Romanian Journal for Plant Protection, Vol. XVI, 2023
ISSN 2248 – 129X; ISSN-L 2248 – 129X

THE IMPACT OF CLIMATE CHANGE ON *FUSARIUM* SPP. AND DEOXYNIVALENOL CONTAMINATION IN WHEAT IN THE MILLING-BAKERY SECTOR - minireview

Valeria Gagiu[1], Elena Mateescu[2], Nastasia Belc[1]*

[1] National Research&Development Institute for Food Bioresources- IBA Bucharest, Bucharest, Romania
[2] National Meteorological Administration (Meteo-Romania), Bucharest, Romania

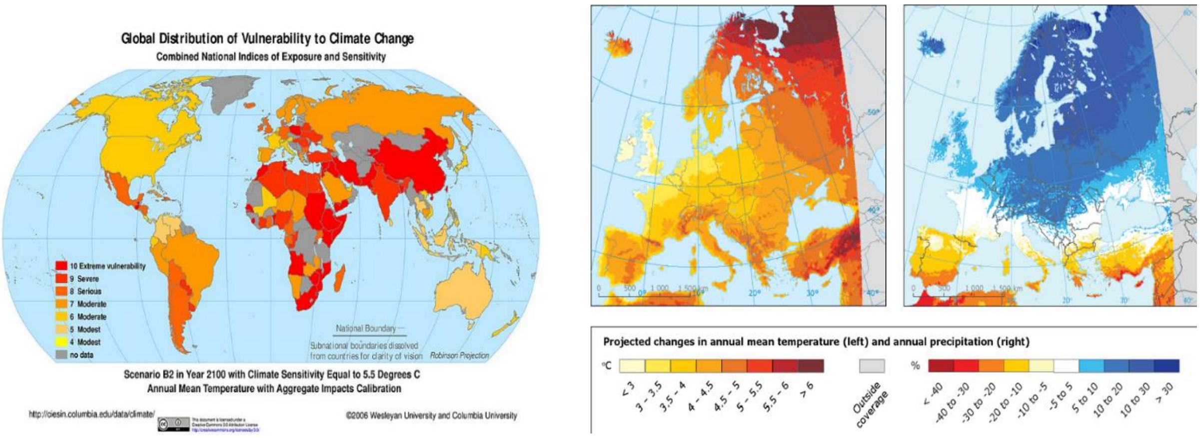
*Corresponding author:
National Research&Development Institute for Food Bioresources— IBA Bucharest
5 Băneasa Ancuța Street, CP 020323, s 2,
Bucharest, ROMANIA
Tel/Fax: 031.620.58.33/34/35
E-mail: valeria.gagiu@bioresurse.ro

Abstract. Climate change affects the quantity and quality of wheat harvests with effects on food safety and security. Consequently, companies must develop and implement appropriate strategies, starting with the acquisition of grains and continuing with the reception, milling of grains and processing of intermediate products, storage and distribution-trade of final products. This research addresses the impact of climate change on the milling-bakery sector in which the optimization of classic and modern technologies will strengthen the economic advantages of companies.

Keywords: *wheat, toxigenic fungi, optimization of milling technology, climate change*

Agriculture is affected and will face significant challenges in the future, considering the effects of extreme weather events on the growth and development of cultivated species. Therefore, environmental problems and food security in the context of current and future climate change are based on complex research and visions at different geographical and temporal scales. The present agroclimatic conditions and the climatic changes predicted by 2100 affect the environment and cereal crops, with negative effects on safety and security (World Bank, 2010; IPCC, 2014, 2018).

Commercial globalization requires the assessment of the risk of mycotoxin contamination of cereals, food and feed, depending on the geographical areas of origin, characterized by different agroclimatic conditions. Forecasts at the global level have suggested that there will be "hot spots" where the temperature will increase by 2–5^{0}C, and the pattern of precipitation fall and drought events will increase in frequency and intensity in certain regions, which will have a significant impact on the production of food crops (Figure 1a) (Magan et al., 2012; IPCC, 2014; Langer et al., 2014). Southern Europe will register a temperature increase of 4–5^{0}C and drought, especially during the summer, which will lead to a 20% decrease in agricultural production, soil degradation and disruptions in ecosystems. Central Europe will register a temperature increase of 3–4^{0}C, precipitation increase in winter and decrease in summer, and an increased risk of flooding (Figure 1b) (IPCC, 2014, 2018). The climate changes forecast for Romania corresponds to those for Europe, with the southern part of the country having a dry temperate continental climate which is characteristic of Southern Europe, and the northern part having a temperate humid continental climate which is characteristic of Central Europe (Busuioc et al., 2012; Sandu & Mateescu, 2014; IPCC, 2014). Forecasts on the effects of climate change on wheat crops have shown that climate change will depress agricultural yields in most countries by 2050, given current agricultural practices and crop varieties; the most affected will be developing countries that are more exposed and less resilient to climate hazards, which will exacerbate insecurity in areas currently vulnerable to hunger and under-nutrition (World Bank, 2010; IPCC, 2014, 2018).



a) **b)**

Figure 1. Climate change (CC): **a)** Global distribution of vulnerability to CC- B2 scenario in 2100 with climate sensitivity 5.5°C (according to IPCC, 2018), **b)** Projected changes in annual mean temperature and precipitation in 2071–2100 (according to IPCC, 2014).

