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Effect of milling procedures on mycotoxin distribution in wheat fractions: A review

Federica Cheli*, Luciano Pinotti, Luciana Rossi, Vittorio Dell'Orto

Department of Health, Animal Science and Food Safety, Università degli Studi di Milano, Via Trentacoste 2, 20134 Milano, Italy

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ABSTRACT

Cereals and cereal by-products constitute a major part of human and animal diet. It has been estimated that up to 25% of the world's crops may be contaminated with mycotoxins. The relevance of mycotoxins on human/animal health prompted the European Community to introduce maximum permissible limits in foods and feeds. Considering the levels indicated by the European legislation, results from literature indicate that sometimes the limits proposed for cereal-derived products may be not warranted by the limit for unprocessed cereals. Therefore, the understanding of how mycotoxin distribution and concentration change during the milling process is a worldwide topic of interest due to the high economic and health impact.

This paper reviews the most recent findings on the effects of wheat milling process on mycotoxin distribution in products and by-products. Published data confirm that milling can minimize mycotoxin concentration in fraction used for human consumption, but concentrate mycotoxins into fractions commonly used as animal feed. The concentration of mycotoxins in wheat by-products may be up to eight-fold compared to original grain. Other physical processes carried out before milling, such as sorting, cleaning, and debranning, may be very efficient to reduce the grain mycotoxin content before milling. Published data show a high variability in mycotoxin repartitioning and sometimes appear conflicting, but this may be mainly due to the type of mycotoxins, the level and extent of fungal contamination, and a failure to understand the complexity of the milling technology. A precise knowledge of such data is vital and may provide a sound technical basis to mill managers to conform to legislation requirements, support risk management and regulatory bodies in order to reduce human and animal exposure to mycotoxins, reduce the risk of severe adverse market and trade repercussions, and revise legislative limits.

1. Introduction

Cereals and cereal by-products constitute a major part of the daily diet of the human and animal populations. The end products of wheat processing are, other than semolina or flour, several by-products coming from the surface layers, characterised by higher micronutrient and bran contents, and mainly used as animal feeds. However, they may represent a source of compounds with unique physico-chemical, nutritional, and functional properties which may have a high value for human nutrition, too (Hemery, Rouau, Lullien-Pellerin, Barron, & Abecassis, 2007).

Among the most important risks associated to wheat product consumption are mycotoxins. Mycotoxins are fungal secondary metabolites that have a great impact on human and animal health (Hussein & Brasel, 2001). This prompted the European Community to establish appropriate maximum levels in foodstuffs and feedstuffs (Commission Directive 2003/100/EC; Commission Recommendation 2006/576/EC; Commission Regulation (EC) No 1881/2006; Commission Regulation (EC) No 1126/2007). Considering the levels indicated by the European legislation, results from literature indicate that sometimes the limits proposed for cereal-derived products may be not warranted by the limit for unprocessed cereals. Therefore, based on occurrence data, the European limits for mycotoxin in cereals could impact the availability of high fibre cereal products. The fate of mycotoxins during cereal processing, such as sorting, cleaning, milling and thermal processes, was studied by several Authors (Brera et al., 2006; Bullerman & Bianchini, 2007; Hazel & Patel, 2004; Kabak, 2009; Kushiro, 2008; Scudamore, 2008; Scudamore & Patel, 2008; Visconti & Pascale, 2010).

This paper reviews the most recent findings on the effects of the milling process on mycotoxin distribution in wheat milling

* Corresponding author. Tel.: +39 02 50315734; fax: +39 02 50315746.
E-mail address: federica.cheli@unimi.it (F. Cheli).

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fractions. A precise knowledge of such data is vital as they may provide a sound technical basis to mill manager and support risk management and regulatory bodies in order to reduce human and animal exposure to dangerous amounts of mycotoxins, and revise legislative limits.

2. Occurrence of mycotoxins in wheat: a safety, economic, and technological topic

FAO's latest estimates for world cereal production in the period 2011–2012 are approximately 2313 million tons (FAO, 2011). For the feed sector, cereals represent the main components of industrial feeds, which estimated production, worldwide, is more than 717 million tons (Best, 2011). It has been estimated that up to 25% of the world's crops grown for foods and feeds may be contaminated with mycotoxins (Hussein & Brasel, 2001). This means that, if the estimated world cereal production is about 2300 million tons (2011), there are potentially over 500 million tons of mycotoxin contaminated grain entering the feed and food supply chain.

The major mycotoxins occurring in wheat, at levels of potential concern for human and animal health, are *Fusarium* mycotoxins. Specific reviews reporting the worldwide occurrence of *Fusarium* toxins in foods and feeds are provided by several authors to whom the reader is directed (Binder, Tan, Chin, Handl, & Richard, 2007; Placinta, D'Mello, & Macdonald, 1999; Rodrigues & Naehrer, 2012; SCOOP TASK 3.2.10, 2003; Visconti & Pascale, 2010; Zinedine, Soriano, Moltó, & Mañes 2007). Some results regarding the occurrence of *Fusarium* toxins in wheat and wheat bran are reported in Table 1. Although mycotoxin contamination levels of wheat present a high variability between regions, years, weather conditions, as well as between varieties and sowing time, deoxynivalenol (DON) has been the most common mycotoxin contaminant of wheat and wheat-based products worldwide, followed by nivalenol (NIV), zearalenone (ZEA), T-2 and HT-2 toxins. Data on the occurrence of *Fusarium* mycotoxins in durum wheat are quite limited. Available data indicated that durum wheat was generally more contaminated than common wheat, but, with the exception of a few samples, no durum wheat sample was noncompliant to the maximum permitted level for DON and ZEA (Visconti & Pascale, 2010).

