

Comparison of deoxynivalenol, ochratoxin A and aflatoxin B₁ levels in conventional and organic durum semolina and the effect of milling

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Summary

The main objective of this study was the comparison of the natural occurrence of mycotoxins in conventional ($n = 12$) and organic ($n = 5$) commercial batches of durum semolina for pasta production. Semolina was produced from durum wheat grown in the region of Aragón (northeastern Spain) during crop season 2007. No aflatoxin B₁ was detected in any of durum semolina batches analysed. The percentage of durum semolina batches that tested positive for ochratoxin A (OA) was 8.3% in conventional and 20% in organic, respectively, while OA mean levels were lower in batches of conventional ($0.07 \mu\text{g}\cdot\text{kg}^{-1}$) than in batches of organic semolina ($0.18 \mu\text{g}\cdot\text{kg}^{-1}$). The frequency of batches that were found positive for deoxynivalenol (DON) was 16.7% in conventional and 20% in organic, respectively, whereas DON mean levels were somewhat lower in batches of conventional ($77 \mu\text{g}\cdot\text{kg}^{-1}$) than in batches of organic semolina ($89 \mu\text{g}\cdot\text{kg}^{-1}$). The small differences in mycotoxin contents between conventional and organic semolina were not statistically significant. The milling study revealed a significant effect of type of fraction on the distribution of deoxynivalenol in milled products, as the distribution factors for DON after experimental milling were 153% for bran, 87% for durum semolina and 108% for flour.

Keywords

mycotoxins; deoxynivalenol; ochratoxin A, aflatoxin B₁; durum semolina; organic; conventional; milling

A variety of *Fusarium* fungi that infect cereal grains prior to the harvest produce mycotoxins of the class of trichothecenes, such as deoxynivalenol (DON), which can be found in the derived cereal products [1]. Chronic low-dose toxicity of trichothecenes is characterized by anorexia, reduced weight gain, diminished nutritional efficiency, neuroendocrine changes and immunological effects [2]. The major sources of dietary intake of DON are products made from cereals. In the latest EU survey (task 3.2.10), the calculated dietary intakes of DON for the entire population and adults were lower than the tolerable daily intake (TDI, $1 \mu\text{g}\cdot\text{kg}^{-1}$ body weight) but that for the group of young children and adolescents was close to or even exceeded TDI in some cases [3].

Aflatoxins are mycotoxins produced primarily by *Aspergillus flavus* and *A. parasiticus*, which are mostly found in areas with hot, humid climates [1]. Aflatoxins, in particular aflatoxin B₁, are genotoxic, carcinogenic substances that contribute

to the risk of liver cancer (group 1 by IARC) and may be present in a large number of foods, including cereals and derived products [4]. Ochratoxin A (OA) is a mycotoxin produced by several fungal species of the genera *Penicillium* and *Aspergillus*, primarily *P. verrucosum* and *A. ochraceus* [1]. Ochratoxin A is a mycotoxin possibly carcinogenic for humans (group 2B by IARC), with nephrotoxic, teratogenic, immunotoxic and neurotoxic properties; the Scientific Panel on Contaminants in the Food Chain has established for it a TWI (tolerable weekly intake) value of $120 \text{ ng}\cdot\text{kg}^{-1}$ body weight [5]. The main contributors to the dietary intake of ochratoxin A in the EU are cereals and cereal products [6].

Cereal products may become contaminated with mycotoxins before harvest, during the time between harvesting and cleaning, sorting and drying, and during storage. Durum wheat is almost exclusively used for human consumption through semolina for pasta making. Each batch of durum

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semolina must comply with the maximum limits for deoxynivalenol ($750 \mu\text{g}\cdot\text{kg}^{-1}$), aflatoxin B₁ ($2 \mu\text{g}\cdot\text{kg}^{-1}$) and ochratoxin ($3 \mu\text{g}\cdot\text{kg}^{-1}$) set by recent European Community Regulation EC No 1881/2006 [7]. The current levels of mycotoxins in durum semolina are largely unknown but it is critical for grain producers and processors to have a better knowledge of mycotoxin contents as well as the practices that can reduce the risk connected with them. The influence of processing on the mycotoxin contamination levels has a great safety and economical relevance. Through cleaning and processing, the contents of mycotoxins in raw cereals may be reduced or redistributed to a varying degree in processed cereal products [8].

