# Evolution of EU Legislation Governing the Presence of Undesirable Substances in Animal Feeds

*Pantelis E. Zoiopoulos & Pantelis I. Natskoulis*

*University of Ioannin*

## ABSTRACT

The legislative framework for undesirable substances in EU territory is explained at first with parallel commenting on the political dimension involved in this issue as regards the sector of animal feeding. Then, a brief account on developments of Community legislation in this field is given, with paying particular emphasis on the delicate subject of "dilution principle". In turn, reference is made to methods available for the analysis of undesirable substances in feeds. Furthermore, the article focuses on two groups of undesirable substances, i.e. firstly mycotoxins, where reference is made to legislative developments in this issue as well as prevention measures, and secondly, dioxins where a look is thrown to the historical background in this subject, while focusing on the dioxin episode in Belgium but also on subsequent findings. The legislative tools to confront problems of undesirable substances presence in the sector of animal nutrition is discussed, concluding with the importance of environmental dimension. Finally, reference is made to developments in Community Legislation for dioxins and mycotoxins during the last decade.

*Keywords:* EU legislation, animal feeds, undesirable substances, dioxins, mycotoxins.

*Classification:* LCC Code: KJE6242

*Language:* English

Great Britain Journals Press

LJP Copyright ID: 392884

London Journal of Medical & Health Research

Volume 26 | Issue 2 | Compilation 1.0

# Evolution of EU Legislation Governing the Presence of Undesirable Substances in Animal Feeds

Pantelis E. Zoiopoulos[α] & Pantelis I. Natskoulis[σ]

## ABSTRACT

*The legislative framework for undesirable substances in EU territory is explained at first with parallel commenting on the political dimension involved in this issue as regards the sector of animal feeding. Then, a brief account on developments of Community legislation in this field is given, with paying particular emphasis on the delicate subject of "dilution principle". In turn, reference is made to methods available for the analysis of undesirable substances in feeds. Furthermore, the article focuses on two groups of undesirable substances, i.e. firstly mycotoxins, where reference is made to legislative developments in this issue as well as prevention measures, and secondly, dioxins where a look is thrown to the historical background in this subject, while focusing on the dioxin episode in Belgium but also on subsequent findings. The legislative tools to confront problems of undesirable substances presence in the sector of animal nutrition is discussed, concluding with the importance of environmental dimension. Finally, reference is made to developments in Community Legislation for dioxins and mycotoxins during the last decade.*

*Keywords:* EU legislation, animal feeds, undesirable substances, dioxins, mycotoxins.

## I. INTRODUCTION

The primary purpose of agriculture is to produce food for human consumption, either directly from plants or through the animals' organism. The EU has focused its attention on protecting consumers, animals, and the environment by introducing transparency in the food production sector through the General Food Law (EU, 2002a). In modern agricultural practices, the concept of maximizing profits by minimizing costs through waste recycling is widespread, making the contamination of agricultural products with undesirable substances appear almost inevitable. In this respect, the BSE (Bovine Spongiform Encephalopathy) scandal emerged (Zoiopoulos, 2011; Zoiopoulos & Drosinos, 2010). Furthermore, with developments in the applications of biotechnology in animal nutrition (Zoiopoulos, 2004) new problems emerged with GM (Genetically Modified) animal feeds (Zoiopoulos, 1998a; 1998b; Zoiopoulos and Natskoulis, 2013).

The risk of food contamination from toxic substances in feed was reviewed by Kan and Meijer (2007), while the transfer of chemical substances from feed to animal products was examined by Leeman et al. (2007). Undesirable substances such as dioxins, mycotoxins, heavy metals, pesticides, and veterinary drugs are almost unavoidable in the environment. At this point, we would like to underline that in Community legislation the term "toxic substance" is rather not in use but that of "undesirable substance", since a substance could be undesirable - i.e. to adversely affect the organoleptic properties of a product, such as colour - but without causing harm to animal health.

In recent years, increasing attention has been paid to consumer risks arising from the presence of toxic substances in animal feed. This was prompted by various livestock products being contaminated with environmental pollutants. The

*Author α:* Laboratory of Animal Science, School of Management of Natural Resources and Enterprises, University of Ioannina, Ioannina 42010, Greece.
σ: Institute of Technology of Agricultural Products, Secretariat General of Agricultural Research, Hellenic Agricultural Organisation (ELGO) - DIMITRA, Likovrisi 14123, Greece.

most well-known examples include the contamination of animal products with dioxins as a result of industrial activities. Additionally, feed has occasionally been found adulterated with hormones, antibiotics, dioxins, and other chemical substances, either intentionally or through poor agricultural or industrial practices. The use of pesticides is an example of "controlled contamination" of crops which can, however, reach the consumer. Furthermore, feed contamination can occur in a more or less biological manner, as in the case of mycotoxins due to, for example, improper storage of feed raw materials.

There are several proposals for the categorization and classification of contaminants or undesirable substances along the food chain (SCAN, 2003), distinguishing between ions and elements, mycotoxins and microbial products, organic pollutants and botanical impurities. D'Mello (2003) differentiates the main groups of contaminants as follows: biotoxins (plant origin, bacterial pathogens and toxins, mycotoxins, etc.) and anthropogenic contaminants (pesticides, dioxins, veterinary drugs, etc.). Finally, Flachowsky and Danicke (2005) classify contaminants found in livestock nutrition into 8 groups as follows: 1. Heavy metals or other inorganic contaminants; 2. Naturally occurring toxic plant substances; 3. Microorganism products such as mycotoxins; 4. Human-origin contaminants; 5. Industrial, exhaust emission, and urban waste contaminants; 6. Fertilizer residues; 7. Plant production processing aids, and 8. Veterinary drugs.

This paper addresses the extensive network of Community legislation covering the presence of undesirable substances in animal feeds. After reporting on legislative developments, the text focuses on two prominent feed contaminants, specifically mycotoxins and dioxins. It should be stressed, however, that reference to provisions of Community legislation in this article in no way substitutes for the legislation itself, as formulated in the Official Journal of the European Union.

## II. LEGISLATIVE FRAMEWORK OF UNDESIRABLE SUBSTANCES IN ANIMAL FEEDS

Problems in the field of animal nutrition are global in nature.

### *2.1. The Political Dimension*

The global trade of animal feeds involves massive volumes and enormous sums of money, and consequently, significant economic interests. Among the most important agricultural commodities traded in international markets are feedstuffs such as maize, the world's leading cereal grain, and soya bean, the world's leading oilseed. These are used exclusively as raw materials in animal nutrition. However, following the GATT agreement (General Agreement on Tariffs and Trade) and its evolution into the WTO (World Trade Organization), which brought profound changes to international trade tariffs, it is said that one way to impose restrictions on the import of cheap products in a country, that are competitive with its own, is the quality of the products themselves. Quality, however, is a concept interwoven with the presence of undesirable substances. The whole issue tends to become more difficult, if not particularly delicate to resolve, when one considers that toxic substances may be present, such as heavy metals measured in ppm, i.e., Kg $10^{-6}$, and dioxins measured in ppt or Kg $10^{-12}$.

