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Peculiarities of cereal grain co-contamination with *Fusarium* mycotoxins

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Abstract

Grain samples of winter and spring wheat (*Triticum aestivum* L.), winter triticale (× *Triticosecale* Wittm.) and rye (*Secale cereale* L.), and spring barley (*Hordeum vulgare* L.) collected at harvesting in 2006 and 2007 were analysed for co-contamination with deoxynivalenol (DON), zearalenone (ZEA), and T-2 toxin (T-2). In milled grain samples, co-contamination with DON, ZEA, and T-2 was estimated by the ELISA method. Our results demonstrated that both winter and spring cereal grain was contaminated with one or more *Fusarium* mycotoxins analysed. Despite the different meteorological conditions of the experimental period (2006 and 2007), mycotoxin concentrations and co-occurrence frequency were higher in spring cereal (wheat and barley) grain than those in winter cereal (wheat, triticale and rye) grain. In 2006, winter cereal grain samples contaminated with one of the tested mycotoxins (DON or T-2) accounted for 15.6%, and those simultaneously contaminated with all three quantified mycotoxins for 25.0%, while in 2007, samples contaminated with one toxin accounted for as little as 3.6%. No samples of spring cereal grain containing only one toxin were found; however, those contaminated with three toxins accounted for 90.6% of the total samples tested of 2006 harvest and for 100% of the samples of 2007 harvest. In most cases, positive correlation existed among grain co-contaminated mycotoxins, but the relationships among mycotoxins were variable both in trend and strength depending on the species, variety and comparable pair of mycotoxins.
Our findings suggest that mycotoxin accumulation was considerably influenced not only by the weather conditions during the crop growing season but also by cereal seasonal type (winter, spring) as well as variety. In 2006, two grain samples and in 2007 one sample of spring barley variety 'Luokė' were extremely heavily contaminated with T-2, whose concentrations amounted to 102.8–132.4 μg kg^{-1}, i.e. were higher than the safe level for human/animal health (100 μg kg^{-1}).

Key words: *Triticum aestivum* L., × *Triticosecale* Wittm., *Secale cereale* L., *Hordeum vulgare* L., varieties, harvest year, grain co-contamination with deoxynivalenol, zearalenone, T-2 toxin.

Introduction

Cereal grains are excellent energy rich, staple food in human nutrition. Mycotoxin contamination in cereal grain-based products is a significant setback for feed/food security. Deoxynivalenol (DON), nivalenol (NIV), T-2 toxin (T-2), fumonisins, zearalenone (ZEA) are common fusariotoxins throughout the world, mainly associated with cereal crops (Krska et al., 2003; Schollenberger et al., 2006; Goyarts et al., 2007). Toxins can be found simultaneously in different compositions in cereal grain (Bennett, Klich, 2003; Schollenberger et al., 2006). Mycotoxins may be considered to be immunologic, hematopoietic, hepatotoxic, nephrotoxic, teratogenic, neurotoxic, mutagenic, carcinogenic, dermonecrotic or they can induce toxicity to the reproductive systems (CAST, 2003). It is known, that co-contamination with mycotoxins appears to exert greater negative effects on health and productivity than single mycotoxins (Malekinejad et al., 2007). Combinations of *Fusarium* mycotoxins result in additive effects, but synergistic and/or potentiating interactions have been observed and are of greater concern in livestock health and productivity (D'Mello et al., 1999). Results of numerous studies indicate that the extent of the risk of feed/food co-contamination with several mycotoxins depends on the level and kind of mycotoxins, the animal kind, animal/human age and the health status, feature or organ assessed, and mycotoxins interactions can be additive, synergistic or antagonistic (Huff et al., 1988; Diaz et al., 1994; Boeira et al., 2000; Ledoux et al., 2003; Speijers, Speijers, 2004; Jestoi, 2005; Malekinejad et al., 2007; Njobeh et al., 2010). As a result, it is difficult or even not possible to define safe levels of mycotoxins. This complex situation makes it necessary to take all relevant precautions. Lithuania like other EU countries has a state inspection system for food/feed safety control. The state control is chiefly pointed to the findings of the exceeding the maximum allowable concentrations (MAC) facts and the suspension of contaminated products sales, when MAC is exceeded. Hazard concentrations below the MAC are important both from scientific and safety viewpoint, because for human and animal

health it is weightier what actual amount of mycotoxins in total their body receives with food or feed used day-to-day than high concentration in products used in driblets and occasionally only: chronic effects are a concern for the long-term health of the human population making low levels of mycotoxins important of food (Degirmencioglu et al., 2005). This study was aimed to assess the co-occurrence of DON, ZEA, and T-2 in grain of winter and spring cereals grown in the temperate climatic zone of Europe (Lithuania) under different weather conditions of harvest years. The specific objective was to identify the relations among grain co-contaminating mycotoxins.