Since the beginning of the 1990s, organic farming has rapidly developed in almost all European countries. Around 4.2% of the total agricultural area was managed organically in the 27 countries of the European Union (EU) in 2007 [9]. In Spain, organic farming with almost one million hectares constitutes around 4% of the agricultural area. In view of the present levels and growing rates, the EU, on average, might possibly have a quarter of its total agricultural land under organic management by 2030 [10]. Organic products of plant origin are grown without the aid of chemical synthetic pesticides and largely without the use of readily soluble mineral fertilizers. Since fungicides are not allowed in organic production and given that mycotoxins constitute a major health hazard, their relative presence in foods produced organically or conventionally has been the subject of many studies. BIRZELE et al. [11] reported that organic farming systems had lower mycotoxin contamination in common wheat (*Triticum aestivum*) than conventional farming systems. However, no significant differences in fumonisin contents were found between organic and conventional Spanish corn [12] and cornflakes from the Belgian market [13].

The present paper reports the results of an investigation on natural occurrence of deoxynivalenol, aflatoxin B₁ and ochratoxin A in 17 commercial batches of conventional and organic durum semolina for pasta making. The effect of experimental dry-milling of durum wheat on the distribution of deoxynivalenol in the milled fractions (bran, semolina and flour) was also investigated.

MATERIAL AND METHODS

Samples and sample preparation

Seventeen ($n = 17$) commercial batches of durum semolina for pasta production were sampled

from milling industries of Aragón (northeastern Spain). Twelve (12) batches were conventional durum semolina and five (5) batches were organic semolina certified as such by the Aragonese Committee for Organic Agriculture (Comité Aragonés de Agricultura Ecológica, CAAE). All semolina samples had been milled from durum wheat (*Triticum durum* Desf.) grown in the provinces of Zaragoza and Huesca, which is believed to be representative of crop season 2007 from this highly productive area of Spain. For mycotoxin analysis, as reported below, each batch sampling of durum semolina consisted of ten sub-samples of 250 g each that were combined and kept at -21°C until analysis.

In order to study the effect of dry-milling on mycotoxins, a durum wheat sample naturally contaminated with DON was subjected in triplicate to experimental milling in a Chopin CD1 mill (Chopin, Villeneuve-la-Garenne, France). Three milled fractions were obtained: 15% bran, 65% durum semolina and 18% durum flour, with the remaining 2% as milling losses.

Reagents for mycotoxin analysis

HPLC grade acetonitrile and methanol were purchased from Lab-Scan (Dublin, Ireland). Ultrapure water was obtained from a Milli-Q Plus apparatus from Millipore (Milford, Massachusetts, USA). Mycosep #225 Trich columns were purchased from Romer Labs (Union, Missouri, USA). The immunoaffinity columns RIDA Aflatoxin and RIDA Ochratoxin A were supplied by R-Biopharm (Darmstadt, Germany). Mycotoxin standards (deoxynivalenol, aflatoxin B₁ and ochratoxin A) were provided by Sigma (St. Louis, Missouri, USA) and stock solutions at $500 \mu\text{g}\cdot\text{ml}^{-1}$ for deoxynivalenol were prepared in acetonitrile, and at $50 \mu\text{g}\cdot\text{ml}^{-1}$ for aflatoxin B₁ and $100 \mu\text{g}\cdot\text{ml}^{-1}$ for ochratoxin A were prepared in methanol. The stock solutions were stored at -21°C . Reagents for phosphate-buffered saline solution (PBS) and sodium chloride were provided by Panreac (Barcelona, Spain).

