Short topical review

Mycotoxin management in the European cereal trading sector

David Siegela,*, Teresa Babuscio b

aBAM Federal Institute for Materials Research and Testing, Richard-Willstätter-Str. 11, 12489 Berlin, Germany
bComité du Commerce des céréales, aliments du bétail, oléagineux, huiles d’olive, huiles et graisses et agrofournitures (COCERAL), Rue du Trône 98, 1050 Brussels, Belgium

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A B S T R A C T

On the world scale, the European Union has established the most comprehensive regulations for mycotoxins in food and feed. These regulations, which are inter alia expressed in the form of maximum levels, largely affect cereal traders. To ensure the safety of their products and compliance with EU legislation traders are required to quantify the mycotoxin levels in their lots. However, while the analytical approaches of research and enforcement are well known and frequently reviewed in the scientific and legal literature, little detailed information is available on the mycotoxin management concepts of trade. The present article is intended to close this gap. On the basis of the results of two surveys conducted amongst European cereal traders in the years 2007 and 2009, three key issues in commercial mycotoxin management are outlined and discussed in the context of the current scientific literature. These are: the issue of sampling, the availability and performance of suitable analytical methods as well as issues evolving from variations between regulatory and contractual maximum levels.

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1. Introduction

1.1. Mycotoxins and the European cereal trading sector

Mycotoxins are toxic secondary metabolites produced by a range of fungi, including those genera which are colloquially referred to as molds. Such fungi are able to infect a multitude of hosts, as for instance cereals, whereas the accumulation of mycotoxins can take place in the field, during storage, processing or even on final food and feed products.
The toxic effects triggered by the ingestion of mycotoxins vary from compound to compound; however, a chronic activity (e.g. carcinogenicity, teratogenicity or mutagenicity) is a common characteristic in most cases (Bhat, Rai, & Karim, 2010; Wild & Gong, 2010). Hence, in order to protect food consumers and livestock, mycotoxin levels in cereals need to be controlled. To do so, the cereal production sector has modified agricultural practices to avoid fungal growth (Kabak, Dobson, & Var, 2006). On the regulatory side, legally binding, EU-wide maximum levels (MLs) for mycotoxins in food were introduced by the European Commission in 2001 and updated subsequently. For feed, a single ML for aflatoxin B₁ and several guidance levels other mycotoxins were set (vide infra). While the food and feed sector accounts for the major share of the total cereal utilization in Europe (Table 1), further, industrial uses of cereals have gained importance in recent years. Such applications are, for instance, the production of bioethanol or biopolymers from cereal based raw materials (Langeveld, Dixon, & Jaworski, 2010). In this context, it was pointed out that mycotoxins can affect bioethanol production by inhibiting the employed yeasts (Boeira, Bryce, Stewart, & Flannigan, 2000; Klosowski, Mikulska, Grajewski, & Blajet-Kosicka, 2010). Further issues arise from the fact that the by-products of bioethanol production, which are frequently used as feed, can have mycotoxin levels even higher than those of the raw material due to concentration effects (Sikov & Wu, 2009; Wu & Munkvold, 2008). For the sum of these reasons, cereal lots intended for industrial uses are often required to comply with quality criteria similar to those applicable to food and feed.

In any case, a conclusive statement on the quality of a cereal lot can only be made when its mycotoxin content is known to a sufficient degree of accuracy. This inherently requires chemical analysis. However, speed, cost and accuracy of the available analytical methods vary widely and usually a compromise has to be made, the nature of which depends on the context and the aim of the analysis. In this respect, the approaches taken by science and regulation are well documented in the scientific and legal literature, while little detailed information is available on the analytical approaches of trade. This is despite the fact that the European cereal market, with a total volume of 324.8 million tons (agricultural year 2009/2010, cf. Table 1) is subjected to the most comprehensive mycotoxin regulations worldwide, involving several maximum levels in the low parts per billion (ppb) range. Traders are required to operate in this area of tension both as buyers and sellers, not only considering official regulations but also specific provisions of commercial contracts. This leads to a high demand in practical and reliable mycotoxin analysis methods.