Materials and methods

Grain samples from Central Lithuania's commercial fields of winter wheat (*Triticum aestivum* L.) varieties 'Ada', 'Zentos', spring wheat (*Triticum aestivum* L.) 'Nandu', 'Triso', winter triticale (× *Triticosecale* Wittm.) 'Tornado' and rye (*Secale cereale* L.) 'Duoniai', 'Hasada', 'Picaso Plus 10' and spring barley (*Hordeum vulgare* L.) 'Luokė', 'Prestige', 'Merkada', 'Orthega' collected at harvesting in 2006 and 2007 were analysed for grain co-contamination with deoxynivalenol (DON), zearalenone (ZEA), and T-2 toxin (T-2) at the Lithuanian Institute of Agriculture (Table 1).

Table 1. Number of cereal samples/varieties analyzed for grain co-contamination with mycotoxins

Harvest year	Winter cereal			Spring cereal		Total
	T. aestivum	*S. cereale*	×*Triticosecale*	*T. aestivum*	*H. vulgare*	
2006	24/2	4/1	4/1	19/2	13/1	64/7
2007	24/2	4/2	0	15/1	18/4	61/9

Method for the analysis of mycotoxins. Quantitative analysis of DON, ZEA, T-2 was carried out using Enzyme Linked Immunoassay (ELISA) commercial kit (Neogen Corporation, Food Safety Diagnostics: Scotland Veratox® for DON 5/5 – 8331NE, Veratox® for ZEA – 8110, Veratox® for T-2 – 8210). The method is based on the antibody antigen interaction and approved by the AOAC Research Institute (Certificate No. 950702).

Reagents. Most of the reagents used were contained in the Neogen test kit. DON, ZEA, T-2 standard solution used for the construction of the calibration curve were at levels of DON 0, 250, 500, 1000, 2000 ppb (μg kg^{-1}); ZEA – 0, 25, 75, 150, 500 ppb (μg kg^{-1}); T-2 – 0, 25, 50, 100, 250 ppb (μg kg^{-1}) all included in the ELISA test kit.

Preparation of samples and test procedure. Part of each sample was subjected to mycotoxicological contamination, and the other part (about 50 g) was air-dried, milled in a mill 'A11 Basic' (IKA, Germany) and kept at −20ºC until analysis. Mycotoxin extraction and tests were performed according to manufacturer's instructions. Extraction of samples was carried out in distilled water (DON), in methanol: water (70:30 v/v) for ZEA and (50:50 v/v) for T-2. The basis of the test is the antigen-antibody reaction. The wells in the microtiter plates were coated with antibodies to each mycotoxin. By adding standards of each mycotoxin or the sample solution the antibody binding sites were occupied in proportion to the concentration of each mycotoxin. Any remaining free binding sites were occupied in the next stage by enzyme labelled toxin (enzyme conjugate). Any unbound enzyme conjugate was then removed in a washing step. Enzyme substrate and chromogen were added to the wells and incubated. Bound enzyme conjugate converted the colourless chromogen into a blue product. The addition of the stop reagent resulted in a colour change from blue to red. The optical densities of samples and controls from standard curve were estimated by a multichannel photometer "Multiskan Ascent" ("Thermo Electron Corp.", Finland), supplied with internal software, using a filter of 650 nm. A calibration curve for the standards for each toxin dilution (reagents) was plotted using a standard concentration against the percentage inhibition of the respective standard. For determination, each mycotoxin concentration was automatically calculated from the calibration curves, obtained by plotting absorbance intensity against the logarithm of analyte concentration. The determination coefficients r^2 ranged as follows: for DON 0.988–0.998, ZEA 0.982–0.998, T-2 0.980–0.996. The measured absorbance was automatically converted to the mycotoxin concentration units – μg kg^{-1}. The results were estimated taking into account the lowest calibration curve's mycotoxin concentration value (LOD – limit of detection), which is for: DON – 100.0 μg kg^{-1} (ppb), ZEA – 10.0 μg kg^{-1} (ppb), T-2 – 7.5 μg kg^{-1} (ppb) (manufacturer's methodical guidelines). While assessing our data with regard to food and forage safety we referred to the EU document No.1881/2006 for DON and ZEA (European Commission, 2006) and global research recommendations for T-2 (Eriksen, Alexander, 1998).