Analysis of mycotoxins in semolina and milled fractions

For the determination of deoxynivalenol (DON), a validated method based on Mycosep column/LC-DAD (diode-array detection) was used [14]. A representative sample of 10 g of durum semolina or of the milled fractions was extracted with 40 ml of a mixture of acetonitrile and water (85 : 15, v/v) using a Vibromatic rocking mixer (JP Selecta, Barcelona, Spain) for 30 min. The extract was filtered through Whatman No. 1 filter paper and 10 ml of it was purified through

the multifunctional column. Cleanup was carried out with Mycosep #225 Trich columns, according to the instructions of the manufacturer (Romer Labs). Four milliliters of the collected eluate was dried under nitrogen. The residue was dissolved with 1.0 ml of the mobile phase (water/acetonitrile/methanol, 90 : 5 : 5, v/v/v) and aliquots of 100 μ l were injected into the LC-DAD system.

Aflatoxin B₁ (AFB₁) was analysed by the immunoaffinity column/LC-FLD (fluorescence detection) method EN 12955:1999 of the European Committee for Standardization [15], but using post-column photochemical derivatization (PHRED) for quantification instead of the post-column bromination [16]. A representative sample of 10 g of durum semolina was extracted with 2 g sodium chloride and 50 ml methanol/water (7 : 3, v/v) using an Ultraturrax homogenizer (IKA, Staufen, Germany) for 2 min. The extract was filtered through Whatman No. 1 filter paper, and the volume of 5 ml of it was diluted with 15 ml of PBS and purified through the immunoaffinity column. Cleanup was carried out with RIDA Aflatoxin columns, according to the instructions of the manufacturer (R-Biopharm). Aliquots of 100 μ l of the aflatoxin-containing eluate were injected into the LC-FLD system, which was connected to an LCTech UVE photochemical reactor (Dorfen, Germany) set at 254 nm. The LCTech UVE was connected between the HPLC and the fluorescence detector.

The technique for extraction, cleanup and determination of ochratoxin A was based on the immunoaffinity column/LC-FLD (fluorescence detection) method EN 14132:2003 of the European Committee for Standardization [17]. A representative sample of 10 g of durum semolina was extracted with 40 ml acetonitrile/water (6 : 4, v/v) using the Ultraturrax homogenizer for 3 min. The extract was filtered through Whatman No. 1 filter paper, and the volume of 4 ml of it was diluted with 16 ml of PBS and purified through the immunoaffinity column. Cleanup was carried out with RIDA Ochratoxin A columns, according to the instructions of the manufacturer (R-Biopharm). Aliquots of 100 μ l of the ochratoxin-containing eluate were injected into the LC-FLD system and the identity of OA was confirmed by methyl-ester formation. To an amber vial containing 25 μ l of OA residue, 75 μ l of hydrochloric acid (6 mol·l⁻¹) and 400 μ l of methanol were added. The vial was shaken, closed and left for 6 h in an incubator at 25 °C. A 100 μ l aliquot was analysed using liquid chromatography with fluorescence detection and compared with blanks and standards prepared in the same manner.

HPLC apparatus

The LC system consisted of an Agilent Technologies (Santa Clara, California, USA) 1100 high-performance liquid chromatograph coupled to an Agilent fluorescence detector (FLD) at 365 nm (excitation) / 435 nm (emission) for AFB₁ and at 333/460 nm for OA, and an Agilent diode-array detector (DAD) at 220 nm for analysis of DON. The LC column was Ace 5 C₁₈, 250 × 4.6 mm, 5 μ m particle size (Advanced Chromatography Technologies, Aberdeen, United Kingdom). For the analysis of AFB₁ by LC-FLD, the isocratic LC mobile phase was water/acetonitrile/methanol (60 : 20 : 20, v/v/v) pumped at a flow rate of 1.0 ml·min⁻¹. The isocratic mobile phase for LC-FLD analysis of OA was water/acetonitrile/acetic acid (51 : 48 : 1, v/v/v) at a flow rate of 1.0 ml·min⁻¹. For DON analysis by LC-DAD, the mobile phase was water/acetonitrile/methanol (90 : 5 : 5, v/v/v) at a flow rate of 1.0 ml·min⁻¹.