### *2.2. Evolution of Community legislation*

EU legislation on undesirable substances in animal feed constitutes a particularly critical area. The first piece of legislation adopted in this field was Directive 74/63 (EEC, 1974), which aimed at defining Maximum Permitted Levels (MPLs) in ppm (mg/kg) for various types and categories of feed for different livestock species to secure the health of animals and humans consuming their products. The Annex of this Directive contained three sections: 1. Substances (ions or elements) such as As, Pb, F, Hg, nitrates, etc.; 2. Microorganism products, particularly aflatoxin B1 from fungus *Aspergillus flavus*, as well as other naturally occurring undesirable substances like hydrocyanic acid, free gossypol, theobromine, mustard oil, etc.; and 3. Botanical impurities such as weed seeds (*Lolium*, *Datura*, etc.).

Over the years, one more Annex was added to Directive 74/63, which concerned the definition of MPLs for undesirable substances, particularly aflatoxin B1 in raw materials, mainly oilseed cakes and meals. Following certain preceding amendments and the recasting of various pieces of legislation necessitated by the General Food Law (Regulation 178/2002), Directive 2002/32 (EU, 2002b) on undesirable substances in animal feeds was adopted. To give an example of an undesirable substance in Annex I of this Directive, the case of heavy metal cadmium (Cd) is selected, the content of which should not exceed 1 ppm in feed materials of vegetable origin, 2 ppm in those of animal origin, 10 ppm in phosphates, and 15 ppm in premixes.

Furthermore, for a uniform approach to cases of elevated levels of undesirable substances, "action thresholds" were established to trigger off investigations aimed at identifying the sources of undesirable substances in Member States. Moreover, Directive 1999/29 (EU, 1999) contained a safeguard clause, that is, when a Member State has grounds to believe that an MPL set in Annex I, or when an undesirable substance not included in it, poses a risk to animal or human health or the environment, then the Member State may temporarily reduce or establish a new MPL, while simultaneously notifying the Commission.

Also, a new development in the legislation on undesirable substances in animal feed is the adoption of Community rules covering the issue of inevitable carry-over of authorized coccidiostats and histomonostats not purposely put in the feed, with their subsequent presence in produced foods. This was achieved through the issuing of Directive 2009/8 (EU, 2009b). Subsequently, the European Commission, in order to cover also the issue of the presence of residues of these substances in products of animal origin and thus protect public health, adopted Regulation 124/2009 (EU, 2009c), setting MPLs for the presence of these substances in foods. Finally, Directive 2002/32 contains a provision resolving at the time the long-pending debate on the "dilution principle" regarding contaminated feeds.

### *2.3 The Dilution Principle*

With Directive 77/101 (EEC, 1977) a list for "straight feeds" was adopted, while with Directive 92/87 (EEC, 1992) another list was published, this one for "raw materials" or "ingredients" of "compound" feeds or mixtures. A paradox appears here, namely the existence of two lists for the same feed. This distinction is "artificial" or even "political". To simplify, "straight feed" was the feed intended directly for the farmer, while 'raw material' was the same feed intended for the feed industry. This distinction was made to overcome problems regarding the use of feed containing an undesirable substance exceeding the MPL set in Directive 74/63. The reason is that a recognized feed industry possesses the appropriate scientific staff and equipment to detect, identify, and measure the content of an undesirable substance that exceeds the MPL set for that feed in Annex I, but remains within the upper limit set in Annex II for the corresponding raw material. This enables the feed industry to dilute the feed with others free of this undesirable substance, so that the final mixture administered to the animal remains within the maximum limit set for complete or complementary feeds for a specific species or physiological state of the animal.

Ultimately, the possibility of "dilution" for excessively contaminated feeds was abolished by the consolidated Directive 2002/32, which had a major impact on international feed trade. The relevant provision in Article 5 of this Directive states: "Member States shall ensure that products intended for animal feed which contain levels of an undesirable substance exceeding the MPL set in Annex I for these feeds cannot be mixed for dilution purposes with the same or other products intended for animal feeding". Nevertheless, Article 8 of the same Directive opens a "window" regarding the possibility of defining criteria for detoxification processes of contaminated feed and in any case, Member States must secure that measures are taken to guarantee the correct application of the accepted procedure for contaminated products destined for animal feeding. A significant work on the detoxification of feeds has been edited by Flachowsky (2006).

### 2.4 Methods of Analysis

As early as 1971, the then EEC adopted analytical methods for the official control of undesirable substances in animal feeds. Additionally, in 1976, the EEC issued methods for the sampling of feeds for control purposes via Directive 76/371 (EEC, 1976a). The first group of undesirable substances covered by official control methods included hydrocyanic acid, mustard oil, theobromine, lupin alkaloids, and trypsin inhibitor (EEC, 1971). Subsequently, the EEC issued official methods for the determination of gossypol in cottonseed oil by-products (EEC, 1972). It later issued an official method for the determination of aflatoxin B1 in feeds, which was based on TLC (Thin Layer Chromatography) (EEC, 1976b). Much later, when the MPL for aflatoxin B1 in complementary feeds for dairy cows was set at 5 ppb - below the lower detection limit of the TLC method (which was 10 ppb) - a method based on HPLC was introduced.

At this point, we would like to note that the subject of classical, rapid, but also modern emerging techniques for the analysis of mycotoxins has been reviewed by Krska and Welzig (2006). Furthermore, Binder (2007), in reviewing this subject, states that the requirements for fast results created rapid test systems which often prove satisfactory, though in certain situations it may be necessary to combine them with validated chromatographic techniques. In this spirit, a variety of immunological methods exist, such as ELISA or radioimmunoassay (RIA). Specifically, ELISA test kits are considered to have high throughput for feed samples, requiring small sample amounts and short analysis times (less than 1 hour, or even as short as 15 minutes). However, ELISA results for certain substrates should only be considered reliable if the kits have been validated for the corresponding agricultural commodities—for example, feed shipments on vessels involving bulk quantities, where the issue of sampling is rather critical. Finally, Directive 2002/70 (EU, 2002c) was published for the determination of dioxins and dioxin-like PCBs in feed. It should also be emphasized that, following the recasting of Community Directives as a consequence of the fundamental Regulation 178/2002 for food and feed, the consolidated and updated Regulation 152/2009 (EU, 2009a) was issued in the field of official analytical methods for feeds.