The statistical analysis was done using *Stat* software adapted in the *Visual Basic for Application* as macro program to run in the *Excel* (Tarakanovas, Raudonius, 2003).

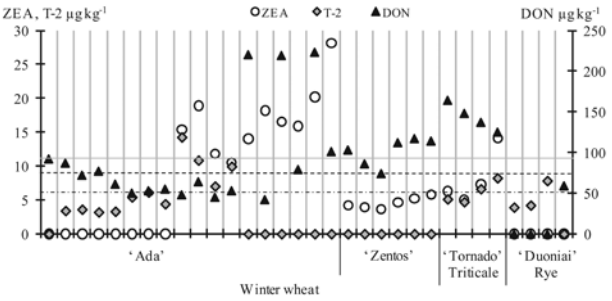
Meteorological conditions were recorded at the Dotnuva Meteorological Station (Table 2). The year 2006 was noted for extremely dry weather. The spring was cool, late and dry. May was warm, but June was cool and extremely dry with a precipitation rate of as little as 11% of the long-term rate. The extreme drought with high temperatures that occurred in July severely affected cereals at milk maturity stage. The rainy end of July and August interfered with harvesting. The weather conditions in 2006 were unfavourable for the spread of fungal diseases throughout the further plant growing season. In the spring of 2007, warm and dry weather prevailed. Winter crops resumed vegetation on the last days of March. Excess of moisture was felt from May throughout the entire plant growing season. The summer of the year 2007 was humid, except for the droughty period at the beginning of June, the average amount of precipitation was higher or the same as long-term mean (98.2–52.5 mm in May, 61.5–61.3 mm in June). The temperature was 1–2ºC higher than long-term mean. During the 2007 growing season the weather conditions were favourable for the occurrence and development of fungal diseases in cereal stands, especially for fungi that produce mycotoxins.

Table 2. The weather conditions during the 2006–2007 period

Year/parameter	April	May	June	July	August
2006					
Average air temperature ºC	6.7	12.6	16.8	21.3	18.1
Average air temperature ºC over period 1924–2006	5.7	12.2	15.6	17.6	16.6
± deviation in ºC from the previous period	+1.0	+0.4	+1.2	+3.7	+1.5
Average rainfall in mm	19.2	45.0	6.8	40.4	105.0
% from average of the period 1924–2006	51.34	86.54	11.11	55.34	142.28
Days with rainfall ≥1 mm	7	8	4	7	16
2007					
Average air temperature ºC	6.9	13.5	17.6	17.2	18.7
Average air temperature ºC over period 1924–2007	5.7	12.2	15.6	17.6	16.6
± deviation in ºC from the previous period	+0.4	+1.3	+2.0	-0.4	+2.1
Average rainfall in mm	15.8	98.2	61.5	118.1	50.8
% from average of the period 1924–2007	42.5	187.1	100.3	160.5	69.0
Days with rainfall ≥1 mm	4	12	9	16	11

Results and discussion

Co-contamination of winter cereal grain samples with DON, ZEA, T-2. Only negligible or even traceable concentrations of mycotoxins were detected in winter cereal grain samples harvested in 2006 (Fig. 1). DON concentrations varied from 0 to 223 µg kg^{-1}, ZEA concentrations ranged from 0 to 28.1 µg kg^{-1}, T-2 from 0 to 14.2 µg kg^{-1}. More than 1/3 of winter cereal samples contained the concentrations of all three mycotoxins below the limit of detection (< LOD). Winter rye grain was found to be the least contaminated: only one of trichotecenes was found per sample with concentrations < LOD. When comparing winter wheat varieties, the concentration of DON > LOD was more frequent for 'Zentos' than for 'Ada', whereas T-2 was more frequent for 'Ada' (Fig. 1).



Note. Lines —, - - -, and - · - signify LODs for DON, ZEA, and T-2.