The commercial use of rapid mycotoxin test kits has recently been discussed in detail (Aldrick, van Egmond, & Solfrizzo, 2009). However, although rapid test kits are of high importance in the commercial sector, there are several other major issues which need to be addressed. We thus felt the need to explore the trade sector’s approaches to mycotoxin management in a more comprehensive fashion. This was done on the basis of quantitative data gathered through of two surveys amongst European cereal traders in the years 2007 and 2009.

As a basis for the forthcoming discussion, a brief introduction to the legal and contractual provisions relevant to cereal traders will be given. Subsequently, by interpreting the survey results, three current key issues in the field of commercial mycotoxin management will be outlined. By doing so we intend to document the current situation in European cereal trading with respect to mycotoxin management and to raise awareness for the prevalent “analytical needs” of the sector.

### 1.2. MLs in the EU

The general principles of the EU legislation on contaminants in food were laid down in 1993 (The Council of the European Communities, 1993). This legal act empowered the European Commission to take measures ensuring the protection of public health, including the introduction of MLs (Zmudzki & Wisniewska-Dmytrow, 2004). As a consequence, the Commission’s Scientific Committee for Food (SCF) established MLs for aflatoxins, ochratoxin A and patulin in food by 2001 (European Commission, 2001). This initial regulation replaced former national legislation. It was updated several times and substituted in 2006 by EU regulation 1881/2006 (European Commission, 2006c) which was further updated in 2007 and 2010 (European Commission, 2007, 2010b).

Summa summarum, the EU has implemented the most comprehensive regulations for food mycotoxins worldwide (van Egmond, 2004; van Egmond, Schothorst, & Jonker, 2007). The established MLs (Table 2) are binding in all member states.

The major factors affecting an ML are the toxicity of the respective mycotoxin, its occurrence in food products and the intake of the concerned food products by the population (Wu, 2004). Hence, the same mycotoxin may have different MLs in different cereals. Moreover, MLs depend on the state of processing. This may be illustrated using the example of fumonisin B₁/₂ MLs in maize and derived products, which are 4000 μg/kg for unprocessed maize, 1400–2000 μg/kg for different maize flours, 1000 μg/kg for maize based foods, 800 μg/kg for maize-based breakfast cereals and only 200 μg/kg for maize based children/infant food (European Commission, 2006c, 2007).

For feed, the legal situation is somewhat different, with only aflatoxin B₁ being regulated with binding MLs (range: 5–20 μg/kg) (European Commission, 2003; The European Parliament and the Council, 2002a). For the remaining toxins regulated in solid foods—deoxynivalenol (DON), zearalenone (ZON), ochratoxin A (OTA) and the fumonisins B₁ and B₂—only non-binding guidance values are set for feed (European Commission, 2006a). This is due to the fact that, with the exception of the aflatoxins, contaminated feed does not directly or indirectly impact the human health, i.e. there is merely a negligible carryover to animal products (European Commission, 2006a).

In the case of lots intended for industrial purposes (e.g. bioethanol or biopolymer production) neither MLs nor guidance levels have been established.

Mycotoxin MLs have a direct impact on all European food/feed business operators and traders. The obligation for a proactive mycotoxin control on their part is legally rooted in EU Regulation 178/2002, in which it is stated that “Food and feed business operators at all stages of production, processing and distribution within the businesses under their control shall ensure that foods or feeds satisfy the requirements of food law which are relevant to their activities and shall verify that such requirements are met.” (The European Parliament and the Council, 2002b). Hence, routine
mycotoxin analysis is essential for the purposes of both consumer protection and legal compliance.