### 2.5 Developments at Community level

With Regulation 178/2002 of the European Parliament and of the Council, EFSA (European Food Safety Authority) was established. The EFSA CONTAM group, specifically the EFSA Panel on Contaminants in the Food Chain, completed its final Opinion on a series of 30 risk assessments undertaken over a period of 5 years in the field of undesirable substances in animal feed (EFSA, 2011a). These Opinions were provided following a request from the European Commission to EFSA to study the potential risks associated with animal and human health due to the presence of these undesirable substances in feeds. In most cases, the EFSA CONTAM group at the time did not identify any risk to animal health resulting from feed consumption at maximum permitted levels, provided that good agricultural practices were followed. However, adverse effects on animal health could not be excluded, such as from the mycotoxin deoxynivalenol for pigs or gossypol for sheep. Indicatively, Opinions were provided by the EFSA CONTAM panel on risks to animal and human health from γ-HCH and other hexachlorocyclohexanes (EFSA, 2005), tropane alkaloids from the weed *Datura spp.* (EFSA, 2008a), gossypol (EFSA, 2008b), and the mycotoxins zearalenone (EFSA, 2011b) and phomopsins (EFSA, 2012) due to the presence of these undesirable substances in food and feed.

## III. MYCOTOXINS

Mycotoxins are chemical compounds produced by certain fungi. Many such compounds exist, but only a few are regularly found in food and feed. Nevertheless, those actually encountered in food and feed are of great importance for human and animal health. In fact, mycotoxins are secondary metabolites produced by fungi, which cause a toxic reaction in the animal when ingested with food. The most widely distributed fungi of this type belong to the genera *Fusarium*, *Aspergillus*, and *Penicillium*. These fungi produce mycotoxins and contaminate food and feed through mycelium growth before and during harvest, or during storage (Bhatnagar et al., 2004). For practical reasons, in the feed manufacturing industry, aflatoxins, ochratoxins, zearalenone, and fumonisins are of particular interest, and the extent of damage caused by each category much depends on the species of the fungus. Aflatoxin B1 is considered the primary hepato-carcinogenic mycotoxin for animals. Trout, ducklings, and piglets are the most sensitive animals (Weidenborner, 2001). The setting of limits and regulatory provisions for mycotoxins can be influenced by several factors (Binder, 2007; Egmond and Jonker, 2004). These factors, which are of both, scientific and social nature, are as follows: 1) availability of toxicological data, 2) availability of data on occurrence in various agricultural commodities, 3) knowledge of the distribution of mycotoxin concentrations within a feed lot, 4) availability of analytical methods, 5) national legislation, and 6) the need for adequate market supply of food.

### 3.1 Evolution of Community Legislation

A report on the decision-making process, as well as an overview of developments in Community legislation on mycotoxins in the food and feed sector, has been published by Verstraete (2006). Regarding animal feed specifically, the legislation refers only to aflatoxin B1, starting from Directive 74/63 and extending to Directive 2002/32. The MPL for aflatoxin B1 in feed materials is 0.02 mg/kg (20 ppb), while for dairy mixtures for cows, it is 0.005 mg/kg (5 ppb). Community legislation (Directive 2002/32) does not define MPLs for mycotoxins other than aflatoxin B1 in feed. However, Commission Recommendation 2006/576 (EU, 2006a) provides recommendations for monitoring the presence of toxins deoxynivalenol, zearalenone, ochratoxin A, T-2 and HT-2, as well as fumonisins, in products intended for animal nutrition. Finally, Patterson (2004) provides the MPLs for various mycotoxins in animal feed in both the USA and Canada.
Recent developments in EU legislation for mycotoxins in animal feeds have focused on three main pillars: tightening the criteria for detoxifying contaminated feeds, standardizing the use of mycotoxins-detoxifying additives, and converting long standing recommendations in mandatory legal limits for specific toxins. More specifically, Regulation 2015/786 mandates that any process used to reduce mycotoxins must be scientifically validated and shown it does not result in toxic residues or alter the feeds' safety. In addition, this Regulation reinforced that mixing highly contaminated with clean feed to lower the average toxins levels is strictly forbidden (EU, 2015). Recent scientific opinions from EFSA Risk Assessments have paved the way for legislative updates. In fact, it concluded that current levels of Ochratoxin A (OTA) in feeds pose a low risk to poultry and pigs, but monitoring remains a priority due to potential kidney toxicity (EU, 2023). In addition, regarding T-2 and HT-2 mycotoxins, EU is currently reviewing the guidance values for these toxins in feeds to determine whether they should be converted to mandatory maximum limits under Directive 2002/32/EC.

### 3.2 Prevention Of Mycotoxins

When the elimination of mycotoxins from feed raw materials is not possible due to adverse weather conditions prior to harvest or improper storage, then therapeutic and preventive strategies must be utilized to minimize production losses and ensure the safety and quality of animal products. Preventive strategies include organic and inorganic adsorbents, which minimize intestinal absorption of mycotoxins and help their excretion via faeces.

Binder (2007) states that management practices aimed at maximizing plant yields can substantially reduce mycotoxin contamination. These include the use of adapted varieties, appropriate fertilization, weed control, necessary irrigation, and crop rotation (Edwards, 2004). However, even the better management strategies cannot eliminate mycotoxin contamination in years favourable for plant disease development. For post-harvest mycotoxin control, it is necessary to consider the prevention of conditions favouring fungal growth with subsequent toxin production, such as the water activity of stored products, temperature, seed condition, air composition between grains, microbial interactions, and the presence of chemical or biological preservatives (Shapira and Paster, 2004). Furthermore, Commission Recommendation 2006/583 (EU, 2006b) was issued, recommending measures for the prevention and reduction of *Fusarium* toxins in cereal grains and their products.

The subject of environmental conditions affecting the presence of mycotoxins in feeds was reviewed by Sanchis (2004), while the control of mycotoxins during storage and detoxification techniques were reviewed by Shapira and Paster (2004). Finally, the subject of mycotoxin control was studied by Jenning (2004), and the control of mycotoxins in animal feeds by Patterson (2004) as well as Natskoulis and Zoiopoulos (2014a).

Furthermore, due to the advancement in analytical techniques on (multi)mycotoxins determination, new concerns are rising regarding the toxicity of mycotoxins. With more sufficient "weapons" available, scientific community recently investigates, on the one hand the toxicity of emerging mycotoxins, not studied or regulated by legislation yet, but apparently present in our food chain (EFSA, 2014), and on the other hand the additive toxicological effect of co-occurring mycotoxins in a product (Schuchardt et al., 2014).