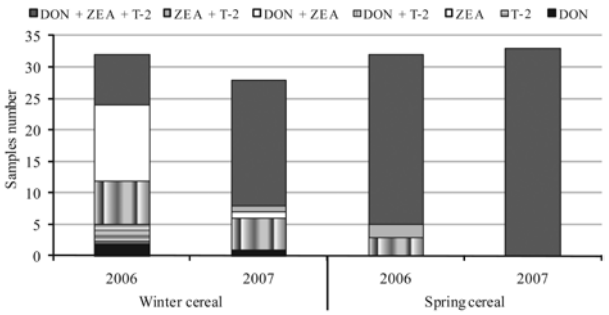
Figure 1. DON, ZEA and T-2 co-occurrence in winter cereal grain samples of 2006 harvest

In 2007 harvest year, grain analyses showed mycotoxin contamination on winter cereal grain to be higher than in 2006, but *Fusarium* mycotoxins were little dependent on the variety or cereal species (Fig. 2).

About 71% of the winter cereal grain samples, i.e. 20 of 28 tested (Figs 2–3) in 2007 were co-contaminated with all three *Fusarium* mycotoxins DON, ZEA, T-2. DON was present on 96.4%, ZEA on 78.6%, T-2 on 93.0% of the samples. Although trichothecenes level in almost all winter cereal grain, and ZEA concentration in most of them were > LOD, the level of contamination did not exceed the allowable limits. The summarised results (Fig. 3) indicate that in 2006 the co-contamination with all three *Fusarium* mycotoxins was lower both in winter and spring cereal grain compared with that in the year 2007. In 2006, the winter cereal grain contaminated with one mycotoxin DON or T-2 made up 16% (5 samples) and in 2007 one sample of winter wheat variety 'Zentos' was contaminated with DON only. In 2006, the percentage of samples co-contaminated with three mycotoxins was three times less. In 2006, during the cereal growing period, conditions were less favourable for the distribution of pathogenic fungi, including *Fusarium*, than those in 2007 (Table 2).

Note. Lines —, - - -, and - · - signify LODs for DON, ZEA, and T-2.

Figure 2. DON, ZEA, T-2 co-occurrence in winter cereal grain samples of 2007 harvest

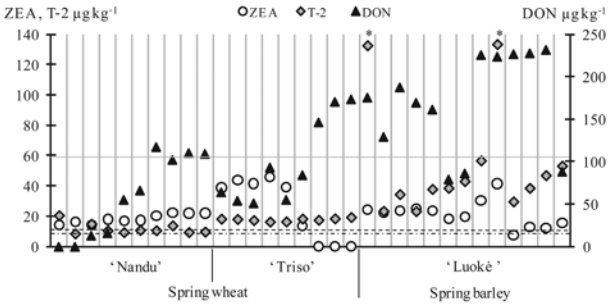


Note. Data with mycotoxin concentration < LOD were included.

Figure 3. Frequency of cereal grain co-contamination with DON, ZEA, T-2

Co-contamination of spring cereal grain samples with DON, ZEA, T-2. Spring cereal grain was more heavily contaminated with mycotoxins than winter cereal

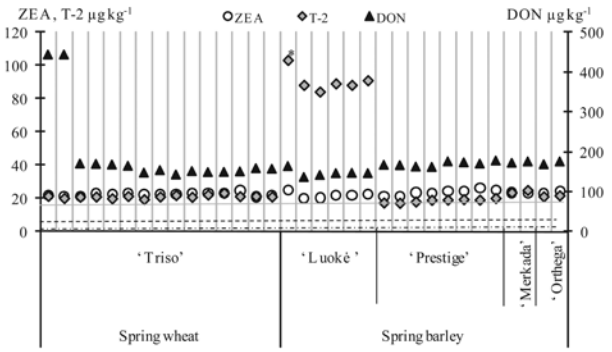
grain: DON was identified in 94.0%, ZEA in 97.0%, T-2 in 100% of the spring cereal grain harvested in 2006. The presence of all the three mycotoxins was identified in 90.6% of the samples; mycotoxin T-2 in combination with DON and with ZEA were identified in 3 and 2 of the 32 tested spring cereal samples, and together made up only 9.4% of the samples (Figs 3–4). No samples were found with only one mycotoxin. Moreover, mycotoxin concentrations were also higher for spring cereal grain than those for winter cereal grain of the same harvest year. This can be linked to the changed weather conditions: spring cereals are harvested later than winter cereals and rainy weather occurred at the end of July and August (Table 2). Two grain samples of spring barley variety 'Luokė' were extremely heavily contaminated with T-2, whose concentrations amounted to 132.4 and 133.3 μg kg^{-1}, i.e. were higher than the safe level for human/animal health (100 μg kg^{-1}) (Eriksen, Alexander, 1998).



