A, 1216, 8192–8199.

Roda A., Simoni P., Ferri E. N., Girotti S., Ius A., Rauch P., 1999. Determination of PAHs in various smoked meat products and different samples by enzyme immunoassay. Journal of the Science of Food and Agriculture 79, 58–62.

Sanders L. C., Wise S. A., 1997. Polycyclic Aromatic Hydrocarbon Index. NIST Special Publication 922. National Institute of Standards and Technology, Gaithersburg http://ois.nist.gov/pahpages/index.pdf (1997).

Sanders P., 2007. Veterinary drug residue control in the Euro pean Union. Technologija mesa 48, 59–68.

SCF, Scientific Committee on Food, 2001. Opinion of the Scientific Committee on Food on the risk assessment of dioxins and dioxin-like PCBs in food, 30 May 2001, Update based on new scientific information available since the adoption of the SCF opinion of 22nd November 2000, European Commission CS/CNTM/DIOXIN/20final .

SCF, Scientific Committee on Food, 2002. Opinion of the Scientific Committee on Food on the risks to human health of polycyclic aromatic hydrocarbons in food. http://ec.europa.eu/food/food/chemicalsafety/contaminants/out153_en.pdf.

Scipioni A., Saccarola G., Centazzo A., Arena F., 2002. FMEA methodology design, implementation and integration with HACCP system in a food company. Food Control 13, 495–501.

Schober W., Luch A., Soballa V. J., Raab G., Stegeman J. J., Doehmer J., Jacob J., Seidel A., 2006. On the species-specific biotransformation of dibenzo[a, l]pyrene. Chemico-Biological Interactions, 161, 37–48.

Schwägele F., 2005. Traceability from a European perspective, Meat Science 71, 164–173.

Schwind K. H., Dänicke S., Jira W., 2009. Survey of dioxins, dioxin-like PCBs and marker PCBs in German feeds of plant origin. Journal für Verbraucherschutz und Lebensmittelsicherheit 10.1007/s00003-009-0548-4.

ΣChain, 6th Framework Programme (EC) Project, 2006. Developing a stakeholders' guide on the vulnerability of food and feed chains to dangerous agents and substances (FP6 – 518451). Available: http://www.sigmachain.eu.

Shahidi F., 1992. Prevention of lipid oxidation in muscle foods by nitrite and nitrite-free compositions. ACS Symposium Series, 500, 161–182.

Tannenbaum S.R., Wishnok J.S., Leaf C.D., 1991. Inhibition of nitrosamine formation by ascorbic acid. American Journal of Clinical Nutrition, 53, 247–250.

Toth L., 1983. Chemie der Räucherung, Verlag Chemie, Berlin.

Tricker A. R., 1997. N-nitroso compounds and man: Sources of exposure, endogenous formation and occurrence in body fluids. European Journal of Cancer Prevention 6, 226–268.

Tsuji L. J. S., Wainman B. C., Jayasinghe R. K., Van Spronsen E. P., Liberda E. N., 2009. Determining tissue-lead levels in large game mammals harvested with lead bullets: Human health concerns. Bulletin of Environmental Contamination and Toxicology, 82, 435–439.

Van den Berg M., Birnbaum L., Bosveld A.T.C., Brunstrom B., Cook P., Feeley M., Giesy J. P., Hanberg A., Hasegawa R., Kennedy S. W., Kubiak T., 1998. Toxic equivalency factors (TEFs) for PCBs, PCDDs, PCDFs for humans and wildlife, Environ Health Perspect, 106, 775–792.

Varzakas T. H., Arvanitoyannis I. S., 2009. Application of failure mode and effect analysis and cause and effect analysis on processing of ready to eat vegetables — Part II. International Journal of Food Science and Technology, 44, 932–939.

Waegeneers N., Pizzolon J. C., Hoenig M., de Temmerman L., 2009. The European maximum level for cadmium in bovine kidneys is in Belgium only realistic for cattle up to 2 years of age. Food additives and contaminants: Part A — Chemistry, analysis, control, exposure and risk assessment, 26, 326–332.

Wall P., 2009. Food safety: A global challenge. In: Cnossen, H.J., Wassens H.L., Heeres H.L., Luijchx N. B . L., 2009. Editors, Vulnerabilities in the food chain, 7–8.

Ward F. W., Coates M. E., 1987. Dietary fats and N-nitrosation in the rat. British Journal of Nutrition 58, 221–231.

Warthesen J., Scanlan R., Bills D., Libbey L., 1975. Formation of heterocyclic N-nitrosamines from the reaction of nitrite and selected primary diamines and amino acids. Journal of Agricultural and Food Chemistry 23, 898–902.

Wirth F., 1991. Restricting and dispensing with curing agents in meat products, Fleischwirtschaft 71, 1051–1054.

Ziegenhals K., Hübschmann H. J., Speer K., Jira W., 2008. Fast-GC/HRMS to quantify the EU priority PAH. Journal of Separation Science 31, 1779–1786.

Hemijska bezbednost u industriji mesa

Andrée Sabine, Jira Wolfang, Schwägele Fredi, Schwind K. H., Wagner Hubertus

Rezime: Od Drugog svetskog rata, ponašanje i stavovi potrošača u razvijenim zemljama su se drastično promenili. Prvo je postajala potražnja za dovoljnim količinama hrane nakon ratnih godina gladovanja, zatim se pojavila želja za boljim kvalitetom, a danas, većina potrošača traži bezbednu i zdravu hranu visokog kvaliteta. Prema tome, jedinstven pristup, koji će sačinjavati dosledni standardi, naučni principi i stroge kontrole, neophodan je kako bi se obezbedilo zdravlje potrošača i održalo njihovo poverenje i zadovoljstvo. Hemijska analiza duž celog lanca (praćenje), od primarne proizvodnje do potrošača i od potrošača do primarne proizvodnje (sledljivost), predstavlja veoma važan preduslov za osiguranje bezbednosti i kvaliteta hrane. Predmet pažnje ovog rada je "hemijska bezbednost mesa i proizvoda od mesa" uzimajući u obzir neorganske, kao i organske rezidue i kontaminante, korišćenje nitrita u proizvodima, pojavu veterinarskih lekova, kao i tzv. Failure Mode and Effect Analysis (FMEA) - Analiza neuspeha i efekata, kao sistema kojim se ocenjuju (određuju prioriteti) slaba mesta/koraci u okviru lanca ishrane kako bi se eliminisala odnosno smanjila njegova ranjivost.

Ključne reči: *hrana, meso, proizvodi od mesa, neorganske rezidue, organske rezidue, nitriti, veterinarski lekovi, FMEA.*

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