Wheat is the second most cultivated cereal and records the most extensive areas in the Northern Hemisphere in Asia, Europe and North America (Figure 2) (CGIAR, 2014; Lantican et al., 2016; Gagiu et al., 2022). In 2021, the harvested area and the production share of wheat by region were 44.2% in Asia, 34.9% in Europe, 12.9% in the Americas, 4.2% in Oceania and 3.8% in Africa. The top ten producers of wheat were represented by China mainland, India, the Russian Federation, the United States of America, France, Ukraine, Australia, Pakistan, Canada and Germany, but the wheat yield was not correlated with the area of cultivation because these countries have different agroclimatic conditions and economic development (FAO, 2023).

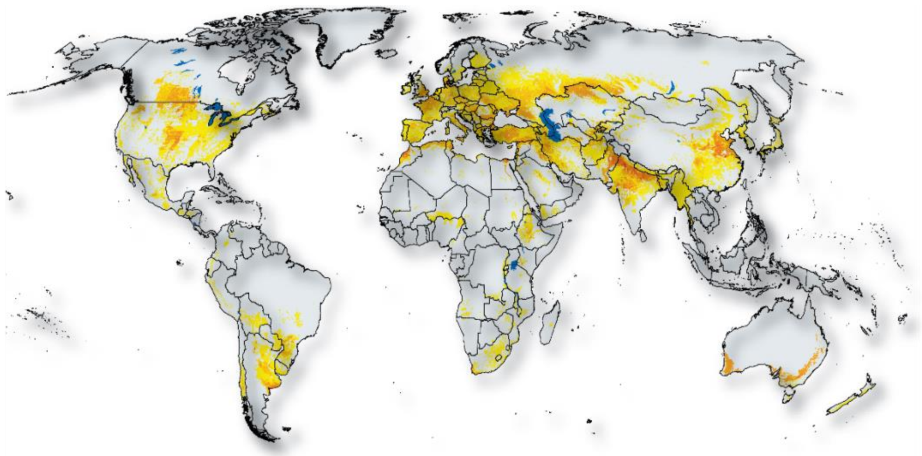


Figure 2. Global areas where more wheat is grown (according to CGIAR, 2014; Lantican et al., 2016).

Romania had a productivity of 4.797 tons of wheat per hectare in 2021, being included in the first group of global wheat growers. This yield of the wheat crop can be explained by the favorable agro-climatic conditions, the modern agricultural technologies that were acquired and the development of the agricultural sector after Romania's accession to the European Union in 2007 (Toma et al., 2010; Feher et al., 2017; Ivașcu & Dănulețiu, 2021; FAO, 2023; Gagiu et al., 2023). Within 2008 to 2021, the average values of wheat yield in Romania varied yearly from 1.610 to 4.891 t/ha, with a mean value of 3566 t/ha during these thirteen years (FAO, 2023; Gagiu et al., 2023). An important role in the evolution of production, productivity and quality of wheat crop in Romania and worldwide was played by the increase in air temperature and climate change (Mäkinen et al., 2018; WBG–CCKP, 2021; Senapati et al., 2021; Poggi et al., 2022; FAO, 2023; Rumler et al., 2023; Zahra et al., 2023; Gagiu et al., 2023).

As a result of climate change, the frequency, intensity and duration of extreme weather events (heavy precipitation and flood; heatwave and drought) have increased, with an impact on the pattern of fungal and mycotoxin contamination in cereals. In Europe, contamination with *Fusarium* spp. fungi and their mycotoxins (deoxynivalenol and zearalenone) prevails in the northern part with a colder climate, while contamination with *Aspergillus* spp. and *Penicillium* spp. fungi and their mycotoxins (aflatoxins, ochratoxin A and fumonisin B) prevails in the southern part with a hot and wet Mediterranean climate (Paterson & Lima, 2010; Battilani et al., 2012, 2016; Schatzmayr & Streit, 2013; Backhouse, 2014; Spinonni et al., 2015; Medina et al., 2015; Pinotti et al., 2016; Gagiu et al., 2018a, 2018b, 2021, 2022; Gruber-Dorninger et al., 2019).

Deoxynivalenol (DON, vomitoxin) is an intermediate product of the *Fusarium* spp. metabolism and belongs to the trichothecene type B group. *Fusarium* spp. and deoxynivalenol contamination in wheat crops are influenced by agroclimatic factors, especially during the flowering period, geographical and hydrological factors, and have local, regional and annual variation (Lindblad et al., 2012; Bernhoft et al., 2012; Langer et al., 2014; Calori-Dominguez et al., 2016; Gagiu et al., 2016, 2017, 2018a, 2018b, 2021, 2022). *Fusarium* Head Blight (FHB, scab) infection and deoxynivalenol contamination in wheat are also affected by oxygen levels, mechanical breakdown of cereals and the presence of fungal spores, the amount of soil crop residues, in flowering time variety susceptibility and fungicide applications, cultivation practices, drying speed, and faulty storage with the emergence of so-called "hot spots" (Figure 3) (Maiorano et al., 2008; Shah et al., 2017). The adverse effects of fungal and mycotoxin contamination in cereals are represented by the decrease in crop yield and the reduction of the physical-chemical, technological, nutritional and food safety quality of the cereal-based food (Figure 4) (Pestka & Casale, 1989; CAST, 2003; Siuda et al., 2010).

Figure 3. Fusarium Head Blight symptoms in wheat (according to Shah et al., 2017).