The analytical methods were validated in-house with respect to recovery and precision using five assays with matrix spiked at 1000 μ g·kg⁻¹ (DON) and 1 μ g·kg⁻¹ (AFB₁ and OA). The recoveries for DON, AFB₁ and OA, were 100%, 92% and 83%, respectively, with repeatability (RSD_r) lower than 15%. The limit of detection (LOD) for deoxynivalenol was 100 μ g·kg⁻¹, and for aflatoxin B₁ and ochratoxin A was 0.1 μ g·kg⁻¹.

Statistical analyses

The results from mycotoxin analyses were subjected to descriptive and comparative statistics according to SACHS [18]. The incidence of batches containing DON, AFB₁ and OA (% positives) were expressed as the percentage of samples containing levels above the corresponding LOD. For each mycotoxin, the mean and standard error were calculated using LOD/2 for results lower than LOD. Calculations were performed on StatView SE+Graphics (Abacus Concepts, Berkeley, California, USA) for Macintosh personal computers. The overall differences between conventional and organic batches were checked with non-parametric Mann-Whitney U test at a significance level of 0.05.

RESULTS AND DISCUSSION

Analysis of mycotoxins in durum semolina batches

Generally, mycotoxins in cereal products are formed by mould infection in the field mainly caused by *Fusarium* species, and during storage mainly by *Penicillium* and *Aspergillus* species. No af-

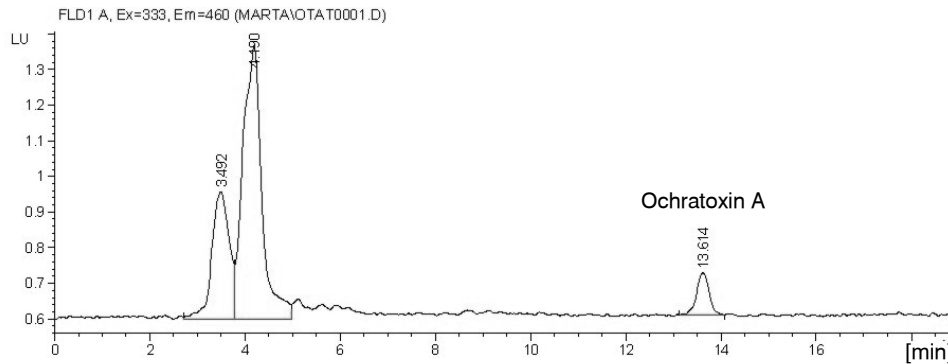


Fig. 1. HPLC-FLD chromatogram of a semolina sample containing ochratoxin A at $0.70 \mu\text{g}\cdot\text{kg}^{-1}$.

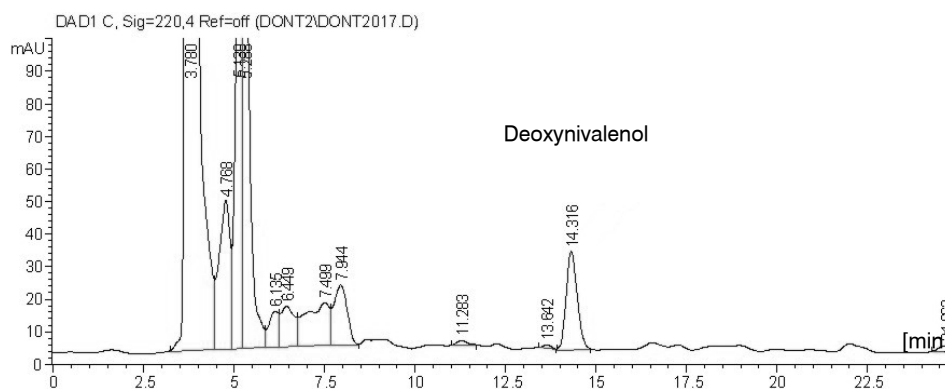


Fig. 2. HPLC-DAD chromatogram of a semolina sample containing deoxynivalenol at $294 \mu\text{g}\cdot\text{kg}^{-1}$.

