Prevention of Mycotoxin Contamination of Meat and Meat Products

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Abstract

In meat mycotoxins can occur primarily as a result of indirect transmission from animals exposed to natural contaminated feed. In case of meat products the possible occurrence of mycotoxins is strongly influenced by the particular recipe, i.e. the origin of meat and edible tissues used and the quality of ingredients such as spices, which are often highly contaminated with different mycotoxins. Other sources of contamination are the use of fungal derivatives in food processing, the use of toxigenic species or strains of fungal starter cultures for fermented products or when undesired moulding takes place.

Among the farmed animals relevant mycotoxin residues could be found in edible tissues and blood sera from pigs and poultry, while organs or muscle meat from ruminants are of no importance because of the decomposition activity of the rumen flora. Highest toxin concentrations could mainly be expected in liver and kidney, being often the target organs for mycotoxins. Transmission of mycotoxins and/or their metabolites to animal tissues has been proven for several mycotoxins among which aflatoxins and ochratoxins are of most importance because of their carcinogenic and genotoxic properties. In Europe, special interest is focused on ochratoxin A, for which the setting of maximum tolerable levels in various food stuffs and beverages is discussed. Ochratoxin A has been shown to occur in edible tissues of swine, a variety of sausages and spices.

To ensure the safety of meat, prevention strategies have to include all stages of food production with the aim to avoid fungal as well as mycotoxin contamination. The most important step lies at the stage of animal feeding and the reduction of the carry - over risk of mycotoxins from feed to animals. For safe meat products concepts for risk management and prevention measures are needed, which allow the detection and exclusion of the use of contaminated raw materials and spices. Fungal derivatives such as pigments used as colouring agents have to be evaluated toxicologically. Strategies for minimising the mycotoxin risk in mould-ripened meat products require fungi which are generally regarded as safe (GRAS status). Selection criteria therefore must be focused particularly on the absence of mycotoxin production on the fermented food substrate and should include the use of bioassays.

Key words: ochratoxin A, citrinin, aflatoxins, *Monascus*, *Penicillium*, spices, starter cultures.

Table 1 Relevance of naturally occurring mycotoxins for animal production as residues in food of animal origin

Mycotoxin	Animal Production	Carry Over in Meat and Edible Tissues*
Deoxynivalenol	+	—
T-2 Toxin	—	—
HT-2 Toxin	—	—
Diacetoxyscirpenol	—	—
Zearalenone	+	—
Fumonisin	+	—
Patulin	—	—
Aflatoxins	+	+ (milk)
Ochratoxin A	+	+ (swine)

*Based on naturally occurring levels found in feed in European countries

Introduction

Mycotoxins are a mixed group of fungal metabolites which possess a variety of toxic effects and which can be found on a wide range of commodities. Due to their toxic properties and high stability to heat treatment, the presence of mycotoxins in the food chain is potentially hazardous to the health of both humans and animals. In table 1 the more important naturally occurring mycotoxins and their relevance for animal production and as residues in food of animal origin are listed. Among these, ochratoxin A plays the major role as a residue in meat.

Sources of Contamination of Meat

In meat mycotoxins can occur primarily as a result of indirect transmission from animals exposed to natural contaminated feed (Fig. 1). Transmission of mycotoxins and/or their metabolites via feed to animal tissues has been experimentally proven for several mycotoxins. Among the farmed animals relevant mycotoxin (particular ochratoxin A) residues can be found in tissues from pigs, less in tissues from poultry and generally not in meat from ruminants because they can efficiently degrade mycotoxins by means of their rumen flora. In case of ochratoxin A relatively high toxin concentrations can be expected mainly in blood sera, kidneys and liver (Table. 2).

A contribution to the mycotoxin contamination of feeds could also arise from contaminated by-products from the food industry which are used as feed components. For example, grain and malt dusts from the malting plants are combined with dried maltsprouts to feed pellets. In these pellets high ochratoxin A concentrations were found which is due to the use of the dusts (unpublished own results).