## IV. DIOXINS

One of the most serious contaminants of animal feeds is dioxins. Under the name "dioxins" lies a large number of compounds, some of which are highly toxic and confirmed carcinogens (Tuomisto et al., 1999). They are formed as by-products in a number of industrial and thermal processes and enter the environment in various ways, the most important of which is through the release of polychlorinated biphenyls (PCBs) into the atmosphere, during which two classes of compounds called dioxins - specifically polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) - are formed as by-products during synthesis. The majority of environmental pollution with dioxins originates from the energy production sector and industrial activity. Certain PCBs have properties similar to those of dioxins and are often referred to as dioxin-like PCBs and considered together with dioxins. Something over 20 years ago, the EU had the bad experience of a series of incidents involving dioxin contamination of the food chain.
It is clear that one source of human exposure to dioxins is food (Furst et al., 1992), with food of animal origin being the primary source of contamination. It also appears that, for dioxins, food contamination is directly proportional to feed contamination. Therefore, if one wishes to reduce dioxin contamination in the food chain, it is important to adopt dioxin control measures in animal feeds.

### *4.1. Historical Background*

A long history of accidents has occurred resulting in human exposure to dioxins (Covaci et al., 2008), the most notable of which were the rice oil poisonings in Yusho, Japan in 1968 (Tanabe et al., 1989) and Yucheng, Taiwan in 1979 (Soong and Ling, 1997), respectively. Other accidents, less known to the public, include the contamination of French cheese in 1970 with agricultural machinery engine oil, the poisoning of poultry in France in 1970 from plastic netting wire contaminated with dioxins, and contaminated pig feed in piggeries of Montana, USA in 1979 (Lock and Powell, 2008). Although it was neither the largest nor the most serious, the Belgian "PCB-dioxin" crisis was one of the most widely publicized food poisoning incidents in the media.

Covaci et al. (2008) state that the literature is 'generous' with episodes of environmental food contamination by dioxins, such as the dioxin-contaminated waste from Philips Duphar in the Netherlands in 1965. Also, the dioxin contamination of Agent Orange over large areas during the Vietnam War (Schecter et al., 2006a). Additionally, the dioxin contamination of poultry feed in New York in 1971 and Wilmington, USA, in 1972, as well as the large-scale environmental pollution following the incident in Seveso, Italy, when a chemical plant exploded and released 2,3,7,8-tetrachloro-dibenzo-p-dioxin (TCDDs) into the environment - a group of the most toxic synthetic compounds the humanity has ever known (Alaluusua et al., 2004). Furthermore, the "burial" of barrels with dioxin-contaminated residues in Lekkerkerk, Netherlands, in 1980, and the various adverse incidents that took place between 1996 and 2002 in Germany, Brazil, the USA, and other countries, where animal feeds (kaolinitic clay, citrus pulp, etc.) were contaminated with dioxins (Schecter et al., 2006b).

Thus, in 1998, in Germany, elevated dioxin levels were found in cow's milk. This was due to an ingredient in the dairy mixture, specifically dried citrus pulp of Brazilian origin (Malisch, 2000), which had been exported to a number of EU countries. The exact cause of the contamination was slow to be identified. Initially, it was attributed to an agent added to the fuel to increase efficiency during the pulp dehydration process. However, the exact cause was later found to be the limestone used to raise the pH and facilitate the removal of water from the hydrophilic pectins of the fresh citrus pulp during the dehydration process.

Immediately after the incident, the EU began to address the issue of dioxin contamination in feed seriously. First, it took measures to discard the contaminated pulp, and second, it introduced for the first time an MPL for dioxins in dried citrus pulp in Directive 1999/29 on undesirable substances in animal feed, at a level of 500 pg. This was the first time it was noted that, not only in Europe but worldwide, very few laboratories were capable of performing reliable dioxins analyses covering the entire range of its constituent congeners.

### *4.2. The Dioxins Incident*

While the case of "Mad Cow Disease" in Britain in 1996 became known as a "scandal" - as it is rumoured to have resulted from the deliberate action of the meat industry to compress the production costs of meat-and-bone meal, followed by an initial State attempt for a cover-up - the 1999 dioxin event in Belgium became known as an "episode" because it was due to an accident. Thus, fat contaminated with dioxins was incorporated, due to negligence (unintentionally), into the rations of various farm animals, mainly poultry (Broeckaert and Bernard, 2000). Egg hatchability dropped dramatically and egg production fell to approximately 30% (Covaci et al., 2008). It was found that waste oil from transformers, heavily contaminated with PCBs, was mistakenly mixed with used frying oils from collection bins intended for incorporation into animal feeds after refining. It appears that extensive waste recycling is a rather vulnerable area that can lead to feed contamination.

Scheprens et al. (2001) provide a brief but accurate report on the Belgian dioxin episode. These authors state that in 1999, approximately 30 kg of polychlorinated biphenyls (PCBs) and 1 kg of dioxins entered the food chain via about 1,500 tons of feed containing 60 tons of contaminated fat from a Belgian fat-melting company. This episode drew global interest both within and outside Belgium and forced the Belgian government to take drastic measures to protect public health, including a large-scale food control program with PCBs and dioxins measurements in over 20,000 and 450 samples of feeds and fat, respectively (Bernard et al., 1999).

Furthermore, Van Larebeke et al. (2001) provide an extensive description of the Belgian PCBs and dioxins episode. These authors write that in Belgium, about 20 companies collect animal fat from slaughterhouses, melt it, and sell it to feed industries. It is common practice in Belgium to add domestic waste fat collected at community recycling centres to this material. In January 1999, at the Flemish fat-melting company Verkest, 40-50 kg of mineral oil containing polychlorinated biphenyls (PCBs, most probably oil from worn-out old transformers coming from a waste recycling centre) was mixed with fat sent to 10 feed industries. Between January 15 and 31, 500 tons of animal fat containing approximately 60-80 tons of contaminated fat with 40-50 kg of PCBs and nearly 1 kg of dioxins, were distributed to poultry farms and to a lesser extent, rabbit farms, cattle farms, and piggeries, mainly in Belgium. However, small quantities were exported to the Netherlands, France, and Germany. The 500 tons of contaminated feed represented a limited percentage of the total amount of feeds produced and used in Belgium, which was estimated to exceed 28,000 tons per week. The aforementioned authors also report the pathological conditions first recorded in February 1999. These included a decrease in egg production and hatchability, and an epidemic of chick edema disease.

Covaci et al. (2008), approximately ten years after the event, provide a detailed review of the Belgian PCBs/dioxins crisis. These authors conclude that the consequences of this food crisis were: 1) the introduction of standards for PCBs in feeds in Belgium and, in 2002, harmonized standards in the EU, as well as for food of animal origin, 2) systematic national controls on food of animal origin, and 3) the creation of a Federal Agency for the Safety of foods in Belgium. The risk for human health from this major food incident was assessed with controversial results. It was suggested that, since only a small proportion of the food chain was contaminated, large-scale adverse effects on the Belgian population are unlikely. However, another assessment suggests that neurotoxic effects in infants, as well as behavioural impacts, might be observed. The same authors concluded that poor crisis management by the government had dramatic political and economic consequences (Authors' Note: On June 9, 1999, the causes of the crisis were announced, and the following day the Jean-Luc Dehaene government fell). However, this episode made both politicians and the public aware that food safety constitutes an issue of top priority. Furthermore, the PCBs crisis imposed a system for effective and rapid surveillance of the food chain, as well as risk communication, through the issuing of reliable and transparent Regulations, leading to a reduction in risk levels. Finally, it rendered the introduction of Community MPLs for PCBs and dioxins urgent.