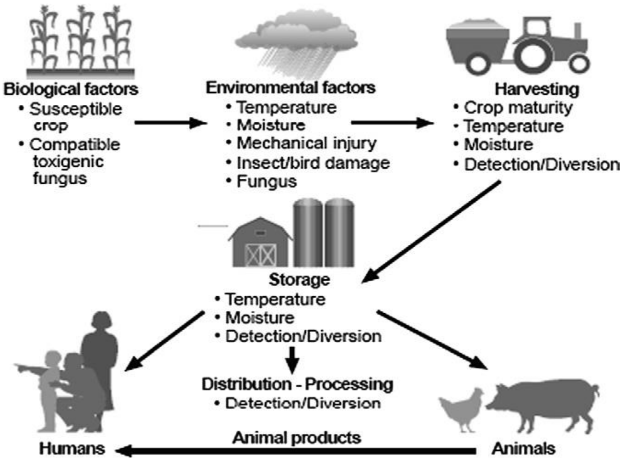


Figure 4. Factors influencing the appearance of mycotoxins in the agro-food chain (according to Pestka & Casale, 1989; CAST, 2003).

The cereals contaminated in the field and the by-products of the milling process are used to obtain compound feeds when they do not exceed the maximum limits for feed ingredients, according to European regulations. Because the compound feeds are made from different types of cereals, the co-occurrence of mycotoxins can have amplified synergistic effects on animal and human health. In animals, the effects of deoxynivalenol are represented by feed refusal and emesis in pigs, feed refusal only at very high concentration in poultry, and ruminants are the least sensitive (Pinotti et al., 2016). Biomonitoring of deoxynivalenol and deoxynivalenol-3-glucoside in human volunteers showed total renal excretion in 24 hours and statistically significant regional differences for deoxynivalenol and zearalenone concentrations in pig urine, in three regions with different climate conditions in Sweden (Mengelers et al., 2019; Gambacorta et al., 2019). Monitoring of mycotoxin contamination in cereals, food and feed from different global climate regions is very important because they can be notified by the *Rapid Alert System for Food* and *Feed* **(***RASFF*) of the European Commission with impact on the economy and trade (Schatzmayr & Streit, 2013; Pinotti et al., 2016).

The cereal-based food technology comprises several phases with different effects on contamination levels because *Fusarium* spp. and deoxynivalenol can penetrate the sheaths of grains and reach the endosperm (Belluco et al., 2017; Khaneghah et al., 2018; Zhang et al., 2022). The cleaning stage of the cereals, before storage and/or technological processing, is crucial for the reduction of mycotoxin levels in grain; however, very high contamination caused by agroclimatic conditions makes the most efficient technologies insufficient (Giordano et al., 2017; Schaarschmidt & Fauhl-Hassek, 2018). The milling process can be achieved by conventional technology or modernized (debrannig process before milling), the latter having positive effects on the economy, process, product quality and food safety. However, the modern technologies have high costs for investment, technological consumption and maintenance of the process (Singh & Singh, 2010; Edwards et al., 2011, 2018; Tibola et al., 2015, 2016, 2019; Savi et al., 2016; Giordano et al., 2017; Ficco et al., 2020; Pascale et al., 2020; Qi et al., 2022; Zhang et al., 2022). The degree of debranning could be modulated by time and rate to separate the outermost fractions that have the highest contamination level; the debranning efficiency is hugely variable but only in the lower to moderate levels of deoxynivalenol contamination (Bottega et al., 2009; Cheli et al., 2010, 2013; Tibola et al., 2015, 2016, 2019). To increase the efficiency of the debranning process, companies can include optical sorting machines for altered and infected grains (Blandino et al., 2013; Giordano et al., 2017; Schaarschmidt & Fauhl-Hassek, 2018; Tibola et al., 2019; Pascale et al., 2020). Among the large companies producing milling equipment we mention Bühler AG (Switzerland), AGI (Manitoba, Canada), Henry Simon (United Kingdom), Alapala (Turkey) and Sangati Berga S.A. (Brazil) (World Grain, 2023; Bühler Group, 2023).

The influence of agroclimatic conditions on the cereal, food and feed contamination with mycotoxins in different geographical areas is a new and current topic in the mycotoxins field, but the need for research on mycotoxin contamination during the industrial milling technology in correlation with the agroclimatic conditions in different geographical areas represents a research niche that was demonstrated by the researchers of the present paper (Gagiu et al., 2016, 2017, 2018a, 2018b, 2021; 2022). Research should be focused on the development, testing and validation of experimental models that demonstrate the impact and effectiveness of the optimized industrial milling technology of contaminated wheat and integration in the field to the post-harvest stages, to increase the effectiveness of industrial management in the current and future climate change conditions. This approach has a high degree of novelty because most published articles present information on the incidence and level of mycotoxins in cereal-based food, the effect of processing types of equipment and baking parameters on mycotoxin content, without a deep correlation with climate change (Cheli et al., 2010, 2013; Edwards et al., 2011, 2018; van der Fels-Klerx et al., 2012; Tamba-Berehoiu et al., 2012; Blandino et al., 2013; Paterson et al., 2014; Tibola et al., 2016, 2019; Savi et al., 2016; Calori-Dominguez et al., 2016; Gagiu et al., 2016, 2017, 2018a, 2018b; Giordano et al., 2017; Belluco et al., 2017;

Schaarschmidt & Fauhl-Hassek, 2018; Khaneghah et al., 2018). The initial evaluations must be carried out in the technological conditions existing in the companies, and the physico-chemical, technological, microbiological and toxicological analyzes of the wheat and by-products must be carried out from samples taken during the reception, sorting, debranning phases and from the milling fractions using high-performance analytical methods. By including the optical sorting and debranning machines and optimizing the operating parameters, the capacity and effectiveness of the mill's production (flour yield, flour refinement, time reduction of milling process diagram) will increase. When establishing the milling parameters, the quality indicators of the wheat lots and the agroclimatic characteristics of the regions of wheat cultivation and purchase must be taken into account. Next, in the validation of the optimized grinding process, the annual weather parameters must be used, because they determine the annual, regional and local variation of the physico-chemical, microbiological and toxicological indicators of the grains (Gagiu et al., 2021, 2022). These approaches are supported by the scientific data obtained in national and European projects that showed that the intensity of the drought will increase in the south and southeast of Romania, and extreme weather events are unpredictable in terms of frequency and intensity and can lead to the appearance of mycotoxins in cereals (Battilani et al., 2012, 2016; Busuioc et al., 2012; Sandu & Mateescu, 2014; ICPP, 2014, 2018; Spinoni et al., 2015; Gagiu et al., 2018 a, 2018b, 2021, 2022; WBG-CCKP, 2021).