latoxin B₁ was detected in any of durum semolina batches analysed, indicating that raw material (durum wheat grains) was not contaminated and the storage conditions had been adequate. In a recent European survey only 7% out of 3010 samples of cereals other than maize were found positive for aflatoxin B₁, averaging out at $0.14\text{--}0.35 \mu\text{g}\cdot\text{kg}^{-1}$ and reaching a maximum of $109 \mu\text{g}\cdot\text{kg}^{-1}$ [4]. Aflatoxins are usually found in plant foods as a result of fungal contamination, with the rate and degree of contamination dependent on temperature, humidity and storage conditions; they are mostly produced in areas with hot, humid climates. Though a wide range of foods may be contaminated with aflatoxins, they have been most commonly associated with tree nuts, groundnuts, oilseeds and maize among cereals.

The frequency of ochratoxin A (OA) in analysed batches of durum semolina was low (11.8% positives), the contamination levels were in the low range (LOD to $0.70 \mu\text{g}\cdot\text{kg}^{-1}$) and mean was $0.10 \mu\text{g}\cdot\text{kg}^{-1}$. Fig. 1 shows a representative HPLC-FLD chromatogram of a positive sample contaminated with ochratoxin A. In Spain, low OA

levels have been detected in wheat and different wheat products [19]. The weak OA contamination of semolina reported in the present paper is very similar to that reported by ARAGUÁS et al. [20] in 21 samples of breakfast cereals of the Spanish market, ranging from $0.16 \mu\text{g}\cdot\text{kg}^{-1}$ to $0.36 \mu\text{g}\cdot\text{kg}^{-1}$. The EU in the Scientific Cooperation Assessment Project on OA analysed 979 samples of wheat (28% were found positive for OA), with a mean of $0.27 \mu\text{g}\cdot\text{kg}^{-1}$ [6]. Ochratoxin A is produced by several species of the genus *Penicillium* and *Aspergillus* that can contaminate food commodities prior to harvest or, more commonly, during storage. Recent analyses of the dietary exposure of adult European consumers to OA revealed that, at present, the weekly exposure ranges from 15 ng to 60 ng OA per kg body weight per week, and cereals and derived products contributed from 40% to 60% to the intake [5].

Deoxynivalenol (DON) was detected in 17.6% durum semolina batches showing content levels in the range between LOD and $294 \mu\text{g}\cdot\text{kg}^{-1}$, with a mean of $80 \mu\text{g}\cdot\text{kg}^{-1}$. Fig. 2 shows a representative HPLC-DAD chromatogram of a positive sam-

ple contaminated with deoxynivalenol. The low semolina DON level reported here differs from other studies. In the United States, MANTHEY et al. [21] surveyed 123 semolina samples from the durum wheat crop grown in the Northern Plains and reported a mean semolina DON level of $1800 \mu\text{g}\cdot\text{kg}^{-1}$. Similarly, all 33 samples of durum wheat flour marketed in Denmark in 2000 and 2001 tested positive for DON at a mean level of $1155 \mu\text{g}\cdot\text{kg}^{-1}$, over 70% of samples contained more than $500 \mu\text{g}\cdot\text{kg}^{-1}$, and 58% of the samples contained more than $1000 \mu\text{g}\cdot\text{kg}^{-1}$ [22]. *Fusarium* species infect the grain prior to the harvest. As compared to other cereals, durum wheat is highly susceptible to *F. graminearum* infection and the subsequent contamination by deoxynivalenol [23], in particular under wet weather conditions during flowering.

In summary, both frequencies and mycotoxin contamination levels were low in durum semolina. As durum wheat grains are subsequently processed into final food products, there is some cleaning, sorting, mixing and homogenization during food processing, which may have contributed to the low mycotoxin levels in semolina.