Ochratoxin A in Meat and Edible Tissues

Ochratoxin A (OTA) is a mycotoxin occurring throughout the food chain²⁾. Recently, an epidemiological study on the "Ochratoxin A contamination of foods and its impact on

Sources of Contamination of Meat with Mycotoxins

Fig. 1 Sources of contamination of meat with mycotoxins

Table 2 Levels of Ochratoxin A in Meat and Edible Tissues ($\mu\text{g}/\text{kg}$)

sample	number of samples	positive samples (%)	mean	median	range
Kidney (swine)	61	27 (44)	0.43	<0.01	0.1-9.33
Liver (swine)	59	10 (17)	0.07	<0.01	<0.01-2.72
Pork	58	10 (17)	0.02	<0.01	<0.01-0.14
Beef	58	1 (2)	0.01	<0.01	<0.01-0.03
Poultry meat	41	0 (0)	0	0	0

Detection limit : $0.01 \mu\text{g}/\text{kg}$; samples with concentrations below the detection limit were assigned with $<0.01 \mu\text{g}/\text{kg}$

consumers in the Federal Republic of Germany” has been carried out²⁾. As a part of the study the contamination of meat and meat products has been investigated⁹⁾. Remarkable amounts of OTA were detected only in pork and edible tissues of swine (Table. 2) The highest percentage of positive samples were found in samples of kidneys, a lower percentage in the liver and muscle meat. In the kidneys also the highest amounts of OTA (up to $9.3 \mu\text{g}/\text{kg}$), followed by liver samples (up to $2.7 \mu\text{g}/\text{kg}$) have been detected. Only low levels were found in pork ; beef and poultry meat showed no importance in this respect.

Sources of Contamination of Meat Products with Mycotoxins

Fig. 2 Sources of contamination of meat products with mycotoxins

Sources of Contamination of Meat Products

An overview on the possible sources of contamination of meat products with mycotoxins is given in Fig. 2. The recipe, particularly the use of kidney and liver of swine and/or blood plasma is of most importance for a possible contamination of meat products with ochratoxin A⁴⁾. Other sources could be compounds of plant origin (e.g. vegetables) and cheese which are used in certain products, contaminated spices and colouring agents like *Monascus* extract. In addition to this indirect contamination a direct contamination of meat products by undesired moulding or the use of toxigenic fungal starter cultures could be possible.

Ochratoxin A in Meat Products

The available studies demonstrate that processing has little or no influence on the occurrence of OTA in meat products⁴⁾. The highest percentage of OTA-positive samples has been found in blood sausages and liver type sausages with about 70%, followed by salamis and bologna type sausages with about 50%, raw cured joints with 35% and the others with less than 20% (Table. 3). In the blood sausages and liver type sausages also the highest amounts of OTA were found with values up to 3 and 4 $\mu\text{g}/\text{kg}$ ⁵⁾. All the other meat products were found to be contaminated only with low OTA levels.

Ochratoxin A in Spices

The meat industry uses large quantities of spices. The occurrence of aflatoxins and

Table 3 Levels of Ochatoxin A in Meat Products ($\mu\text{g}/\text{kg}$)

Meat product	number of samples	positive samples (%)	mean	median	range
Blood sausage	57	44 (77)	0.16	0.04	<0.01-3.16
Liver type sausage	53	36 (68)	0.15	0.02	<0.01-4.56
Salami type sausage	56	28 (50)	0.04	<0.01	<0.01-0.27
Bologna type sausage	45	21 (47)	0.04	<0.01	<0.01-0.38
Raw cured joints	40	14 (35)	0.02	<0.01	<0.01-0.18
Sausage with poultry meat	40	7 (17)	0.01	<0.01	<0.01-0.03
Beef sausage	31	5 (16)	0.02	<0.01	<0.01-0.19
Cooked joints	21	3 (14)	0.01	<0.01	<0.01-0.04

Detection limit : 0.01 $\mu\text{g}/\text{kg}$; samples with concentrations below the detection limit were assigned with <0.01 $\mu\text{g}/\text{kg}$

Table 4 Occurrence of ochratoxin A in spices and herbs

Sample type	Number analysed	Number positive %	Concentration ($\mu\text{g}/\text{kg}$)			
			Mean	Median	Min	Max
Paprika	58	50 (86.2)	1.54	0.41	0.05	16.43
Nutmeg	35	28 (80.0)	3.29	2.64	0.22	15.23
Peppers	32	14 (43.8)	0.59	0.25	0.05	2.04
Coriander	31	21 (67.7)	1.48	1.08	0.19	3.88
Other spices	35	13 (37.1)	0.41	0.13	0.05	1.92
Herbs	13	2 (15.4)	0.08	0.08	0.05	0.11
Total	204	128 (62.7)	1.66	0.69	0.05	16.43

ochratoxin A in various spices such as pepper, chilli, curry, paprika, coriander and nutmeg has been reported^{1,7,10,11)}. In a recently carried out study on the occurrence of ochratoxin A in spices, highest frequencies of positive samples as well as toxin levels has been found in paprika, nutmeg, peppers and coriander (Table. 4).

