

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

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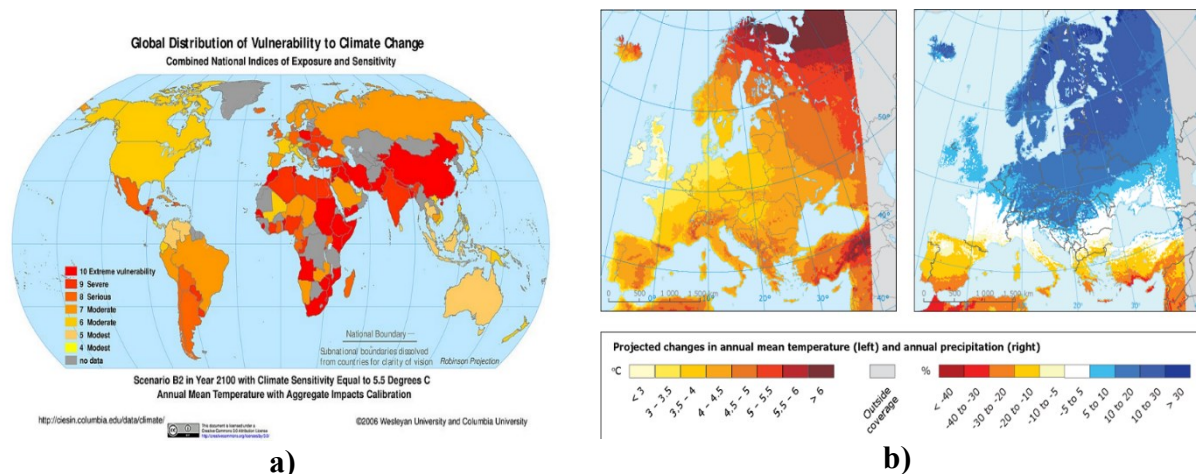
**Abstract.** Climate change affects the quantity and quality of wheat harvests with effects on food safety and security. Consequently, companies must develop and implement appropriate strategies, starting with the acquisition of grains and continuing with the reception, milling of grains and processing 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).

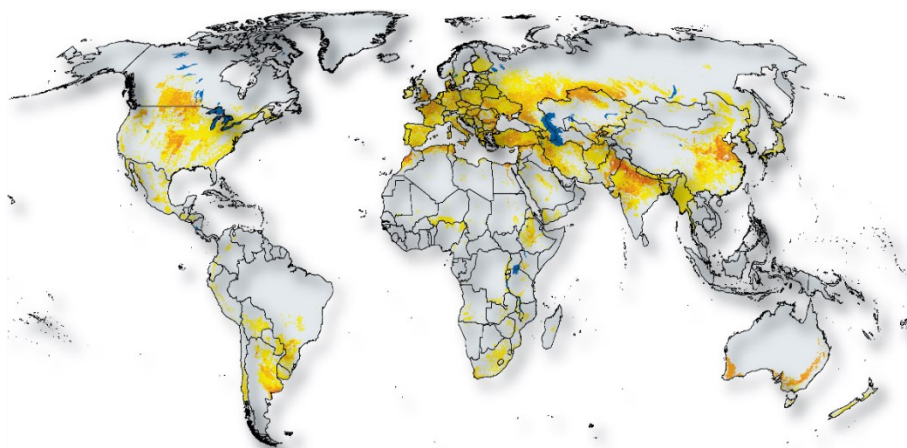
Commercial globalization requires the assessment of the risk of mycotoxin contamination of cereals, food and feed, depending on the geographical areas of origin, characterized by different agroclimatic conditions. Forecasts at the global level have suggested that there will be "hot spots" where the temperature will increase by 2–5<sup>0</sup>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<sup>0</sup>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<sup>0</sup>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).



**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; Gagliu 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

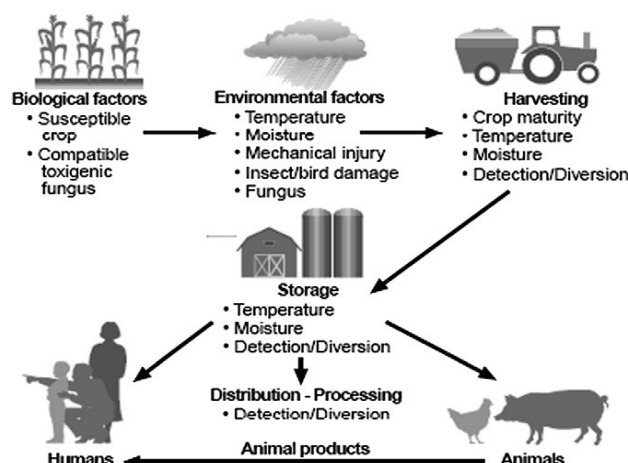
2007 (Toma et al., 2010; Feher et al., 2017; Ivaşcu & Dănuleşiu, 2021; FAO, 2023; Gagliu et al., 2023). Within 2008 to 2021, the average values of wheat yield in Romania varied yearly from 1.610 to 4.891 t/ha, with a mean value of 3566 t/ha during these thirteen years (FAO, 2023; Gagliu et al., 2023). 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; Gagliu 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; Gagliu 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; Gagliu 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 (debranning 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; Gagliu 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 (Gagliu 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; Gagliu 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.

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