In conclusion, grain processors must be aware of the risks produced by climate change on the agri-food chain and optimize their technologies to ensure food security and safety. The scientific results will have international relevance due to technological and economic advantages, especially for companies which have representation in more countries on different continents.

Funding: This research was funded through the Nucleu Programme (Grant no. PN 23 01 03 04) by the Ministry of Research, Innovation and Digitalization.

References

BACKHOUSE, D. (2014). Global distribution of *Fusarium graminearum*, *F. asiaticum* and *F. boothii* from wheat in relation to climate. *European Journal of Plant Pathology*, 139, 161–173. Doi: https://doi.org/10.1007/s10658-013-0374-5

BATTILANI, P.; TOSCANO, P.; VAN DER FELS-KLERX, H.J.; MORETTI, A.; CAMARDO LEGGIERI, M.; BRERA, C.; RORTAIS, A.; GOUMPERIS, T.; ROBINSON, T. (2016). Aflatoxin B1 contamination in maize in Europe increases due to climate change. *Scientific Reports*, 6, 24328. Doi: https://doi.org/10.1038/srep24328

BATTILANI, P.; ROSSI, V.; GIORNI, P.; PIETRI, A.; GUALLA, A.; VAN DER FELS-KLERX, H. J.; BOOIJ, C. J. H.; MORETTI, A.; LOGRIECO, A.; MIGLIETTA, F.; TOSCANO, P.; MIRAGLIA, M.; DE SANTIS, B.; BRERA, C. (2012). Modelling and mapping the emergence of aflatoxins in cereals in the EU due to climate change. *Scientific Report Submitted to EFSA*, 9, 1, 223E. DOI 10.2903/sp.efsa.2012.EN-223

BELLUCO, B.; COSTA DE CAMARGO, A.; MICOTTI DA GLORIA, E.; TADEU DOS SANTOS DIAS, C.; BUTTON, D.C.; CALORI-DOMINGUES, M.A. (2017). Deoxynivalenol in wheat milling fractions: A critical evaluation regarding ongoing and new legislation limits. *Journal of Cereal Science*, 77, 284-290. doi: https://doi.org/10.1016/j.jcs.2017.08.008

BERNHOFT, A.; TORP, M.; CLASEN, P.E.; LØES, A.K.; KRISTOFFERSEN, A.B. (2012). Influence of agronomic and climatic factors on *Fusarium* infestation and mycotoxin contamination of cereals in Norway. *Food Additives & Contaminants: Part A*, 29, 7, 1129–1140. Doi: 10.1080/19440049.2012.672476

BIERBAUM, R. M.; FAY, M.; ROSS-LARSON, B. (2010). World development report 2010: development and climate change. World development report, Washington, D.C.: *World Bank*

Group. Available from: http://documents.worldbank.org/curated/en/201001468159913657/World-development-report-2010-development-and-climate-change

BLANDINO, M.; SACCO, D.; REYNERI, A. (2013). Prediction of the dry-milling performance of maize hybrids through hardness-associated properties. *Journal of the Science of Food and Agriculture*, 93, 1356-1364. Doi:10.1002/jsfa.5897

BOTTEGA, G.; CARAMANICO, R.; LUCISANO, M.; MARIOTTI, M.; FRANZETTI, L.; PAGANI, M.A. (2009). The debranning of common wheat (*Triticum aestivum* L.) with innovative abrasive rolls. *Journal of Food Engineering*, 94, 1, 75-82, Doi: https://doi.org/10.1016/j.jfoodeng.2009.03.002

BUHLER GROUP (2023). Bühler locations worldwide (140 countries). Share our global and local expertise. Available from: https://www.buhlergroup.com/content/buhlergroup/global/en/locations.html

BUSUIOC, A.; CAIAN, M.; BOJARIU, R.; BORONEANT, C.; BACIU, M.; DUMITRESCU, A. (2012). Scenarii de Schimbare a Regimului Climatic in Romania Pe Perioada 2001-2030 [Scenarios for Changing the Climate Regime in Romania for the Period 2001-2030]. Administrația Națională de Meteorologie: București, România, 25 pp. Available from: http://mmediu.ro/new/wp-content/uploads/2014/02/2012-04-23_schimbari_climatice_ schimbareregimclimatic2001_2030.pdf

CALORI-DOMINGUES, M.A.; GIL BERNARDI, C.M.; SARTORI NARDIN, M.; VENDRAMINI DE SOUZA, G.; GREGORIO RIBEIRO DOS SANTOS, F.; DE ABREU STEIN, M.; MICOTTI DA GLORIA, E.; DOS SANTOS DIAS, C.T.; COSTA DE CAMARGO, A. (2016). Co-occurrence and distribution of deoxynivalenol, nivalenol and zearalenone in wheat from Brazil. *Food Additives & Contaminants: Part B*, 9, 2, 142-151. Doi: 10.1080/19393210.2016.1152598.