### 4.3. Subsequent Findings

Immediately after the incident in Belgium, still in 1999, another case of dioxins contamination was discovered in Austria involving a kaolinitic clay used as an additive, specifically as a pelleting agent or binder in animal feeds. This agent had been mined in Germany. The EU took immediate measures to address the problem by adding a footnote to the relevant legislation, setting the MPL for certain binding agents at 500 pg/kg. Another incident with dioxins in feed took place in 2000. Dioxins were found in certain premixes containing choline chloride of Spanish origin. This substance is classified as a provitamin and is used as a feed additive. However, the problem was not the pure choline itself, but rather the carrier of vegetable origin which, although declared as corn cob meal, was actually sawdust, apparently from wood treated with an insecticidal preservative (eventually pentachlorophenol was detected).

Another case of dioxin contamination in the feed sector refers to two products from the USA, in which dioxin contamination was detected in 2002 in Ireland. These products are administered to pigs as a copper source but also contained peat as an appetite enhancer, and imports of these preparations into the EU were banned. Finally, exactly 12 years after the Belgian episode, another serious incident of dioxins contamination in an agricultural product, specifically meat, took place in Germany. And one should think that Germany is considered one of the strictest countries in the Community regarding controls in animal production. It seems that the phenomenon of recycling, which is endemic to food crises, it also recycles the concept of "dioxin episode".

### 4.4. Legislative Tools

Two main tools were available at the time within EU animal nutrition legislation to cope with the major dioxins' episode involving recycled contaminated oil in Belgium. First, the Decision on prohibited ingredients in animal nutrition (EEC, 1991), and second, Directive 1999/29 on undesirable substances in feeds. However, legislative efforts to include used frying oil in the list of prohibited feed materials were unsuccessful, as the majority of Member States believed that frying oil itself was not the cause of the problem, but rather the improper collection method that allowed PCB-contaminated transformer oil to enter the food chain. Instead, the implementation of strict conditions was proposed to the industry, including GMP (Good

Manufacturing Practice) and HACCP (Hazard Analysis and Critical Control Points).

The second alternative solution for the EU was to set MPLs for dioxins in the Directive on undesirable substances in animal feeds, in order to control the circulation of feed materials with dioxins exceeding this level. One might suggest that the existing MPL of 500 ppt, established for dried orange pulp, should be extended to cover all feed, but this is risky due to the fluctuation of dioxins levels in various raw materials. This proved extremely difficult in practice, as a number of unexpected obstacles emerged during the investigation of the consequences of implementing such MPLs. The EU delayed for two and a half years before adopting MPLs for dioxins in all types of animal feeds and did so with the footnote that the proposed levels should be reviewed later following further scientific evidence.

Recent research has transitioned from single toxicity assessments to complex interdisciplinary studies, notably adapting the "One Health" framework to link environment, animal, and human health (Houlihan et al., 2025). Major surveys in Ireland (2016-2018) and Belgium (2014-2024) have tracked dioxins levels in human milk, showing a downward temporal trend in exposure due to tighter regulatory bans (Anjelkovic et al., 2024; Houlihan et al., 2021). Furthermore, research post-2015 has heavily targeted the reduction of dioxins formation during waste processing by using sulphur oxide (Li, 2024), whereas new environmental risks have emerged with the burning of improperly managed health care waste (Muyise et al., 2024). Finally, major developments in EU legislation on dioxins after 2015 have been driven by 2018 EFSA's Scientific Opinion that drastically lowered the safety threshold for human exposure, in other words lowering TWI (Tolerable Weekly Intake) (EFSA, 2018). This scientific shift triggered off a wave of new maximum levels for various food categories and more stringent industrial monitoring (EU 2022; EU 2023; EU, 2024).

### *4.5 Problems In Animal Nutrition Practice*

After the dioxins episode in Belgium in 1999 and before taking measures for MPLs, the EU conducted a study to obtain indications for the background of dioxins levels in various animal feeds. However, the result of this study was unexpected: the natural level of dioxins in feed materials of marine origin from "closed seas", particularly from the Baltic Sea - which were considered of the highest quality in chemical composition and protein content - was remarkably high. In fact, the dioxin level in fish oil was much higher compared to fishmeal due to the lipophilic nature of these pollutants. European fishmeal and fish oil, which were found with an average dioxin content of the order of 1.2 and 4.8 ng/kg on Dry Matter basis, respectively (SCAN, 2000), were more heavily contaminated than those originating from the South Pacific Ocean (Chile or Peru), which contained 0.14 and 0.61 ng/kg DM, respectively. The problem was mainly concentrated on feeds for fish farming (Tacon, 1993), as approximately 20% of the total global production of fishmeal and fish oil was used in fish farming (EUROSTAT, 1999).

Generally, rations for livestock (cattle, sheep and goats, pigs, poultry) are formulated at a protein level of about 15-20%, whereas the protein required for the nutrition of carnivorous fish is about three times higher. The fishmeal content in these can reach 70%. Fish oil has a higher energy content and is also a good source of essential ω-3 type fatty acids. To provide the required nutrients to farmed fish, it is necessary that almost 2/3 of their ration consists of fishmeal and fish oil. Fish farming constitutes a growing sector in the EU, and this requires delicate handling of the situation so that not to jeopardize the future of this promising sector.

Ultimately, the EU adopted dioxin MPLs for various types of feed (9 in total), but these varied among different feed materials; for example, 0.75 ng/kg for feed materials of plant origin, 2.25 for fishmeal, and 6.0 ng/kg for fish oil, meaning the latter values are 3 and 8 times higher than those for plant-based feed materials. The EU also proposed setting both target and action levels for dioxins in plant origin feed materials (in the updated Directive 2002/32).

### *4.6 The Environmental Dimension*

There is a school of thought in Europe advocating that the problem of dioxin contamination in animal feed cannot be solved solely by setting MPLs and controlling the circulation of feeds, and that these efforts are time-consuming and expensive, as the cost of a full dioxin analysis is very high. The quantities of feeds traded are immense, and one wonders "who is going to pay the price for dioxins analyses on a daily basis?". Environmental pollution with dioxins is mainly caused by atmospheric emissions from various sources such as municipal wastes incineration, chemical production, etc. (EU, 2000, 2002d). Taking into account the impact of environmental pollution in the case of animal feeds, measures should be taken aiming at the general reduction of the atmospheric dioxins load. Therefore, there is a view that the problem of dioxin pollution should be addressed at its true source, namely at the environmental level. However, this is primarily a matter of political decision. Some thoughts on the issue of dioxins in animal feeds have been expressed twelve years ago (Natskoulis and Zoiopoulos, 2014b).