1.3. Consequences of ML violations

Although the economic consequences of an officially detected mycotoxin ML violation vary from case to case, a rough estimate can be made for import controls done at an EU border. A figure for the average cost of an “EU border rejection” is given by Wu (2008). It includes testing and sampling, transportation, demurrage (storage, time, and labor costs), financial adjustments as well as reprocessing and amounts to €7300—11,000 (Wu, 2008). This figure, however, covers only administrative expenses. An ML violation can imply additional costs, depending on the further fate of the concerned lot. In the special case of a lot violating the (low) MLs for food but complying with the (higher) guidance values for feed, it is feasible to re-declare the lot as feed. The dilution of contaminated lots with uncontaminated material, on the other hand, is forbidden. Other mycotoxin reduction techniques applicable to contaminated food lots, e.g. the use of adsorbents to remove/inactivate mycotoxins, are not permitted. In the case of feed, additives can be employed for purposes of detoxification, however, this use is limited to lots which do not exceed the MLs or guidance levels (The European Parliament and the Council, 2002a, 2003). Hence, if a lot is contaminated too heavily to be re-declared as feed, the EU officials can request its destruction, which results in a total loss for the carrier. There is no clear legal guideline for deciding whether a lot violating EU regulations is rejected, destroyed or accepted after re-declaration. This decision is thus dependent on the administrative discretion of the EU officials conducting the control (cf. Article 18 of EC regulation 882/2004 (The European Parliament and Council, 2004)).

The above considerations similarly apply to the intra-European food and feed market, which is monitored through official market controls. However, differently to border controls, an intra-European mycotoxins ML violation will entail the tracing and identification of the source of contamination (The European Parliament and the Council, 2004). In 2009, a total of 6 border rejections and 8 intra-European alerts due to mycotoxins in cereals and bakery products were reported to the Rapid Alert System of Food and Feed of the EU (cf. 443 border rejections and 39 alerts due to mycotoxins in nuts, nut products and seeds in the same timeframe) (European Commission, 2008).

1.4. Other legal provisions affecting cereal traders

A second aspect of EU mycotoxin legislation, indirectly affecting the cereal processing industry and traders, concerns the technicalities associated with ML surveillance and enforcement. The two issues relevant in this context are sampling and analytical method performance. In both cases the legislator intends to define suitable techniques and promote their application in all member states. There is, however, an important difference in the approaches taken: while in the case of sampling regulations provide concrete protocols, analytical methods are regulated merely in terms of their performance criteria, which include mycotoxin dependent acceptable ranges for a method’s recovery as well as maximum levels for its typical relative standard deviation. Actual methods are not rooted in EU regulations. However, the European Commission recommends the use of methods which have been established as “European Standards” (cf. Section 3.3).2

Regulations addressing the technical issues discussed above exist for food (European Commission, 2006b, 2010a) and feed (European Commission, 2009). They apply to all European enforcement bodies, including local authorities, port health authorities and public analysts. While non-regulatory (i.e. commercial) analysts are not bound by the provisions, they may choose to align their analytical methodologies with the methods of the enforcing bodies for the sake of consistency. This can help to better predict the outcome of an official control.

1.5. Contractual provisions

In addition to the official regulations, European cereal traders have to consider provisions originating from contractual

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1. This “non-dilution rule” does not apply to those feed mycotoxins subject to a guidance level rather than an ML. It furthermore only applies to lots which are “marketed for the first time”. This is, for instance, the case when a lot is delivered to an EU market from a silo. However, before testing and marketing, a farmer may fill the silo with several batches of grains, which were not individually tested for mycotoxins.

2. Before being adopted by CEN, methods are subject to an international, collaborative validation study (Horwitz, 1995). The adoption process itself includes peer reviews, consultations and an international voting (Gilbert & Anklam, 2002). The European Commission actively requests “European Standards” for mycotoxin analysis as expressed in its mandate M 383 to CEN (European Commission, 2006d), in which it is stated that “the establishment of standardized methods of analysis is of utmost importance to guarantee a uniform application and control of the European legislation in all Member States.” However, the CEN adoption has been criticized for being too slow, causing the adopted methods to lack behind the technical state-of-the art (Gilbert, 1999).
agreements with business partners. Business contracts in cereal trading are mostly standardized and drafted by organizations like The Grain & Feed Trade Association (GAFTA, issuing standardized contracts for international trade) or several national organizations like IncoGrain (France) and AGER (Italy).