Note. * – T-2 concentration exceeded safe level; lines —, - - -, and - · - signify LODs for DON, ZEA and T-2.

Figure 4. DON, ZEA, T-2 co-occurrence in spring cereal grain samples of 2006 harvest

All the spring cereal samples from the harvest year 2007 were simultaneously contaminated with all three mycotoxins DON, ZEA, T-2: DON concentration varied from 138.0 to 445.0 μg kg^{-1}, ZEA ranged from 20.0 to 26.3 μg kg^{-1}, and T-2 from 17.0 to 102.8 μg kg^{-1} (Fig. 5). The T-2 concentrations exceeding the safe limit or close to this limit (83.8–102.8 μg kg^{-1}) were identified in the spring barley variety 'Luokė' grain. In 2007, spring cereal grain co-contamination with the three mycotoxins reached 100% (Fig. 3).



Note. * – T-2 concentration exceeded safe level; lines —, - - -, and - · - signify LODs for DON, ZEA and T-2.

Figure 5. DON, ZEA, T-2 co-occurrence in spring cereal grain samples of 2007 harvest

High precipitation and relatively high temperatures during the period when wheat is most susceptible to infection (i.e. from flowering to the soft dough stage of kernel development) (Edwards, 2004; Haj lova et al., 2007) were obviously factors responsible for the higher mycotoxin levels. Spring cereal grain samples were more co-contaminated both in 2006 and 2007 compared with those of winter cereal. Winter cereals were harvested earlier than spring crops and heavy rainfall in August affected safety of spring cereal crop. According to Supronienė (2009), 3–4 *Fusarium* species (*F. avenaceum*, *F. poae*, *F. sporotrichioides*) prevailed on winter cereals of 2006 harvest in Lithuania, while on spring cereal grains higher diversity of *Fusarium* species (5–6 species) was identified: in addition to the above-mentioned species, *F. culmorum*, *F. tricinctum* and highly phytotoxic *F. equiseti* commonly occurred. It is known that separate *Fusarium* species distinguish for their cytotoxicity: *F. sporotrichioides* and *F. equiseti* show the highest average cytotoxicity (Brian et al., 1961; Langseth et al., 1999). According to reference data, *F. tricinctum* is fungi producing zearalenone (Varnaitė, Raudonienė, 2005), as well as T-2 toxin (Stahl et al., 1973).

The relationship among mycotoxins was variable both in trend and closeness and depended on the species, variety and comparable pair of mycotoxins (Table 3). In most cases, positive correlation existed among grain contaminating mycotoxins. A correlation significant at $P < 0.01$ or $P < 0.05$ was established between DON and ZEA, ZEA and sum of trichotecenes DON + T-2 concentration in grain of variety 'Nandu' in 2006 (r = 0.905** and 0.895**), varieties 'Zentos' and 'Luokė' in 2007 (r = 0.624** and 0.584* and 0.972** and 0.976**, respectively). A negative correlation was found between ZEA and trichotecenes concentration only for grain of spring wheat variety 'Triso' (Table 3).

The correlation coefficients of ZEA against DON and DON + T-2 ranged from −0.876** and −0.878** in grain of 2006 harvest year to −0.444 and −0.441, respectively in grain of 2007 harvest year. The relationship between ZEA and T-2 was variable: a weak negative correlation was found in 2006 (r = −0.599 and −0.450) in the grain of both spring wheat varieties 'Triso' and 'Nandu', and a positive insignificant correlation was found in 2007 (r = 0.338) for grain of variety 'Triso'. ZEA concentration correlated well with that of T-2 in the grain of winter wheat in 2007 and of 'Luokė' in 2006 (r = 0.581*). The published data agree with our results: the close relationship among mycotoxins does not always exist in co-contaminated samples (Doko et al., 1996; Miedaner, Perkowski, 1996; Neuhof et al., 2008); however Edwards (2009) found a good correlation between DON and zearalenone concentrations, although the relative concentration of DON and zearalenone fluctuated between years.

Thus, our study revealed frequent grain simultaneous contamination with *Fusarium* mycotoxins, although the mycotoxin concentration exceeded the allowable safe limit in only a few cases. The presence of all three toxins, sometimes even more, in one sample can cause unpredictable consequences both for human and animal health, despite the fact that mycotoxin concentrations in grain samples, in most cases, were within the permissible range (Commission Regulation (EC) No. 1881/2006). The hazards, including mycotoxins, identification is part of the first HACCP (hazard analysis critical control points) principle (Aldred et al., 2004). Research evidence on food and feed products in this respect is still very limited.