## V. CONCLUSIONS

Although progress has been made by developing alternative, i.e. cleaner, forms of practising animal production without the use of chemicals, like the so called "Organic Livestock Farming" (Zoiopoulos and Hdjigeorgiou, 2013; Zoiopoulos and Natskoulis, 2025) there are questions still pending in the field of presence of undesirable substances related to animal feeds. Initially, it must be emphasized that the possibility of applying the "dilution principle" regarding undesirable substances in the animal feed sector has been eliminated from Community legislation. However, a "window" has been opened regarding the possibility of defining criteria for the detoxification process of feeds and, in this spirit, efforts should, among others, focus on the field of mycotoxins prevention. Regarding dioxins, fishmeal and especially fish oil are the most heavily contaminated feed materials and fish farming is the most critical sector. Raw materials, especially those that are products from recycling, must be controlled for their quality and safety. The application of GAP (Good Agricultural Practice), GMP (Good Manufacturing Practice), and HACCP principles should be generalized in the production and processing of feed materials. Control programs should also be executed at European level in the field of raw material contamination. Furthermore, carry-over coefficients for dioxins from the environment, and particularly from the soil, into animal tissues and products should be investigated. In this spirit, the work of Verstraete (2011) is significant regarding the risk management of undesirable substances in animal feed, following the updated risk assessments conducted within the Community territory. Finally, environmental pollution with dioxins, which subsequently enter the food chain, is an important problem on which the scientific community should focus its attention, but the issue of environmental pollution is primarily political. However, we can be optimistic that solutions will be found within the European Union territory, despite the complexity of the matter and the involved difficulties.

*Conflict of Interest*

The authors have no conflict of interest.

## REFERENCES


1. Alaluusua, S., Calderara, P., Gerthoux, P. M., Lukinmaa, P.-L., Kovero, O., Needham, L., Patterson, D. G. Jr., Tuomisto, J. & Mocarelli, P. (2004). Developmental dental aberrations after the dioxin accident in Seveso. *Environ. Health Perspect.*, *112*, 1313-1318.
2. Andjelkovic, M.; Van Overmeire, I.; Joly, L.; Poma, G.; Malarvannan, G.; Vleminckx, C.; Malysheva, S. V.; Vanhouche, M.; Van Loco, J.; Van Nieuwenhuyse, A.; Covaci, A. (2024). Persistent organic pollutants in human milk of Belgian mothers: levels, time trend and exposure assessment for nursing infants. J. Environ. Exposure Assessment, *3*, 23.
3. Bernard, A., Hermans, C., Broeckaert, F., De Poorter, G., De Cock, A. & Houins, G. (1999). Food contamination by PCBs and dioxins. Nature, 401, 231-232.

4. Bhatnagar, D., Payne, G. A., Cleveland, T. E. & Robens, J. F. (2004). Mycotoxins: current issues in USA. In: D. Barug, H. P. van Egmond, R. Lopez-Garcia, W. A. Osenbruggen and A. Visconti, (Eds), Meeting the Mycotoxin Menace (pp. 17-47), Wageningen: Wageningen Academic Press.
5. Binder, E. M. (2007). Managing the risk of mycotoxin in modern feed production. Feed Sci. Technol., 133, 140-166.
6. Broeckaert, F. & Bernard, A. (2000). Polychlorinated biphenyls (PCBs) and dioxins (PCDD/Fs) in the Belgian contaminated food chain: sources, profiles and correlations, Final Report. Belgium: Ministry of Agriculture.
7. Covaci, A., Voorspoels, S., Schepens, P., Jorens, P., Blust, R. & Neels, H. (2008). The Belgian PCB/dioxin crisis - 8 years later: An overview. Environ. Toxicol. Pharmacol., 25, 164-175.
8. D'Mello, J. P. F. (2003). Food Safety Contaminants and Toxins (p. 480). Wallingford, Oxford, UK: CAB Publications, CAB International.
9. Edwards, S. G. (2004). Influence of agricultural practices on Fusarium infection of cereal and subsequent contamination of grain by trichothecenes mycotoxins. Toxicol. Lett., 153, 29-35.
10. EEC (1971). First Commission Directive 71/250/EEC of 15 June 1971 establishing Community methods of analysis for the official control of feeding-stuffs. OJ L 155, 12.7.1971, p. 13.
11. EEC (1972). Third Commission Directive 72/199/EEC of 27 April 1972 establishing Community methods of analysis for the official control of feeding-stuffs. OJ L 123, 29.5.1972, p. 6.
12. EEC (1974). Council Directive 74/63/EEC of 17 December 1973 on the fixing of maximum permitted levels for undesirable substances and products in feedingstuffs. OJ L 38, 11.2.1974, p. 31.
13. EEC (1976a). First Commission Directive 76/371/EEC of 1 March 1976 establishing Community methods of sampling for the official control of feedingstuffs. OJ L 102, 15.4.1976, p. 1.
14. EEC (1976b). Seventh Commission Directive 76/372/EEC of 1 March 1976 establishing Community methods of analysis for the official control of feedingstuffs. OJ L 102, 15.4.1976, p. 8.
15. EEC (1977). Council Directive 77/101/EEC of 23 November 1976 on the marketing of straight feedingstuffs. OJ L 32, 3.2.1977, p. 1.
16. EEC (1991). Commission Decision 91/516/EEC of 9 September 1991 establishing a list of ingredients whose use is prohibited in compound feedingstuffs. OJ L 281, 9.10.1991, p. 23.
17. EEC (1992). Commission Directive 92/87/EEC of 26 October 1992 establishing a non-exclusive list of the main ingredients normally used and marketed for the preparation of compound feedingstuffs intended for animals other than pets. OJ L 319, 4.11.1992, p. 19.
18. EFSA (2005). Opinion of the Scientific Panel on Contaminants in the Food Chain related to γ-HCH and other HCH as undesirable substances in animal feed. EFSA J. 250, 1-39.
19. EFSA (2008a). Tropane alkaloids (from Datura sp.) as undesirable substances in animal feed. Scientific Opinion of the Panel on Contaminants in the Food Chain. EFSA J. 691, 1-55.
20. EFSA (2008b). Gossypol as undesirable substance in animal feed. Scientific Opinion of the Panel on Contaminants in the Food Chain. EFSA J. 908, 1-55.
21. EFSA (2011a). From http://www.efsa.europa.eu/News Story: 15 April 2009. Accessed on 12 December 2025.
22. EFSA (2011b). Scientific Opinion on the risks for public health related to the presence of zearalenone in food. EFSA Panel on Contaminants in the Food Chain. EFSA J. 9, 2197.
23. EFSA (2012). Scientific Opinion on the risks for animal and public health related to the presence of phomopsins in feed and food. EFSA Panel on Contaminants in the Food Chain. EFSA J. 10, 2567.
24. EFSA (2014). CONTAM Panel (EFSA Panel on Contaminants in the Food Chain), Scientific Opinion on the risks to human and animal