Comparison of conventional and organic samples

The percentage of durum semolina batches that were found positive for OA was 8.3% in conventional sector and 20% in organic sector, respectively. Ochratoxin mean levels were lower in conventional ($0.07 \mu\text{g}\cdot\text{kg}^{-1}$) than in organic ($0.18 \mu\text{g}\cdot\text{kg}^{-1}$) batches, but the difference was not statistically significant ($p > 0.05$; Tab. 1). By contrast, higher OA contents were obtained in 74 conventional and 26 organic bread samples available in Spain and Portugal, five samples exceeding the European maximum permitted limit of OA ($3 \mu\text{g}\cdot\text{kg}^{-1}$) for this product [24]. The incidence of OA varied between 20.3% and 23.0% for conventional and organic bread, respectively, and levels ranged from $0.04\text{--}20 \mu\text{g}\cdot\text{kg}^{-1}$ to $0.03\text{--}0.81 \mu\text{g}\cdot\text{kg}^{-1}$ for conventional and organic bread, respectively. In another study, JUAN et al. [25] compared ochra-

toxin A contamination in organic and conventional cereals from Spain and Portugal. Four out of 11 organic wheat samples (36%) were found positive for OA averaging out at $0.84 \mu\text{g}\cdot\text{kg}^{-1}$, while 5 out of 10 conventional wheat samples (50%) contained OA at a mean of $0.22 \mu\text{g}\cdot\text{kg}^{-1}$.

In a recent review of the available literature about organic food safety, MAGKOS et al. [26] compared several studies on the OA incidence in organic and conventional cereals and cereal products, and observed that only in three out of 12 investigations, the OA contamination in organic samples was higher than in conventional ones, while the others reported similar levels. In a Danish study, the levels of OA in organically grown rye were higher than in conventionally grown based on multiyear mean contents, though OA levels in conventional and organic wheat were very similar [27]. Likewise, the ochratoxin A occurrence in cereal grains from conventional and organic Polish farms was almost the same [28].

As shown in Tab. 1, the percentage of durum semolina batches that were found positive for DON was 16.7% in conventional sector and 20% in organic sector, respectively. Deoxynivalenol mean levels were somewhat lower in conventional ($77 \mu\text{g}\cdot\text{kg}^{-1}$) than in organic ($89 \mu\text{g}\cdot\text{kg}^{-1}$) batches, but the difference was not statistically significant ($p > 0.05$).

Occasionally, higher trichothecene contents have been determined in organic foods than in their conventional counterparts. For instance, in a recent comparison between conventional and organic French foods, organic wheat and barley were higher contaminated by deoxynivalenol than the conventional ones, but the differences were not significant [29]. Conversely, deoxynivalenol contents of conventionally grown wheat were found to be significantly higher than in organic wheat grown in Thuringia, Germany [30]. The SCOOP project 3.2.10 reported a comparison between 41 conventional and 12 organic durum wheat samples from The Netherlands in which DON contamination in conventional durum wheat ($293 \mu\text{g}\cdot\text{kg}^{-1}$) was high-

Tab. 1. Comparison of mycotoxin contents in the tested durum semolina batches, shown by sample type (conventional or organic).

Sample type	Ochratoxin A			Deoxynivalenol		
	Positive [%]	Mean \pm SE [$\mu\text{g}\cdot\text{kg}^{-1}$]	Maximum [$\mu\text{g}\cdot\text{kg}^{-1}$]	Positive [%]	Mean \pm SE [$\mu\text{g}\cdot\text{kg}^{-1}$]	Maximum [$\mu\text{g}\cdot\text{kg}^{-1}$]
Conventional ($n = 12$)	8.3%	0.07 ± 0.01	0.23	16.7%	77 ± 20.8	294
Organic ($n = 5$)	20%	0.18 ± 0.13	0.70	20%	89 ± 38.6	243
Total ($n = 17$)	11.8%	0.10 ± 0.04	0.70	17.6%	80 ± 18	294

SE – standard error.

Tab. 2. Levels and distribution factors of deoxynivalenol (DON) in milled fractions of durum wheat.