Table 3. Coefficients of linear correlation between mycotoxin concentrations in grain of wheat and barley varieties separately

Pairs	Winter wheat		Spring wheat		Spring barley	
	'Ada'	'Zentos'	'Triso'	'Nandu'	'Luokė'	'Prestige'
2006 harvest year						
DON × ZEA	n.c.†	n.c.	−0.876**	0.905**	0.103	n.d.‡
DON × T-2	n.c.	n.c.	0.517	−0.383	0.218	n.d.
ZEA × T-2	n.c.	n.c.	−0.599	−0.450	0.581*	n.d.
ZEA × (DON + T-2)	n.c.	n.c.	−0.878**	0.895**	0.364	n.d.
2007 harvest year						
DON × ZEA	0.625	0.624**	−0.444	n.d.	0.972**	0.496
DON × T-2	0.717*	0.276	−0.182	n.d.	0.906*	0.649
ZEA × T-2	0.834**	0.269	0.338	n.d.	0.929**	0.822*
ZEA × (DON + T-2)	0.688	0.584*	−0.441	n.d.	0.976**	0.570

Note. †not computed: majority of samples were contaminated < LOD or mycotoxins not detected, ‡mycotoxins not determined; *, ** – significant at $P < 0.05$ and $P < 0.01$, respectively.

Conclusions

1. The weather conditions of harvest year exert significant effect on the accumulation of *Fusarium* mycotoxins. Mycotoxin contamination severity both in winter and spring cereal grain was greater in 2007 growing season with the weather conditions favourable for the occurrence and development of fungal diseases, especially for fungi that produce mycotoxins, compared with that in dry and hot 2006 growing season.

2. Spring cereal (wheat and barley) grains are more susceptible to be contaminated with higher mycotoxin level than winter cereal (wheat, triticale and rye) grain. A trend was revealed that T-2 concentrations were higher in the spring barley grain samples than other cereal species irrespective of the experimental year.

3. The severity of grain contamination with mycotoxins depends on the variety: DON and T-2 concentrations were significantly higher in the grain of spring wheat variety 'Triso' compared with 'Nandu' grain (2006) and T-2 concentration was higher in the grain of 'Luokė' than in 'Prestige' (2007) when comparing spring barley varieties. Variety 'Luokė' was found to contain T-2 in the concentrations that might be a threat to human and animal health.

4. Simultaneous co-occurrence of mycotoxins depends both on the year and cereal species, as well as on seasonal type.

4.1. In 2006, winter cereal grain samples contaminated with one mycotoxin accounted for 15.6%, with three mycotoxins for 25% of the samples tested.

4.2. No spring grain samples were found contaminated with one mycotoxin and those co-contaminated with three toxins accounted for 90.6% of the samples tested.

4.3. In 2007, the frequency of simultaneous mycotoxin contamination both on winter and spring cereal grain was markedly higher, since winter cereal grain samples contaminated with one toxin accounted for as little as 3.6%, and all the spring cereal grain samples tested were found to be 100% co-contaminated with DON, ZEA, T-2.

5. The relationship among grain co-contaminating toxins was variable both in trend and closeness and depended on the species, variety and comparable pair of mycotoxins; however, positive correlations were observed in most cases.

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References

Aldred D., Olsen M., Magan N. The use of HACCP systems to control mycotoxins: the case of cereals // Magan N., Olsen M. (eds). Mycotoxins in food: detection and control. – Cambridge, UK, 2004, p. 139–173

Bennett J. W., Klich M. Mycotoxins // Clinical Microbiology Reviews. – 2003, vol. 16, p. 497–516

Boeira L. S., Bryce J. H., Stewart G. G., Flannigan B. The effect of combinations of *Fusarium* mycotoxins (deoxynivalenol, zearalenone and fumonisin B1) on growth of brewing yeasts // Journal of Applied Microbiology. – 2000, vol. 88, p. 388–403

Brian P., Dawkins A. W., Grove J. F. et al. Phytotoxic compound produced by *Fusarium equiseti* // Journal of Experimental Botany. – 1961, vol. 12, p. 1–12

CAST (Council for Agricultural Science and Technology). Mycotoxins: Risks in plant, animal, and human system. Task Force Report, No. 139. – Ames, USA, 2003, p. 48–58

Degirmencioglu N., Esecali H., Cokal Y., Bilgic M. From safety feed to safety food: the application of HACCP in mycotoxin control // Archivos de Zootecnia. – 2005, vol. 8, p. 19–32