With respect to mycotoxins, the contracts usually define acceptable contractual maximum levels (CMLs). CMLs are commonly oriented toward the official MLs, however, in some cases a client will request CMLs lower than the official ML. This is due to one major consideration: as outlined above, mycotoxin MLs are higher for unprocessed raw materials than for processed food products. The underlying reduction factor represents the extent of mycotoxin reduction presumably achieved through the processing of raw materials. In the case example of fumonisins in maize, the legally rooted reduction factor going from raw maize (ML: 4000 µg/kg) to maize flour (particle size >500 µm, ML: 1400 µg/kg) is 35% (European Commission, 2007). Hence, the legislator expects that milled maize will contain merely 35% of the fumonisins present on the raw maize. However, food processors can experience different, variable reduction factors. In the worst case scenario, the processed product will thus violate an ML although the raw material complied with all relevant regulations. To avoid such conflicts, the processing industries can (and will) request CMLs distinctly below the official ML. Therefore, cereal traders may be bound by provisions even stricter than the ones established by the European Commission.

CMLs are of particular importance also for lots intended for industrial purposes, because mycotoxins can, for instance, interfere with yeasts used in the production of bioethanol (cf. Section 1.1).

In the case a lot is found to exceed a CML during a business transaction, a penalty or a cancellation of the transaction will result.

2. Methods

Two survey rounds were done (round 1: 20th of June to 31st of July 2007, round 2: 20th of August to 20th of September 2009), with the questionnaire being revised and extended for the second round (2009). Traders from Austria, Belgium, Denmark, France, Germany, Italy, Poland, Portugal, Spain, Sweden, and the United Kingdom participated in the 2007 survey. In 2009, replies were obtained from traders in Belgium, Denmark, France, Germany, Greece, Hungary, Ireland, Italy, the Netherlands, Portugal, Sweden, and the United Kingdom.

In the 2009 survey, each participant was asked to specify the volume of cereals traded (comprising imports as well as local production) as well as the number of farmers represented by his business. The total volume of cereals traded (237,840,441 tons) and farmers (1,965,350) in the involved EU member states (MSTs) in 2009 were taken from COCERAL cereal balance sheets. Based on these data, the received survey replies directly represented 21% of the farmers active in the involved EU MSTs in 2009 (for the 2007 survey similar data were not available).

The obtained replies were averaged for each EU MST, returning the MST-dependant mean reply \( R_{\text{MST}} \) [%]. The latter was assumed to be representative for the whole cereal volume traded in the respective MST. The overall result for all MSTs (\( R \) [%]) was obtained as the average of all \( R_{\text{MST}} \) weighted by the individual MST’s share of the cereal volume traded by all participating MST’s:

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R = \frac{1}{V_{\text{All}}} \sum_{\text{MST}} V_{\text{MST}} R_{\text{MST}}
\]  

with \( R \) [%] = overall result, \( V_{\text{MST}} \) = volume traded in MST, \( V_{\text{All}} \) = volume traded in all MST’s, \( R_{\text{MST}} \) = mean reply for MST [%].

3. Results and discussion

3.1. Prevention

Once a lot is found to contain mycotoxins, it must not be diluted (cf. Section 1.3). Hence, prevention is the key strategy in avoiding mycotoxin related losses. There are several approaches successfully lowering the average contamination level of agricultural commodities pre- and post-harvest, however, it should be kept in mind that molds are ubiquitously occurring organisms, which can never be fully eliminated under field conditions (Bhat et al., 2010). Typical pre-harvest prevention techniques (directed against field mycotoxins) include the use of mold resistant crop varieties, agricultural practices like field management as well as the use of chemical and/or biological fungicides. Post-harvest methods (directed against storage mycotoxins) are usually focused on the improvement of storage conditions, which can be achieved by effective drying, temperature control and/or fungicide treatment (Kabak et al., 2006; Magan, Aldred, Mylona, & Lambert, 2010).

In the 2009 survey, 60% of the traders stated to advise their contractual farmers on mycotoxin risk management (20% did not advise, 20% did not reply to the question). Fig. 1 shows details on the kinds of advice given. Subsequent to advising, 80% of the traders saw a reduction of the mycotoxin problem (18% saw no change while 2% reported a worsening of the situation). These data stress the high potential of prevention in managing mycotoxin related risks.