CHELI, F.; PINOTTI, L.; ROSSI, L.; DELL'ORTO, V. (2013). Effect of milling procedures on mycotoxin distribution in wheat fractions: A review. *Lebensmittel-Wissenschaft & Technologie - Food Science and Technology,* 54, 2, 307–314. Doi:10.1016/j.lwt.2013.05.040

CHELI, F.; CAMPAGNOLI, A.; VENTURA, V.; BRERA, C.; BERDINI, C.; PALMACCIO, E.; DELL'ORTO, V. (2010). Effects of industrial processing on the distribution of deoxynivalenol, cadmium and lead in durum wheat milling fractions. *Lebensmittel-Wissenschaft & Technologie - Food Science and Technology,* 43, 1050-1057. Doi:10.1016/j.lwt.2010.01.024

COUNCIL FOR AGRICULTURAL SCIENCE AND TECHNOLOGY (CAST) (2003). Mycotoxins: Risks in plant, animal and human systems. *Task Force Report* no. 139, Ames, 199 pp. ISBN 1-887383-22-0. Available from: https://www.cast-science.org/publication/mycotoxins-risks-in-plant-animal-and-human-systems/

EDWARDS, S.G.; KHARBIKAR, L.L.; DICKIN, E.T.; MACDONALD, S.; SCUDAMORE, K.A. (2018). Impact of pre-harvest rainfall on the distribution of *Fusarium* mycotoxins in wheat mill fractions. *Food Control*, 89, 150–156. Doi: https://doi.org/10.1016/j.foodcont.2018.02.009

EDWARDS, S.G.; DICKIN, E.T.; MACDONALD, S.; BUTTLER, D.; HAZEL, C.M.; PATEL, S.; SCUDAMORE, K.A. (2011). Distribution of *Fusarium* mycotoxins in UK wheat mill fractions. *Food Additives and Contaminants,* 28, 1694–1704. https://doi.org/10.1080/19440049.2011.605770

FEHER, A.; GOȘA, V.; RAICOV, M.; HARANGUȘ, D.; CONDEA, B.V. (2017). Convergence of Romanian and Europe Union agriculture – evolution and prospective assessment. *Land Use Policy*, 67, 670-678, Doi: https://doi.org/10.1016/j.landusepol.2017.06.016

FICCO, D.B.M.; BORRELLI, G.M.; MIEDICO, O.; GIOVANNIELLO, V.; TARALLO, M.; POMPA, C.; DE VITA, P.; CHIARAVALLE, A.E. (2020). Effects of grain debranning on bioactive compounds, antioxidant capacity and essential and toxic trace elements in purple durum wheats. *Lebensmittel-Wissenschaft & Technologie,* 118, 108734. Doi: https://doi.org/10.1016/j.lwt.2019.108734

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS (FAO) (2023). Crops and livestock products (Production). March 24, 2023, Minor Revision. Faostat Database. Available from: https://www.fao.org/faostat/en/#data/QCL

GAGIU, V.; CAIAN, M.; DOBRE, A.; OPREA, O.A.; MATEESCU, E.; BELC, N. (2023). Evaluation of the quantitative indicators of wheat crops in Romania in the period 1961–2021 (Poster). Publisher: University of Agronomic Sciences and Veterinary Medicine of Bucharest, Faculty of Agriculture, Romania; and CERES Publishing House Bucharest, Romania. Book of Abstracts, p. 179, International Conference "*Agriculture for Life, Life for Agriculture*", Section 1: Agronomy. ISSN-L 2457-3205.

https://agricultureforlife.usamv.ro/images/2023/Book_of_Abstracts/Agronomy_Book_of_Abstract_2023.pdf

GAGIU, V.; MATEESCU, E.; BELC, N.; OPREA, O.A.; PIRVU, G.P. (2022). Assessment of *Fusarium*-Damaged Kernels in Common Wheat in Romania in the Years 2015 and 2016 with Extreme Weather Events**.** *Toxins***,** 14, 5, 326. Doi: https://doi.org/10.3390/toxins14050326

GAGIU, V.; MATEESCU, E.; DOBRE, A.A.; SMEU, I.; CUCU, M.E.; OPREA, O.A.; ALEXANDRU, D.; IORGA, E.; BELC, N. (2021). Deoxynivalenol occurrence in triticale crops in Romania during the 2012–2014 period with extreme weather events. *Toxins*, 13, 7, 456. Doi: https://doi.org/10.3390/toxins13070456

GAGIU, V.; MATEESCU, E.; ARMEANU, I.; DOBRE A.A.; SMEU, I.; CUCU, M.E.; OPREA, O.A.; IORGA, E.; BELC, N. (2018b). Post–harvest contamination with mycotoxins in the context of the geographic and agroclimatic conditions in Romania. *Toxins*, 10, 12**,** 533. Doi: https://doi.org/10.3390/toxins10120533

GAGIU, V. (2018a). Triticale Crop and Contamination with Mycotoxins under the Influence of Climate Change—Global Study. *Journal of Hygiene and Engineering Design*, 23, 30–45. Available from: https://keypublishing.org/jhed/jhed-volumes/jhed-volume-23-fqs-4-valeria-gagiu-2018-triticale-crop-and-contamination-with-mycotoxins-under-the-influence-of-climate-change-global-study/

GAGIU, V.; MATEESCU, E.; SMEU, I.; DOBRE, A.A.; CUCU, M.E.; OPREA, O.; IORGA, E.; BELC, N. (2017). A survey of the cereal contamination with deoxynivalenol in Romania, for 2011–2013 period. *Romanian Biotechnology Letters*, 22, 1, 12240–12249. Available from: https://www.researchgate.net/publication/312026550_A_Survey_of_the_Cereal_Contamination_with_Deoxynivalenol_in_Romania_in_2011-2013