Diaz G. J., Squires E. J., Julian R. J., Boermans H. J. Individual and combined effects of T-2 toxin and DAS in laying hens // British Poultry Science. – 1994, vol. 35, p. 393–405

D'Mello J. P. F., Placinta C. M., Macdonald A. M. C. *Fusarium* mycotoxins: a review of global implications for animal health, welfare and productivity // Animal Feed Science and Technology. – 1999, vol. 80, p. 183–205

Doko M. B., Canet C., Brown N. et al. Natural co-occurrence of fumonisins and zearalenone in cereals and cereal-based foods from Eastern and Southern Africa // Journal of Agricultural and Food Chemistry. – 1996, vol. 44, p. 3240–3243

Edwards S. G. *Fusarium* mycotoxin content of UK organic and conventional wheat // Food Additives and Contaminants. – 2009, vol. 26 (4), p. 496–503

Edwards S. G. Influence of agricultural practices on *Fusarium* infestation of cereals and subsequent contamination of grain by trichothecene mycotoxins // Toxicology Letters. – 2004, vol. 153, p. 29–35

Eriksen G. S., Alexander J. *Fusarium* toxins in cereals – a risk assessment. TemaNord 502. – Copenhagen, Denmark. – 1998, 146 p.

European Commission, Commission Regulation (EC). No. 1881/2006 of 19 December 2006 setting maximum levels for certain contaminants in foodstuff // Official Journal of the European Union. – 2006, L 364, p. 5–24

Goyarts T., Dänicke S., Valenta H., Ueberschär K. H. Carry-over of *Fusarium* toxins (deoxynivalenol and zearalenone) from naturally contaminated wheat to pigs // Food Additives and Contaminants. – 2007, vol. 24, p. 369–380

Haj lova J., Lancova K., Sehnalova M. et al. Occurrence of trichothecene mycotoxins in cereals harvested in the Czech Republic // Czech Journal of Food Sciences. – 2007, vol. 25, p. 339–350

Huff W. E., Harvey R. B., Kubena L. F., Rottinghaus G. E. Toxic synergism between aflatoxin and T-2 toxin in broiler chickens // Poultry Science. – 1988, vol. 67 (10), p. 1418–1423

Jestoi M. Emerging *Fusarium*-mycotoxins in Finland: Ph. D. thesis, University of Turku. – Helsinki, Finland, 2005, 120 p.

Krska R., Pettersson H., Josephs R. D. et al. Zearalenone in maize: stability testing and matrix characterization of a certified reference material // Food Additives and Contaminants. Part A. – 2003, vol. 20, p. 1141–1152

Langseth W., Bernhoft A., Rundberget T. et al. Mycotoxin production and cytotoxicity of *Fusarium* strains isolated from Norwegian cereals // Mycopathologia. – 1999, vol. 144, p. 103–113

Ledoux D. R., Broomhead J. N., Bermudez A. J., Rottinghaus G. E. Individual and combined effects of the *Fusarium* mycotoxins fumonisin B_1 and moniliformin in broiler chicks // Avian Diseases. – 2003, vol. 47 (4), p. 1368–1375

Malekinejad H., Schoevers E. J., Daemen I. J. J. M. et al. Exposure of oocytes to the *Fusarium* toxins zearalenone and deoxynivalenol causes aneuploidy and abnormal embryo development in pigs // Biology of Reproduction. – 2007, vol. 77, p. 840–847

Miedaner T., Perkowski J. Correlations among *Fusarium culmorum* head blight resistance, fungal colonization and mycotoxin contents in winter rye // Plant Breeding. – 1996, vol. 115, p. 347–351

Neuhof T., Koch M., Rasenko T., Nehls I. Distribution of trichothecenes, zearalenone, and ergosterol in a fractionated wheat harvest lot // Journal of Agricultural and Food Chemistry. – 2008, vol. 56, p. 7566–7571

Njobeh P. B., Dutton M. F., Koch S. H. et al. Simultaneous occurrence of mycotoxins in human food commodities from Cameroon // Mycotoxin Research. – 2010, vol. 26, p. 47–57

Schollenberger M., Müller H. M., Rüfle M. et al. Natural occurrence of 16 *Fusarium* toxins in grains and feedstuffs of plant origin from Germany // Mycopathologia. – 2006, vol. 161 (1), p. 43–52

Speijers G. J. A., Speijers M. H. M. Combined toxic effects of mycotoxins // Toxicology Letters. – 2004, vol. 153, iss. 1, p. 91–98

Stahl C., Vanderhoef L. N., Siegel N. *Fusarium tricinctum* T-2 toxin inhibits auxin-promoted elongation in soybean hypocotyls // Plant Physiology. – 1973, vol. 52, p. 663–666

Supronienė S. Factors influencing the occurrence of Fusarium fungi and mycotoxin accumulation in cereal grain: doctoral thesis, LUA. – Akademija, Kauno r., 2009, 92 p.