health related to the presence of beauvericin and enniatins in food and feed. EFSA J, 12, 3802.
25. EFSA (2018). CONTAM Panel (EFSA Panel on Contaminants in the Food Chain), Knutsen, H.K., Alexander, J., Barregard, L. et al. Scientific Opinion on the risk for animal and human health related to the presence of dioxins and dioxin-like PCBs in feed and food. EFSA J. 16(11), 5333.
26. Egmond, H. P. & Jonger, M. A. (2004). Current regulations governing mycotoxin limits in Food. In N. Magan and M. Olsen (Eds), Mycotoxins in food. Detection and control (pp. 49-68). Cambridge, England: Woodhead Publishing Ltd.
27. EU (1999). Council Directive 1999/29/EC of 22 April 1999 on the undesirable substances and products in animal nutrition. OJ L 115, 4.5.1999, p. 32.
28. EU (2000). Directive 2000/76/EC of the European Parliament and of the Council of 4 December 2000 on the incineration of waste. OJ L 332, 28.12.2000, p. 91.
29. EU (2002a). Regulation (EC) No 178/2002 of the European Parliament and of the Council of 28 January 2002 laying down the general principles and requirements of food law, establishing the European Food Safety Authority and laying down procedures in matters of food safety. OJ L 31, 1.2.2002, p. 1.
30. EU (2002b). Directive 2002/32/EC of the European Parliament and of the Council of 7 May 2002 on undesirable substances in animal feed - Council statement. OJ L 140, 30.5.2002, p. 10.
31. EU (2002c). Commission Directive 2002/70/EC of 26 July 2002 establishing requirements for the determination of levels of dioxins and dioxin-like PCBs in feedingstuffs. OJ L 209, 6.8.2002, p. 15.
32. EU (2002d). Commission Recommendation of 4 March 2002 on the reduction of the presence of dioxins, furans and PCBs in feedingstuffs and foodstuffs. OJ L 067, 09.03.2002, p. 69-73.
33. EU (2006a). Commission Recommendation 2006/576/EC of 17 August 2006 on the presence of deoxynivalenol, zearalenone, ochratoxin A, T-2 and HT-2 and fumonisins in products intended for animal feeding. OJ L 229, 23.8.2006, p. 7.
34. EU (2006b). Commission Recommendation 2006/583/EC of 17 August 2006 on the prevention and reduction of Fusarium toxins in cereals and cereal products. OJ L 234, 29.8.2006, p. 35.
35. EU (2009a). Commission Regulation (EC) No 152/2009 of 27 January 2009 laying down the methods of sampling and analysis for the official control of feed. OJ L 54, 26.2.2009, p. 1.
36. EU (2009b). 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. OJ L 40, 11.2.2009, p. 19.
37. EU (2009c). Commission Regulation (EC) No 124/2009 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. OJ L 40, 11.2.2009, p. 7.
38. EU (2015). Commission Regulation (EU) 2015/786 of 19 May 2015 defining acceptability criteria for detoxification processes applied to products intended for animal feed as provided for in Directive 2002/32/EC of the European Parliament and of the Council. OJ L 125, 21.5.2015, pp. 10-14.
39. EU (2022). Commission Regulation (EU) 2022/2002 of 21 October 2022 amending Regulation (EC) No 1881/2006 as regards maximum levels of dioxins and dioxin-like PCBs in certain foodstuffs. OJ L 274, 24.10.2022, pp. 64-66.
40. EU (2023). Commission Regulation (EU) 2023/915 of 25 April 2023 on maximum levels for certain contaminants in food and repealing Regulation (EC) No 1881/2006. OJ L 119, 103-157.
41. EU (2024). Directive (EU) 2024/1785 of the European Parliament and of the Council of 24 April 2024 amending Directive 2010/75/EU of the European Parliament and of the Council

on industrial emissions (integrated pollution prevention and control) and Council Directive 1999/31/EC on the landfill of waste. OJ L, 2024/1785, ELI.

42. EUROSTAT (1999). Agriculture and Fisheries, Theme 5-22/1999, Luxemburg.
43. Flachowsky, G. & Danicke, S. (2005). From feed to safe food - contribution of animal nutrition to the safety of food. In A.P. Riley (Ed.), New Developments in Food Policy, Control and Research (pp. 65-96). New York, USA: Nova Science Publications.
44. Flachowsky, G. (2006). Möglichkeiten der Dekontamination von "Unerwunschten stiffen nach Angale 5 der Futtermittel verordung (2006)". Braunschweig, Germany: FAL Agricultural Research special issue 294.
45. Furst, P., Beck, H. & Theelen, R.MC., (1992). Assessment of human intake of PCDDs and PCDFs from different environmental sources. Toxic Substance. J., 12, 133-150.
46. Houlihan, M., Wemken, N., Keogh, M., O'Riordain, C., Noone, C., Tierney, J., Cellarius, C., Cleere, K., Morrison, J.J., Daly, S., Harrad, S., Tlustos, C., Coggins, M.A. (2021). Concentrations of polychlorinated dibenzo-p-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs) and polychlorinated biphenyls (PCBs) in human milk from Ireland: temporal trends and implications for nursing infant exposure. Journal of Environmental Exposure Assessment, 1, 2.
47. Jennings, P. (2004). Control of mycotoxins: Raw material production. In N. Magan and M. Olsen (Eds), Mycotoxins in food. Detection and control (pp. 443-460). Cambridge, England: Woodhead Publishing Ltd.
48. Kan, C.A. & Meijer, G.A.L. (2007). The risk of contamination of food with toxic substances present in animal feed. Anim. Feed Sci. Tech., 133, 84-108.
49. Krska, R. & Welzig, E (2006). Mycotoxin analysis: An overview of classical, rapid and emerging techniques. In D. Barug, D. Bhatnagar, H.P. van Egmont, J.W. van der Kamp, W.A. van Osenbruggen & A. Visconti (Eds), The Mycotoxin Fact Book: Food and Feed Topics (pp. 225-247). The Netherlands: Wageningen Academic Publishers.
50. Leeman, W.R., Van Den Berg, K.J. & Houben, G.F. (2007). Transfer of chemicals from feed to animal products: The use of transfer factors in risk assessment. Food Addit. Contam., 24, 1-13.
51. Li, W. (2024). Dioxin Control in the Co-processing of Waste Printed Circuit Board and Copper Concentrate with an Ausmelt Furnace. Aerosol and Air Quality Research, 24, 230126.
52. Lock, C. & Powell, D. (2000). The Belgian dioxin crisis of the Summer of 1999: a case study in crisis communications and management. February 1, 2000. Report No13, Department of Food Science, University of Guelph, p. 24.
53. Malisch, R. (2000). Increase of PCDDs/ PCDFs - contamination of milk, butter and meat samples by use of contaminated citrus pulp. Chemosphere, 40, 1041-1053.
54. Muyise, R., Cresswell, F., Kwizera, R., Laker, E., Owarwo, N., Meya, D., & Lamorde, M. (2024). Pilot project demonstrating the feasibility of HIV antiretroviral therapy waste bottle collection and recycling. Wellcome Open Res., 9, 175.
55. Natskoulis, P. I. & Zoiopoulos, P. E. (2014a). Feed Undesirable Substances as Food Contaminants. 1. Mycotoxins. AGROFood Industry and Hi-Tech., 25(3), 62-65.
56. Natskoulis, P. I. & Zoiopoulos, P. E. (2014b). Feed Undesirable Substances as Food Contaminants. 2. Dioxins. AGROFood Industry and Hi-Tech., 25(5), 38-41.
57. Pattersson, H. (2004). Controlling mycotoxin in animal feed. In N. Magan and M. Olsen (Eds), Mycotoxins in food. Detection and control (pp. 262-304). Cambridge, England: Woodhead Publishing Ltd.
58. Sanchis, V. (2004). Environmental conditions affecting mycotoxins. In N. Magan and M. Olsen (Eds), Mycotoxins in food. Detection and control (pp. 174-189). Cambridge, England: Woodhead Publishing Ltd.
59. SCAN (2000). Dioxins in Feed. Scientific Committee on Animal Nutrition. EC DG Health and Consumer Protection, Brussels.
60. SCAN (2003). Opinion of the Scientific Committee on Animal Nutrition on undesirable substances in feeds, Brussels.