GAGIU, V.; DOJA, L.; MATEESCU, E.; SMEU, I.; CUCU, M.E.; DOBRE, A.A.; OPREA, O.; IORGA, E.; BELC, N. (2016). Contamination with Deoxynivalenol in the Milling—Bakery Industry under the Influence of Climatic Conditions from Romania. *Journal of Hygiene and Engineering Design*, 16, 38–44. Available from: https://keypublishing.org/jhed/jhed-volumes/jhed-volume-16-fqs-5-valeria-gagiu-livia-doja-elena-mateescu-irina-smeu-mirela-elena-cucu-alina-alexandra-dobre-oana-oprea-enuta-iorga-nastasia-belc-2016-contamination-with-deoxyni/

GAMBACORTA, L.; OLSEN, M.; SOLFRIZZO, M. (2019). Pig Urinary Concentration of Mycotoxins and Metabolites Reflects Regional Differences, Mycotoxin Intake and Feed Contaminations. Toxins**,** 11, 7, 378. Doi: 10.3390/toxins11070378

GIORDANO, D.; LOCATELLI, M.; TRAVAGLIA, F.; BORDIGA, M.; REYNERI, A.; COISSON, J. D; BLANDINO, M. (2017). Bioactive compound and antioxidant activity distribution in roller-milled and pearled fractions of conventional and pigmented wheat varieties. *Food Chemistry*, 233, 483–491. Doi: https://doi.org/10.1016/j.foodchem.2017.04.065

GRUBER-DORNINGER, C.; JENKINS, T.; SCHATZMAYER, G. (2019). Global mycotoxin occurrence in feed: a ten-year survey. *Toxins,* 11, 7, 375. Doi: 10.3390/toxins11070375

INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (IPCC) (2018). IPCC, 2018: Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty [Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, 616 pp. Doi: https://doi.org/ 10.1017/9781009157940

INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (IPCC) (2014). Climate Change 2014: Synthesis Report. [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. *Intergovernmental Panel on Climate Change,* Switzerland, 151 pp. Available from: https://www.ipcc.ch/report/ar5/syr/

INTERNATIONAL MAIZE AND WHEAT IMPROVEMENT CENTER (CGIAR) (2014). Wheat in the world. Global wheat cultivation. Map based on You, L., U. Wood-Sichra, S. Fritz, Z. Guo, L. See, and J. Koo. Carretera Mexico-Veracruz, km. 45, El Batan, Texcoco, Eo de México, Mexico. Available from: https://archive.wheat.org/wheat-in-the-world/

IVAȘCU, C.; DĂNULEȚIU, A.E. (2021). Structural Developments in Agricultural Activity after Romania's Accession to the European Union. *''Ovidius" University Annals, Economic Sciences Series, XXI* (2), 142-152. Available from: https://stec.univ-ovidius.ro/html/anale/RO/2021-2/Section%201%20and%202/20.pdf

KHANEGHAH, A.M.; MARTINS, L.M.; VON HERTWIG, A.M.; BERTOLDO, R.; SANT'ANA, A.S. (2018). Deoxynivalenol and its masked forms: Characteristics, incidence, control and fate during wheat and wheat based products processing – A review. *Trends in Food Science & Technology*, 71, 13–24. Doi: https://doi.org/10.1016/j.tifs.2017.10.012

LANGER, S.M.; LONGIN, C.F.H.; WÜRSCHUM, T. (2014). Flowering time control in European winter wheat. *Frontiers in Plant Science*, 5, 537. Doi: 10.3389/fpls.2014.00537

LANTICAN, M.A.; BRAUN, H.J.; PAYNE, T.S.; SINGH, R.P.; SONDER, K.M.; VAN GINKEL, B.M.; ERENSTEIN, O. (2016). *Impacts of International Wheat Improvement Research 1994-2014.* Mexico, D.F.: International Maize and Wheat Improvement Center (CIMMYT). Carretera Mexico-Veracruz, Mexico, ISBN: 978-607-8263-55-4

LINDBLAD, M.; BÖRJESSON, T.; HIETANIEMI, V.; ELEN, O. (2012). Statistical analysis of agronomical factors and weather conditions influencing deoxynivalenol levels in oats in Scandinavia. *Food Additives & Contaminants: Part A*, 29, 10, 1566–1571. Doi: 10.1080/19440049.2011.647335

MAGAN, N.; ALDRED, D.; MEDINA. A. (2012). Food security, climate change and mycotoxins. *Quality Assurance and Safety of Crops & Foods*, 4, 3, 145. Doi: https://doi.org/10.1111/j.1757-837X.2012.00152.x

MAIORANO, A.; BLANDINO, M.; REYNERI, A.; VANARA, F. (2008). Effects of maize residues on the *Fusarium* spp. infection and deoxynivalenol (DON) contamination of wheat grain. *Crop Protection*, 27, 182–188. Doi: https://doi.org/10.1016/j.cropro.2007.05.004

MÄKINEN, H.; KASEVA, J.; TRNKA, M.; BALEK, J.; KERSEBAUM, K.C.; NENDEL, C.; GOBIN, A.; OLESEN, J.E.; BINDI, M.; FERRISE, R.; MORIONDO, M.; RODRÍGUEZ, A.; RUIZ-RAMOS, M.; TAKÁČ, J.; BEZÁK, P.; VENTRELLA, D.; RUGET, F.; CAPELLADES, G.; KAHILUOTO, H. (2018). Sensitivity of European wheat to extreme weather. *Field Crops Research*, 222, 209-217. Doi: https://doi.org/10.1016/j.fcr.2017.11.008