Tarakanovas P., Raudonius S. Agronominių tyrimų duomenų statistinė analizė taikant kompiuterines programas *Anova*, *Stat*, *Split-Plot* iš paketo *Selekcija* ir *Irristat*. – Akademija, Kauno r., 2003, 58 p.

Varnaitė R., Raudonienė V. Chromatographic characteristics of secondary metabolites of micromycetes detected on grain // Botanica Lithuanica. – 2005, vol. 7 (suppl.), p. 77–82

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Javų grūdų užterštumo *Fusarium* mikotoksinais ypatumai

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Santrauka

Grūdų užterštumas mikotoksinais deoksinivalenoliu (DON), zearalenonu (ZEA) ir toksinu T-2 (T-2) tirtas žieminio bei vasarinio kviečio (*Triticum aestivum* L.), žieminio kvietrugio (× *Triticosecale* Wittm.) bei rugio (*Secale cereale* L.) ir vasarinio miežio (*Hordeum vulgare* L.) 2006 m. ir 2007 m. derliaus grūdų mėginiuose. DON, ZEA ir T-2 koncentracijos nustatytos ELISA metodu sumaltuose grūdų mėginiuose. Tyrimų duomenys rodo, kad ir žieminių, ir vasarinių javų grūdai, užauginti skirtingomis oro sąlygomis pasižyminčiais metais, buvo užteršti vienu ar keliais *Fusarium* mikotoksinais deoksinivalenoliu (DON), zearalenonu (ZEA) bei T-2 toksinu (T-2). Nepaisant nevienodų meteorologinių sąlygų, abiem (2006 ir 2007) tyrimų metais mikotoksinų koncentracijos grūdų mėginiuose ir jų užterštumo keliais mikotoksinais dažnis buvo didesnis vasarinių javų (kviečių bei miežių) nei žieminių javų (kviečių, kvietrugių bei rugių). Žieminių javų grūdų mėginių, užterštų vienu iš tirtų toksinų (DON arba T-2), 2006 m. nustatyta 15,6 %, o užterštų visais trimis kvantifikuotais toksinais – 25,0 %. 2007 m. žieminių javų grūdų mėginių, užterštų tik vienu toksinu, nustatyta 3,6 %. Vasarinių grūdų mėginių, užterštų vienu toksinu, nenustatyta nė vienais tyrimų metais, o trimis toksinais užtersta 90,6 % 2006 m. ir 100 % 2007 m. derliaus mėginių. Nors daugeliu atvejų nustatyta teigiama koreliacija tarp grūdus vienu metu užteršiančių mikotoksinų, tačiau šie ryšiai kryptimi bei stiprumu buvo skirtingi, ir tai priklausė nuo javų rūšies, veislės bei lyginamų mikotoksinų poros.

Tyrimų rezultatai leidžia daryti prielaidą, kad didelę įtaką mikotoksinų kaupimuisi turėjo ne tik meteorologinės sąlygos augalų augimo metu, bet ir javų tipas (vasariniai, žieminiai) ir netgi veislė. Išryškėjo tendencija, kad vasarinių miežių tirtų grūdų mėginiuose T-2 koncentracija buvo didesnė nei kituose, nepaisant tyrimų metų. Veislės 'Luokė' vasarinių miežių grūdų du mėginiai 2006 m. ir vienas mėginys 2007 m. buvo labai užteršti toksinu T-2. Koncentracija siekė 102,8–132,4 μg kg^{-1}, t. y. viršijo žmonių ir gyvūnų sveikatai saugią koncentraciją (100 μg kg^{-1}).

Reikšminiai žodžiai: *Triticum aestivum* L., × *Triticosecale* Wittm., *Secale cereale* L., *Hordeum vulgare* L., javų rūšys ir tipas, derliaus metai, grūdų užterštumas mikotoksinais, deoksinivalenolis, zearalenonas, T-2 toksinas.