3.2. Sampling

Once harvested, the crop needs to be subjected to chemical analysis in order to determine its contamination grade. This is fully acknowledged amongst cereal traders: in the 2009 survey, 98% of the participants stated to test their lots for mycotoxins.

Since it is technically impossible to analyze an entire lot non-destructively, a representative sample is taken and analyzed. This seemingly simple sampling step, however, bears to highest potential for errors in the whole analytical chain (Blanc, 2006; van Egmond et al., 2007; Miraglia, De Santis, Minardi, Debegnach, & Brera, 2005; Whitaker, 2006). The main reason for this is the inhomogeneous distribution of mycotoxins in agricultural commodities and lots thereof, whereas the degree of inhomogeneity depends on whether the mycotoxin was formed in the field ("field mycotoxins", like DON, ZON and the fumonisins) or during storage ("storage mycotoxins", like OTA), cf. Table 2. From a sampling perspective, storage mycotoxins are more problematic,
because they are formed in “localized hot spots”, leading to a highly inhomogeneous distribution (Casado, Parsons, Weightman, Magan, & Origgi, 2009). A concise illustration of this issue is given by Blanc, who stated that in a 10 kg lot, consisting of 20,000 peanuts, a single, highly contaminated kernel is sufficient to cause the whole lot to violate the EU aflatoxin ML (Blanc, 2006). Hence, whether this single kernel is sampled or not will entirely determine the test result, which—in any case—will not be representative for the whole lot. To account for the pronounced inhomogeneity of contaminants, individuals are sampled or not will entirely determine the test result, which—in any case—will not be representative for the whole lot. To account for the pronounced inhomogeneity of contaminants, individuals are sampled or not will entirely determine the test result, which—in any case—will not be representative for the whole lot. To account for the pronounced inhomogeneity of contaminants, individuals are sampled or not will entirely determine the test result, which—in any case—will not be representative for the whole lot. To account for the pronounced inhomogeneity of contaminants, individuals are sampled or not will entirely determine the test result, which—in any case—will not be representative for the whole lot. To account for the pronounced inhomogeneity of contaminants, individuals are sampled or not will entirely determine the test result, which—in any case—will not be representative for the whole lot. To account for the pronounced inhomogeneity of contaminants, individuals are sampled or not will entirely determine the test result, which—in any case—will not be representative for the whole lot. To account for the pronounced inhomogeneity of contaminants, individuals are sampled or not will entirely determine the test result, which—in any case—will not be representative for the whole lot. To account for the pronounced inhomogeneity of contaminants, individuals are sampled or not will entirely determine the test result, which—in any case—will not be representative for the whole lot. To account for the pronounced inhomogeneity of contaminants, individuals are sampled or not will entirely determine the test result, which—in any case—will not be representative for the whole lot. To account for the pronounced inhomogeneity of contaminants, individuals are sampled or not will entirely determine the test result, which—in any case—will not be representative for the whole lot. To account for the pronounced inhomogeneity of contaminants, individuals are sampled or not will entirely determine the test result, which—in any case—will not be representative for the whole lot. To account for the pronounced inhomogeneity of contaminants, individuals are sampled or not will entirely determine the test result, which—in any case—will not be representative for the whole lot. To account for the pronounced inhomogeneity of contaminants, individuals are sampled or not will entirely determine the...
The vast majority of portable methods used for mycotoxin analysis are based on enzyme-linked immunosorbent assays (ELISAs) (Köppen et al., 2010; Krska & Molinelli, 2009; Zheng et al., 2006). Other, more recent rapid methods are based on fluorescence polarization, for instance. In the case of ELISAs, qualitative, semi-quantitative and quantitative kits exist, whereas the speed of analysis usually decreases in the order given. In any case, a major advantage of the ELISA technique is its portability and ease of use compared to stationary, chromatography based systems. Ready-to-use ELISA kits for mycotoxin analysis are offered by several companies. However, a major disadvantage is the possibility of false positive results due to cross-reactions or false negative results due to the inhibition of the ELISA antibodies by matrix components (Anklam et al., 2002). Studies on the risk associated with false positive or false negative results originating from rapid test kits have been discussed in detail (Alldrick et al., 2009). It is important to note that false results can occur not only upon using test kits of different manufacturers on the same sample, but also upon using the same test kit on different samples of the same agricultural commodity (Alldrick et al., 2009).