MEDINA, Á.; RODRIGUEZ, A.; SULTAN, Y.; MAGAN, N. (2015). Climate change factors and *Aspergillus flavus*: effects on gene expression, growth and aflatoxin production. *World Mycotoxin Journal,* 8, 171–179. Doi:10.3920/WMJ2014.1726

MENGELERS, M.; ZEILMAKER, M.; VIDAL, A.; DE BOEVRE, M.; DE SAEGER, S.; HOOGENVEEN, R. (2019). Biomonitoring of deoxynivalenol and DON-3-glucoside in human volunteers: renal excretion profiles. *Toxins*, 11, 8, 466. Doi: https://doi.org/10.3390/toxins11080466

PASCALE, M.; LOGRIECO, A.F.; GRAEBER, M.; HIRSCHBERGER, M.; REICHEL, M.; LIPPOLIS, V.; DE GIROLAMO, A.; LATTANZIO, V.M.T.; SLETTENGREN, K. (2020). Aflatoxin Reduction in Maize by Industrial-Scale Cleaning Solutions. *Toxins*, 12, 331. Doi: https://doi.org/10.3390/toxins12050331

PASQUALI, M.; BEYER, M.; LOGRIECO, A.; AUDENAERT, K.; BALMAS, V.; BASLER, R.; BOUTIGNY, A.-L.; CHRPOVÁ, J.; CZEMBOR, E.; GAGKAEVA, T.; GONZÁLEZ-JAÉN, M.T.; HOFGAARD, I.S.; KÖYCÜ, N.D.; HOFFMANN, L.; LEVIĆ, J.; MARIN, P.; MIEDANER, T.; MIGHELI, Q.; MORETTI, A.; MÜLLER, M.E.H.; MUNAUT, F.; PARIKKA, P.; PALLEZ-BARTHEL, M.; PIEC, M.J.; SCAUFLAIRE, J.; SCHERM, B.; STANKOVIĆ, S.; THRANE, U.; UHLIG, S.; ADRIAAN VANHEULE, A.; TAPANI YLI-MATTILA, T.; VOGELGSANG, S. (2016). A European Database of *Fusarium graminearum* and *F. culmorum* Trichothecene Genotypes. *Frontiers in Microbiology*, 7, 406. Doi: https://doi.org/10.3389/fmicb.2016.00406

PATERSON, R.; LIMA N. (2010). How will climate change affect mycotoxins in food**?** *Food Research International*, 43, 1902–1914. Doi: https://doi.org/10.1016/j.foodres.2009.07.010

PESTKA, J.J.; CASALE, W. (1989). Naturally occurring fungal toxins. In M.S. Simmons and J. Nriagu (Eds.). *Food Contamination from Environmental Sources*. John Wiley and Sons, Ltd.

PINOTTI, L.; OTTOBONI, M.; GIROMINI, C.; DELL'ORTO, V.; CHELI, F. (2016). Mycotoxin Contamination in the EU Feed Supply Chain: A Focus on Cereal Byproducts. *Toxins***,** 8, 2, 45. Doi: https://doi.org/10.3390/toxins8020045

POGGI, G.M.; ALOISI, I.; CORNETI, S.; ESPOSITO, E.; NALDI, M.; FIORI, J.; PIANA, S.; VENTURA, F. (2022). Climate change effects on bread wheat phenology and grain quality: a case study in the north of Italy. *Frontiers in Plant Science*, 13, 936991. Doi: https://doi.org/10.3389/fpls.2022.936991

QI, Y.; YANG, Y.; HAMADOU, A.H.; LI, B.; XU, B. (2022). Gentle debranning as a technology to reduce microbial and deoxynivalenol levels in common wheat (*Triticum aestivum* L.) and its application in milling industry. *Journal of Cereal Science*, 10, 103518, Doi: https://doi.org/10.1016/j.jcs.2022.103518

RUMLER, R.; BENDER, D.; SCHOENLECHNER, R. (2023). Mitigating the Effect of Climate Change within the Cereal Sector: Improving Rheological and Baking Properties of Strong Gluten Wheat Doughs by Blending with Specialty Grains. *Plants*, 12, 492. Doi: https://doi.org/10.3390/plants12030492

SANDU, I.; MATEESCU, E. (2014). Schimbări Climatice Actuale și Previzibile în România. Schimbări Climatice—Provocare Majoră pentru Cercetarea Agricolă [Current and predictable climate change in Romania. Climate change—A Major Challenge for Agricultural Research]. *Academia Româna—Secția de Științe Agricole și Silvice*: Editura Academiei Române, România, 17–36. ISBN 978-973-27-2421-7

SAVI, G.D.; PIACENTINI, K.C.; TIBOLA, C.S.; SANTOS, K.; MARIA, G.S; SCUSSEL, V.M. (2016). Deoxynivalenol in the wheat milling process and wheat- based products and daily intake estimates for the Southern Brazilian population. *Food Control*, 62, 231–236. Doi: https://doi.org/10.1016/j.foodcont.2015.10.029

SCHAARSCHMIDT, S.; FAUHL-HASSEK, C. (2018). The fate of mycotoxins during the processing of wheat for human consumption. *Comprehensive Reviews in Food Science and Food Safety*, 17, 3, 556-593. Doi: https://doi.org/10.1111/1541-4337.12338