Globalisation of the trade in agricultural commodities and lack of legislative harmonization have contributed significantly to the discussion about the awareness of mycotoxins entering the food chain. Aside from health risks, important economic and trade implications arise from such contamination (Bryden, 2012; Dohlman, 2003; Wu, 2004). The economic costs and impact on the international trade, associated with mycotoxin contamination, are difficult to assess in a consistent and uniform way and impossible to determine accurately (Wu, 2004). The economic impact of mycotoxins, considering the seasonality of contamination for the different toxins, includes loss of crop production, disposal of contaminated foods and feeds, reduced livestock production, loss of human and animal life, increased human and animal health care costs, analytical and regulatory costs, and investment in research. Particularly, the evidence on human health outcomes is too slight to permit an accurate analysis. A few examples of estimated economic costs associated with mycotoxin contamination in different food products are reported in Table 2.

Food safety remains the primary concern with *Fusarium* toxins in wheat. However, the impact on wheat processing properties cannot be ignored, and must be considered when establishing mycotoxins limits. *Fusarium* damage has a detrimental effect on the quality and the processing performance of wheat. *Fusarium* damage may reduce wheat milling performance, affect flour yield and flour ash, with a strong negative effect on flour brightness, and baking performance (Lancova et al., 2008; Siuda, Grabowski, Lenc, Ralcewicz, & Spychaj-Fabisiak, 2010). Changes in enzyme activity after *Fusarium* infection may be responsible of the observed changes in wheat quality (Wang et al., 2005).

3. Fate of mycotoxins during wheat milling

3.1. Sorting and cleaning

Physical and mechanical processes, such as sorting and cleaning prior to milling, may reduce mycotoxin contamination in wheat, by removing kernels with extensive mould growth, broken kernels, fine materials, and dust (Bullerman & Bianchini, 2007; Hazel & Patel, 2004; Kushiro, 2008). This is the materials (screenings) in which most of the toxins accumulate (Pascale et al., 2011; Visconti, Haidukowski, Pascale, & Silvestri, 2004). The most recent findings regarding the effect of sorting and cleaning of wheat on mycotoxin repartitioning are reported in Table 3. Experiments were performed using various kind of wheat, naturally or artificially infected, with mycotoxin contamination from low (<100 μg/kg) to high levels (>10,000 μg/kg). Results indicate that the effect of pre-milling processes and the efficiency of mycotoxin removal are extremely variable. The concentration of mycotoxins in cleaned wheat, compared to that in unclean grains, has ranged from 7 to 63% for DON, from 7 to almost 100% for NIV, and from 7 to 40% for ZEA (Edwards et al., 2011; Lancova et al., 2008; Neuhof, Koch, Rasenko, & Nehls, 2008a). Pascale et al. (2011) reported a 62% and 53% reduction of T-2 and HT-2, respectively, in wheat grains after cleaning. Several factors may be involved in this response, such as the initial condition of the grains, the type and extent of the contamination, and the type of cleaning process. Various equipments for wheat cleaning are available. Selection can be made according to different properties of wheat kernels: shape, size, relative density, and air resistance. Therefore, according to the type and extent of contamination, not all the equipments are equally efficient. Grains heavily *Fusarium* infected become shrivelled and may have lower relative density than healthy grains. Therefore, these can be removed more efficiently by the use of gravity separators rather than by other technological approaches (Hazel & Patel, 2004). The potential practical application of different selection processes and spectrometric analysis, such as mid-infrared spectroscopy or fluorescence analysis, for the selection of *Fusarium*-infected kernels merits further studies (Delwiche, Pearson, & Brabec, 2005; Singh, Jayas, Paliwal, & White, 2009).

According to EU regulations, foodstuffs can be subjected to physical treatments to reduce mycotoxin contamination levels. Interestingly, differences in maximum limits are reported for unprocessed cereals placed on the market for first-stage processing and cereals for direct human consumption.

> First-stage processing shall mean any physical or thermal treatment, other than drying, of or on the grain. Cleaning, sorting and drying procedures are not considered to be 'first-stage processing' insofar no physical action is exerted on the grain kernel itself and the whole grain remains intact after cleaning and sorting. In integrated production and processing systems, the maximum level applies to the unprocessed cereals in case they are intended for first-stage processing (European Commission, 2006, p. 23).

This is an important point with practical implications in the real commercial situation. In the industrial practice, the cleaning equipment may be incorporated in the milling plant, and this makes extremely complex the collection of wheat samples at the right sampling point in order to apply the maximum limits reported in regulations. Failure to take this into account makes it 1)