Laboratory-based mycotoxin analysis is almost exclusively done using HPLC coupled to various detectors like ultraviolet or fluorescence units as well as tandem-mass spectrometry (MS/MS) (Köppen et al., 2010; Turner, Subrahmanyam, & Piletsky, 2009). As most mycotoxins are non-volatile when not derivatized, gas-chromatography (GC) is barely used. Contrary to ELISAs, HPLC based methods do not have to rely exclusively on biological materials (enzymes, antibodies) and hence produce more accurate results. Following on a cleanup by antibody-based immunoaffinity columns (IAC’s) an HPLC separation can largely eliminate false positive results due to antibody cross-reactivity, thus providing a maximum in selectivity. This advantage is reflected by the fact that the mycotoxin methods, which have been adopted by the European Committee for Standardization (CEN) as “European Standards” to date, are altogether based on HPLC, mostly in combination with IAC’s.3

As can be inferred from Figs. 5 to 7, the majority of traders avoid the conflict “speed vs. accuracy” by relying both on rapid and HPLC based methods. Although some alternatives have recently become available (Krska & Molinelli, 2009), ELISAs is still the rapid method of choice. While ELISA kits are mainly used in-house due to their low cost and ease-of-use (Fig. 6), HPLC analyses are frequently outsourced to external laboratories (Figs. 5 and 7). By comparing the data for 2007 and 2009 it can be seen that this allocation became even more pronounced during the period under consideration. The major reasons for this are the steadily decreasing cost of ELISA kits for mycotoxins and the increasing number of accredited, external laboratories offering routine mycotoxin analysis.

The commissioning of ISO/IEC 17025 accredited laboratories is of particular importance to cereal traders (Fig. 8), as the ISO/IEC 17025 standard inter alia ensures the correct reporting of the analytical results obtained. In practice, incomplete reporting often causes ambiguity about a sample’s compliance with a given ML or CML. This is for instance the case when the commissioned...
laboratory does not disclose whether the reported quantitative result was corrected for recovery or not. Further, the uncertainty of the analytical result needs to be established and communicated to the client. Upon an official control, the expanded uncertainty (expansion factor 2, corresponding to a confidence level of 95%) of the test result must be deducted from the recovery corrected test result itself in favor of the owner of the concerned lot (European Commission, 2006b). Hence, only if both recovery and expanded uncertainty are known, a sound decision with respect to ML or CML compliance can be made. Both the ISO/IEC 17025 standard as well as Commission Regulation 401/2006 include provisions to ensure that the respective information, which needs to be obtained by means of method validation, is forwarded to the client.

Concerning the analytes tested for, the data shown in Fig. 9 reasonably reproduce the importance of the different mycotoxins in European cereals. DON, ZON and OTA are the prevalent analytes, as they are known to occur on all major cereals relevant to trade, i.e. barley, maize, millet, oats, wheat, rice, rye, sorghum etc. (Weidenbörner, 2001). The lower analysis frequency for the aflatoxins and the fumonisins is due to the fact that these compounds do not play a major role on certain cereals like barley or wheat (Weidenbörner, 2001). In the special case of the T2/HT2 toxins, European regulations are not yet in place. Hence, the availability of analytical methods and rapid test kits is limited. This might contribute to a lower analysis frequency.

3.4. Conflicts

Mycotoxin related conflicts in cereal trading arise when official or contractual controls indicate the violation of an ML or CML.