Milled fractions	Fraction weight [g]	Fraction percent [%]	DON level ^a [mg.kg ⁻¹]	Distribution factor ^b
Grain	500	100	24.10 ± 0.7	100
Bran	75	15	36.86 ± 1.0	153
Semolina	325	65	20.97 ± 0.7	87
Flour	90	18	25.97 ± 0.8	108
Losses	10	2	–	–

a – mean ± standard error, b – distribution factor refers to durum wheat grain.

er than in the organic durum wheat (134 µg.kg⁻¹), and so was the percent of positives, 61% and 25%, respectively [31]. Recently, MÄDER et al. [32] reported the results of a study on the quality of bread wheat (*Triticum aestivum* L.) grown in a 21-year agrosystem comparison between organic and conventional farming in central Europe, concluding that the quantities of mycotoxins detected in wheat grains were low in all systems and did not differ.

Effect of milling on deoxynivalenol content in durum wheat

The aim of this assay was to investigate the distribution of deoxynivalenol in various durum wheat milled fractions. A non-compliant sample of durum wheat highly contaminated with DON (24100 µg.kg⁻¹) came to the laboratory from a local grower. The sample was subjected in triplicate to experimental dry-milling to obtain bran, semolina and flour, and these milled fractions were analysed by LC-DAD for DON content. The distribution factor is defined as the ratio between the mycotoxin content in the milled fractions and the mycotoxin content in the wholegrain, which can be higher than 100% (concentration factor) or lower than 100% (reduction factor). The distribution factor for bran was 153%, which means that contamination in bran was increased 1.5-fold. By contrast, the distribution factor of 87% observed in semolina revealed that deoxynivalenol in this fraction was slightly reduced compared to whole durum wheat (Tab. 2). The distribution factor for durum flour was 108%, which is important since this milling product can be used for the production of common bread and for the bread base of pizza.

Our results revealed a significant effect of the type of fraction on the distribution of deoxynivalenol. Even though DON was detected in all fractions, bran was found to be more contaminated than semolina, which is the main product for pasta making. This is consistent with the known fact that DON is produced at the site of fungal growth, as *Fusarium* fungi usually colonize the cereal grain

from the external side [33]. However, PINSON-GADAIS et al [34] recently found by a PCR assay that toxigenic *Fusarium* spp. penetrated into the interior of the durum wheat grain, indicating that none of the tissue structures within the grain acted as an effective barrier to fungal invasion and the subsequent synthesis of trichothecene mycotoxins.

Several studies were carried out on durum wheat to determine the stability and partitioning of DON during semolina milling [35, 36]. According to these studies, levels of DON in bran were two or more times greater than in the whole wheat, while the amount of DON retained in semolina was reduced more than two-fold, indicating concentration of the toxin in the outer parts of the grain. Thus, the calculated distribution factors during the processing of cleaned durum wheat were 207% for bran, 48% for semolina, 43% for pasta (dry) and 26% for cooked spaghetti. Our distribution factor for semolina was much higher (87%), which could be explained by the extremely high initial levels of DON (24.10 mg.kg⁻¹ in the grain) as compared to the range of 0.25–9.71 mg.kg⁻¹ reported in the study by VISCONTI et al. [36]. In our study, DON also accumulated in the bran, which is in agreement with reports indicating that the level of deoxynivalenol in milled fractions of US hard red winter wheat was generally highest in the bran fraction with distribution factors of 121% for bran, 111% for shorts and 54% for flour [37].

CONCLUSIONS

Aflatoxin B₁ was not detected in any batches of durum semolina, whereas ochratoxin A and deoxynivalenol occurred in less than 20% batches, with content levels being very low. The low mycotoxin levels could be attributable to the cleaning, sorting, mixing and homogenization during the dry-milling processing of durum wheat into semolina. In the present study, the small differences in mycotoxin contents between conventional and or-

ganic semolina batches were not statistically significant.

The milling study revealed a significant effect of the type of fraction on the distribution of deoxynivalenol in milled products. Even though DON was detected in all milled fractions, bran was found to be more contaminated than semolina. Our data support the idea that the extent of transmission of trichothecenes into final food products is dependent on the contamination level of the grains and, for dry-milled products, the highest contaminated fractions are those that contain the whole or the outer portions of the grain. However, when the grain contamination level is very high, the resulting milled fractions from the inner parts of the grain (semolina, flour) are highly contaminated as well.

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