Fungi and Fungal Derivatives in Food Processing

Several fungal species are traditionally used since centuries to prepare and to preserve certain foods in Asia (e.g. Miso, Angkak) and Europe (e.g cheese, mould fermented dry sausages). Development of new fermented products and of fungal derivatives is often restrained for fear of mycotoxins⁹⁾. Except insufficient general guidelines, there are no

**Selection of non-toxicogenic *Penicillium* spp.
for mould-ripened meat products**

Step I: General appearance

Step II: Technological suitability

Step III: Toxicological safety

Mycotoxin analyses by TLC/HPLC/EIA

Testing of crude extracts on:

- mutagenic activities (AMES-test)
- antibiotic activities
- cytotoxic activities (MTT-bioassay)

Antibiotic activity

MTT-cell culture assay

Fig. 3 Flow chart of a selection scheme to screen out toxigenic *Penicillium* spp.

specific criteria for prevention and evaluation of the mycotoxin risk in food products by using either traditional or new fungal species. The use of toxigenic fungi could therefore be another important source for the contamination of meat products with mycotoxins. An example is red mould rice (*Monascus* extract) as a colouring agent, which is not allowed in the Euroan Union, but nevertheless is illegally used as food additive. This food component with a typical red coulour is mostly used for so called health products with no sodium nitrite and low quality products with less meat. In a recently carried out study it could be shown that different products (vegetarian “meat-like” sausages and Asian food) purchased in Germany contained citrinin levels up to 105 µg/kg³). Furthermore, citrinin concentrations

of 2,800 $\mu\text{g/kg}$ and 157 $\mu\text{g/kg}$ were detected by HPLC-analysis in two samples designated as natural food colorants, while in four samples of red-mould rice from Japan citrinin was found by EIA only in lower concentrations (42–86 $\mu\text{g/kg}$). These data show that the natural origin of fungal extracts could not be a reliable stamp of quality and that a long traditionally use of a fungal extract could not replace chemical and toxicological examinations. Similar to fungal extracts mould starter cultures have to be carefully controlled. For European mould-fermented sausages (e.g. Italian salami) and hams mainly species of the fungal genus *Penicillium* are employed and used because of appearance, aroma, taste and preservation⁹. As *Penicillium* species are known to be potent producers of mycotoxins, the fungal isolates to be considered for food have to be thoroughly investigated for their toxicological potential. In order to meet the demands for toxicological safety, a selection scheme has been worked out which gives the possibility to screen out toxigenic species and which includes the testing of mould-ripened products themselves⁶. The criteria for the first steps of selection are the general appearance and technological suitability, that means: white colour and good and compact covering of the surface of the meat products. The final step is based on the investigation of the toxicological safety by physico-chemical and immuno-chemical mycotoxin analysis and furthermore testing crude extracts obtained from the mould ripened sausages for mutagenic, antibiotic and cytotoxic activities. When testing 249 isolates of *Penicillia* originally isolated from food products by this scheme, only 13 were found to meet the demands on technological suitability and toxicological safety (Fig. 3).

Prevention Strategies

To ensure the safety of meat, prevention strategies has to include all stages of food production with the aim to avoid fungal as well as mycotoxin contamination. The first and most important step lies at the stage of animal feeding and the reduction of the carry - over risk of mycotoxins from feed to animals. For safe meat products concepts for risk management and prevention measures are needed, which allow the detection and exclusion of the use of contaminated raw materials and spices. Fungal derivatives such as pigments used as colouring agents have to be evaluated toxicologically. Strategies for minimising the mycotoxin risk in mould-ripened meat products require fungi which are generally regarded as safe (GRAS status). Selection criteria therefore must be focused particularly on the absence of mycotoxin production on the fermented food substrate and should include the use of bioassays.

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