Figs. 10–12 show that conflicts occur more frequently subsequent to official controls than to contractual controls. In any case, considering that 98% of the traders test their lots for mycotoxins (cf. Section 3.2), the number of yet occurring conflicts is surprising. As for the official controls, a possible explanation might be that the analytical chains (Fig. 3) of trade and the enforcing bodies are not harmonized, thus producing varying results. This problem is accentuated by the fact that there is a lack of harmonized sampling plans for cereals (cf. Section 3.2). Secondly, it can be noted that the mycotoxin analysis methods adopted by CEN to date cover by far not all of the mycotoxin–matrix combinations for which MLs are in effect (European Committee for Standardization, 2009). Also, portable techniques are not yet part of the CEN mycotoxin method portfolio. These shortcomings make it difficult for any food or feed business operator to harmonize or align their analytical chains with those used by the enforcing bodies.

In the case of testing done by trading partners, the analytical chain to be used both by buyer and seller is often very similar. Conflicts due to customer complaints are thus less frequent (Figs. 11 and 12). Even so, there appears to be a residual risk which cannot be avoided by aligning analytical chains. This residual risk is most likely due to performance issues of the involved sampling plans or analytical methods, leading to randomly altered test results.

A conclusion, which can be drawn from all these aspects is, that there is a pronounced need for validating the analytical chains used in commercial mycotoxin analysis. Validation is an essential tool for understanding a procedure’s performance and its influence on the test result. While validation itself does not improve an analytical procedure, it is the only way to make a conclusive statement on whether or not it is actually “fit for purpose”. Consequently, the ultimate goal of validation is to characterize and lower both the buyer’s and the seller’s risk in transactions relying on chemical analysis for quality control (Hubert et al., 2004). While the aligning of the analytical chains used by buyers and sellers (or traders and enforcing bodies) is an easily feasible way to produce more consistent results, it can not replace validation (even if the same methods are used by both parties, the results can vary due to imprecision or lacking robustness of the method; also, identical, but wrong results can be obtained).

Unfortunately, there is a pronounced shortage of validated sampling plans and analytical methods available to traders or contractual laboratories. This introduces some arbitrariness to the analytical results gathered for trade related decisions.

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3 To avoid losses due to unpredictable test results, traders may effect an insurance policy. In 2009, 25% of the traders stated to have been covered by insurance in a mycotoxin related conflict.
4. Conclusions

In this article, we have outlined mycotoxin related legal and technical challenges presented to European cereal traders on the basis of a literature review and quantitative survey data. In conclusion, we believe that the following three issues can be considered most substantial from a trade perspective:

(i) Trade has to consider both MLs and CMLs, whereas the difference between the two arises from the concern about the mycotoxin reduction factors practically achievable by cereal processing. This similarly applies to food, feed and industrial applications. As CMLs are usually lower than official MLs, additional strain is put on cereal traders.

(ii) Sampling is the major source of uncertainty in mycotoxin analysis (cf. Section 3.2). Therefore, harmonized, legally accepted sampling schemes for those types of commodities and lots relevant in cereal trading are required. As a next step, it would be highly desirable to quantify the degree of uncertainty introduced through those sampling schemes in the sense of a sampling plan validation. Such quantitative data are surprisingly limited. This applies both to the legal and the scientific literature.

(iii) Although the European legislation on mycotoxins is harmonized since 2001 and although a range of performance criteria for mycotoxin analysis methods have been legally defined, there still is a pronounced need for validated analytical methods. This need is particularly strong in the field of rapid methods capable of supporting on-site decisions of lot acceptance. Due to the significant risk of false positive or false negative results obtained through the currently available, antibody-based rapid test kits, trade is often forced to rely on lengthy and costly confirmatory analyses by external laboratories (Figs. 3 and 5). Improved rapid test kits, which are adequately characterized by means of comprehensive validation, could largely reduce this burden. It should, however, be acknowledged that test kits need to be applied correctly, that is only in the frame of their technical specifications and only to the matrices they were validated for. In this respect, trained personnel and an appropriate working environment are further fundamental prerequisites (Alldrick et al., 2009).

The issue of food and feed mycotoxins is, after all, by far not resolved and will continuously challenge regulators, scientists and food business operators. In view of this, the present article is intended to contribute to a better understanding between the involved stakeholders. We believe that it should be a common effort to reduce the many sources of uncertainty in modern mycotoxin analysis.

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