61. Schecter, A., Quynh, H. T., Päpke, O., Tung, K.C. & Constable, J.D. (2006α). Agent Orange, dioxins, and other chemicals of concern in Vietnam: update 2006. J. Occup. Environ. Med., 48(4), 408-413.
62. Schecter, A., Birnbaum, L., Ryan, J. J. & Constable, J. D. (2006β). Dioxins: An overview. Environ. Res., 101(3), 419-428.
63. Scheprens, P. J. C., Covaci, A., Jorens, P. G., Hens, L., Scarpe, S. & van Larebeke, N. (2001). Surprising findings following a Belgian food contamination with polychlorobiphenyles and dioxins. Environ. Health Perspect., 109, 101-103.
64. Schuchardt, S., Ziemann, C., Hansen, T. (2014). Combined toxicokinetic and *in vivo* genotoxicity study on *Alternaria* toxins. *EFSA Supporting Publication* 11(11) EN-679, 130 pp.
65. Shapira, R. & Paster, N. (2004). Control of mycotoxins in storage and techniques for their decontamination. In N. Magan and M. Olsen (Eds), Mycotoxins in food. Detection and control (pp. 190-223). Cambridge, England: Woodhead Publishing Ltd.
66. Soong, D.K. & Ling, Y.C (1997). Reassessment of PCDD/DFs and Co-PCBs toxicity in contaminated rice-bran oil responsible for the disease Yu-Cheng. Chemosphere, 34, 1579-1586.
67. Tacon, A. G. J. (1993). FAO Fisheries Circular, No. 856, Rome, Italy.
68. Tanabe, S., Kannan, N., Wakimoto, T. & Tatsukawa, R. (1989). Isomer specific determination and toxic evaluation of potentially hazardous coplanar PCB, dibenzofurans and dioxins in the tissues of "Yusho" PCB poisoning victim and in the causal oil. Toxicol. Environ. Chem., 24, 215-231.
69. Tuomisto, J., Vartiainen, T. & Tuomisto, J.T. (1999). Synopsis on dioxins and PCBs. Kuopio, Finland: National Public Health Institute Publication B17/1999.
70. Van Larebeke, N., Everaert, K., Bernheim, P., Covaci, A., Vlietinck, R. & DePoorter, G. (2007). The Belgian PCBs and dioxin incident of January - June 1999. Expos. Data Health Perspect., 109, 265-273.
71. Verstraete, F. (2006). Decision making process and overview of recent and future European Union Legislation on mycotoxins in food and feed. In D. Barug, D. Bhatnagar, H.P. van Egmont, J.W. van der Kamp, W.A. van Osenbruggen & A. Visconti (Eds), The Mycotoxin Fact Book: Food and Feed Topics (pp. 51-82). The Netherlands: Wageningen Academic Publishers.
72. Verstraete, F. (2011). Risk management of undesirable substances in feed following updated risk assessments. Toxicol. Appl. Pharmacol. DOI: 10.1016/j.taap.2010.09.015.
73. Weidenboerner, M. (2001). Encyclopaedia of Food Mycotoxins, Berlin: Springer.
74. Zoiopoulos, P.E. (1998a). Modified animal feeds must be put to the test. Nature, Vol. 394, 27 August 1998, 823.
75. Zoiopoulos, P.E. (1998b). Keep it clean: Biotech companies should pay for independent research. New Scientist, No 2161, 21 November 1998, 59.
76. Zoiopoulos, P.E. (2004). A review on the applications of biotechnology in animal nutrition. J. Hellenic Vet. Med. Soc., 55, 156-164.
77. Zoiopoulos, P.E. (2011). Feed ban and BSE: The detection and identification of animal proteins in compound feeds. J. Hellenic Vet. Med. Soc., 62(1), 71-81.
78. Zoiopoulos, P.E. & Drosinos, E.H. (2010). The Animal Feed Question in the Shadow of Contemporary Food Crises: The European Challenge. New York, USA: Nova Science Publications.
79. Zoiopoulos, P.E. & Hadjigeorgiou, I. (2013). Critical overview on organic legislation for animal production: Towards conventional-isation of the system? Sustainability, 5(7), 3077-3094.
80. Zoiopoulos, P.E. & Natskoulis, P.I. (2013). "Foreign" dietary DNA in animals and safety evaluation of genetically modified feeds. J. Hellenic Vet. Med. Soc., 64(1), 69-83.
81. Zoiopoulos, P.E. & Natskoulis, P.I. (2025). Special article: Comments on EU Legislation governing organic animal production and the role of values in agriculture. J. Hellenic Vet. Med. Soc., 76(2), 8999-9008.