SCHATZMAYR, G.; STREIT, E. (2013). Global occurrence of mycotoxins in the food and feed chain: Facts and figures. *World Mycotoxin Journal*, 6, 213–222. Doi : https://doi.org/10.3920/WMJ2013.1572

SENAPATI, N.; HALFORD, N.G.; SEMENOV, M.A. (2021). Vulnerability of European wheat to extreme heat and drought around flowering under future climate. *Environmental Research Letters*, 16, 024052, Doi:10.1088/1748-9326/abdcf3

SHAH, L.; ALI, A.; YAHYA, M.; ZHU, Y.; WANG, S.; SI, H.; RAHMAN, H.; MA, C. (2017). Integrated control of Fusarium head blight and deoxynivalenol mycotoxin in wheat. Review. *Plant Pathology*, 67, 3, 532-548. Doi: https://doi.org/10.1111/ppa.12785

SINGH, S.; SINGH, N. (2010). Effect of debranning on the physico-chemical, cooking, pasting and textural properties of common and durum wheat varieties. *Food Research International*, 43, 2277-2283. Doi: https://doi.org/10.1016/j.foodres.2010.07.016

SIUDA, R.; GRABOWSKI, A.; LENC, L.; RALCEWICZ, M.; SPYCHAJ-FABISIAK, E. (2010). Influence of the degree of fusariosis on technological traits of wheat grain. *International Journal of Food Science & Technology*, 45, 2596–2604. Doi: https://doi.org/10.1111/j.1365-2621.2010.02438.x
Siuda et al., 2010

SPINONI, J.; NAUMANN, G.; VOGT, J.; BARBOSA, P. (2015). European drought climatologies and trends based on a multi-indicator approach. *Global and Planetary Change*, 127, 50–57. Doi: 10.1016/j.gloplacha.2015.01.012

TAMBA-BEREHOIU, R.M.; POPA, C.N.; POPESCU, S.; SUCIU, A. (2012). The effect of the *Fusarium* sp. attack on the quality parameters of Romanian wheat. *Scientific Bulletin Series F. Biotechnologies*, 16, 73–76. http://biotechnologyjournal.usamv.ro/index.php/scientific-papers/88-art13

TIBOLA, C. S.; GUARIENTI, E. M.; GUERRA DIAS, A. R.; NICOLAU, M.; BARBOZA DEVOS, R. J.; DALBOSCO TEIXEIRA, D. (2019). Effect of debranning process on deoxynivalenol content in whole-wheat flours. *Cereal Chemistry*, 96, 4, 717-724. Doi: https://doi.org/10.1002/cche.10168

TIBOLA, C.S.; CUNHA FERNANDES, J.M.; GUARIENTI, E.M. (2016). Effect of cleaning, sorting and milling processes in wheat mycotoxin content. *Food Control*, 60, 174–179. Doi: https://doi.org/10.1016/j.foodcont.2015.07.031

TIBOLA, C.S.; CUNHA FERNANDES, J.M.; GUARIENTI, E.M.; NICOLAU, M. (2015). Distribution of *Fusarium* mycotoxins in wheat milling process. *Food Control*, 53, 91-95. Doi: https://doi.org/10.1016/j.foodcont.2015.01.012

TOMA, E.; DACHIN, A.; AILENEI, D.; ANGELESCU, C.; HURU, D.; MOLĂNESCU, G.; SOCOL, C.; SOCOL, A. (2010). Agricultura României în procesul de integrare europeană: evaluări şi prognoze [Romania's agriculture in the process of European integration: evaluations and forecasts]. *Editura Ars Academica*, Bucureşti, 110 pp. ISBN: 978-606-8017-55-6. Available from: https://www.researchgate.net/publication/235988280_Agricultura_Romaniei_in_procesul_de_integrare_europeana_vol_I

VAN DER FELS-KLERX, H.J.; KLEMSDAL, S.; HIETANIEMI, V.; LINDBLAD, M.; IOANNOU-KAKOURI, E.; VAN ASSELT, E.D. (2012). Mycotoxin contamination of cereal grain commodities in relation to climate in North West Europe. *Food Additives & Contaminants Part A*, 29, 10, 581-592. Doi: 10.1080/19440049.2012.689996

ZAHRA, N.; HAFEEZ, M.B.; WAHID, A.; AL MASRURI, M.H.; ULLAH, A.; SIDDIQUE, K.H.M.; FAROOQ, M. (2023). Impact of climate change on wheat grain composition and quality. *Journal of the Science of Food and Agriculture*, 103, 6, 2745-2751. Doi: 10.1002/jsfa.12289

ZHANG, C.; ZHUANG, K.; CHEN, L.; DING, W.; CHEN, X.; SHAO, L.; WANG, G.; WANG, Y. (2022). Reducing deoxynivalenol content in wheat by a combination of gravity separation and milling and characterization of the flours produced. *Journal of Cereal Science*, 104, 103372. Doi: https://doi.org/10.1016/j.jcs.2021.103372

WORLD BANK GROUP–CLIMATE CHANGE KNOWLEDGE PORTAL (WBG-CCKP) (2021**).** *Climate change knowledge portal for development practitioners and policymakers***.** Download Data. Available from: https://climateknowledgeportal.worldbank.org/download-data

WORLD BANK (WB) (2010). World Development Report 2010: Development and Climate Change. *The International Bank for Reconstruction and Development*, Washington DC, USA, 439 pp. Doi:10.1596/978-0-8213-7989-5

WORLD GRAIN (WG) (2023). Companies in milling equipment. Manufacturers Directory. 2023 *Sosland Publishing Company*. https://www.world-grain.com/directories/1441-manufacturers-directory/topic/1472-milling-equipment