Chapter 16

Effect of *Fusarium* spp. Contamination on Baking Quality of Wheat

Ivana Capouchová, Ludmila Papoušková,
Petr Konvalina, Zdenka Vepříková, Václav Dvořáček,
Monika Zrcková, Dagmar Janovská,
Alena Škeříková and Kateřina Pazderů

Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/67657

Abstract

The effect of *Fusarium* spp. contamination on baking quality of winter common wheat and spelt wheat from different growing systems (organic and conventional) was evaluated by the standard technological quality characteristics and by the rheological system Mixolab. The content of *Fusarium* spp. mycotoxins [deoxynivalenol (DON), deoxynivalenol-3-β-D-glucoside (D3G), 3-acetyldeoxynivalenol (3-ADON), and Zearalenones (ZON)] was determined too. Significantly worse standard technological quality parameters and rheological parameters were determined for artificially inoculated variants of both evaluated wheat species. Statistically significant negative correlation coefficients were discovered between content of mycotoxins and many of technological characteristics, for example, DON content and Zeleny sedimentation for common wheat and spelt (−0.60*; −0.66*) and also between DON content and volume weight (−0.63*; −0.95**) for both wheat species. Resulted Mixolab parameters confirmed that *Fusarium* spp. infection worsens both protein and starch characteristics for both wheat species. However, effect of *Fusarium* spp. contamination in spelt wheat was generally less pronounced in comparison with common wheat. Despite of visible shifts of Mixolab curves of samples from organic and conventional growing systems, resulted Mixolab characteristics were statistically comparable.

Keywords: common wheat, spelt wheat, *Fusarium* spp. contamination, mycotoxins, baking quality, organic and conventional growing systems

1. Introduction

Fusarium head blight (FHB) is a fungal disease of small grain cereals caused by pathogen fungi *Fusarium* spp. and has become a serious danger to the worldwide grain industry. Under favourable weather conditions (moist, warm conditions during flowering), the *Fusarium* spores are spread by wind to cereal spikelet, and then, infection expands within the whole ears. This infection can result in the yield loss and reduction of end-use quality [1]. The most important *Fusarium* species is *Fusarium graminearum* that destroys starch granules, storage proteins, and cell walls and subsequently affects the quality of dough properties [2]. FHB also leads to the accumulation of mycotoxins, which are very stable low-molecular secondary metabolites produced during the fungal infection process [3]. Despite the contradictory reports in the literature concerning the close correlations between FHB and mycotoxins content, it is accepted that overall accumulation of mycotoxins in kernel also would require successful infection and colonization stages of host [4]. Moreover, in the case of very strong infectious pressure, induced by artificial inoculation, it is possible to presume that also content of mycotoxins will be high.

The largest group of *Fusarium* mycotoxins is composed of trichothecenes, which are divided into four groups (types A–D) according to their characteristic functional groups, being the types A and B, the most common. Type A is represented by HT-2 toxin (HT-2) and T-2 toxin (T2), while type B includes nivalenol (NIV), deoxynivalenol (DON), fusarenon-X (FUS-X), 15-acetyldeoxynivalenol (15-AcDON), and 3-acetyldeoxynivalenol (3-AcDON), but the most important is DON. Zearalenones (ZONs)—oestrogenic mycotoxins—cover ZON and its metabolites: a-zearalenol (a-ZOL) and b-zearalenol (b-ZOL) [5].

Regarding huge consumption of cereal product understanding of *Fusarium* infestation impacts not only on health but also on grain properties is essential. The negative effects on baking quality of wheat were already found [6, 7]. Knowledge of the rheological properties of flour is fundamental for specifying baking parameters. Different rheological analyses, for example, farinograph, extensograph, amylograph, or mixograph, are used to evaluate baking properties of cereals [8]. However, these methods evaluate only protein or starch characteristics so lately, the new apparatus Mixolab has been developed and was accepted as the International Association for Cereal Science and Technology (ICC) standard method N°173. This system enables to evaluate physical dough properties such as dough stability or weakening and starch characteristics in one measurement by intense mixing and controlled heating of the kneader to 90°C and ensuing cooling to 50°C [9]. Important researches of predicting the bread and cookie baking quality of different wheat flours were carried out [10, 11]. Reports of efficiency of Mixolab to predict baking quality of various wheat genotypes are verified by significant correlation between some Mixolab and rheological parameters, for example, Zeleny sedimentation and loaf volume [12, 13].

By this time, there are not many studies about a capability of Mixolab to predict rheological parameters of common wheat with various grade of fungi infestation [6]; studies about a capability of Mixolab to predict rheological parameters of other wheat species with various grade of fungi infestation are almost not available.

http://dx.doi.org/10.5772/67657

The study was focused on the detection of baking quality changes in common wheat and spelt wheat with a different grade of *Fusarium* spp. contamination, using standard methods for technological quality determination and rheological evaluation by the system Mixolab.

2. Methodology

2.1. Field experiments

Two winter common wheat cultivars (Bohemia and Darwin, both quality group A) and two winter spelt wheat cultivars (Ceralio and Rubiota) from the exact field plot trials, conducted in the years 2010/2011 and 2011–2012 at the experimental station of the Czech University of Life Sciences in Prague (295 m above sea level, average annual temperature 8.4°C, average sum of precipitation 575 mm), were used for the evaluation of the effect of FHB infestation on the *Fusarium* mycotoxins [DON, deoxynivalenol-3-β-D-glucoside (D3G), 3-acetyldeoxynivalenol (3-ADON) and ZON] content in grain, standard technological quality parameters of grain, and rheological parameters of dough. Field plot trials were carried out by the method of randomized blocks in three replications; an average size of experimental plot was 12 m^2. Exact field experiments were conducted in an organic farming system on experimental area, certified for organic farming and in comparison also in usual conventional system, using herbicide treatment and nitrogen fertilization −120 kg N ha^{-1}, applied in two doses −60 kg N ha^{-1} after wheat overwintering, 60 kg N ha^{-1} at the beginning of shooting. Treatments with natural *Fusarium* spp. contamination were evaluated in both growing systems; to ensure a higher level of *Fusarium* infestation, artificial inoculation of flowering ears was used too.

2.2. Artificial inoculation

The isolates of *Fusarium culmorum* and *F. graminearum* used for the artificial inoculation were obtained from the mycological collection of the Crop Research Institute in Prague and cultivated on sterile wheat grains. Wheat grains with the cultures of *F. culmorum* and *F. graminearum* were put into a vessel with water and shaken for 15 min in a laboratory shaker to release the spores into water. The obtained suspension was filtered through the gauze. Then, artificial inoculation was made using the suspension of *F. culmorum* and *F. graminearum* spores in the ratio of 1:1, 10^7 of spores ml^{-1} (Bürker chamber was used for the verification of inoculums density), 2 l of suspension per experimental plot (12 m^2). The suspension was dosed with a hand sprayer at the beginning of the wheat flowering [14]. Harvested grain samples were used for *Fusarium* mycotoxins determination.

2.3. *Fusarium* mycotoxins determination

A modified QuEChERS (quick, easy, cheap, effective, rugged, and safe) procedure was used for the isolation of analytes from the wheat grain. It is the multiresidue determination of wide range of mycotoxins applicable within different matrices (cereals, feed, and others), based on the extraction of analytes with acetonitrile; water and further purification of the extracts consists of the division between the two phases by means of inorganic salts (NaCl, $MgSO_4$). Analytes

were transported into the upper acetonitrile layer, while the polar co-extract matrix (e.g. sugars or amino acids) remained in the aqueous phase [15]. The ultra-high performance liquid chromatograph Acquity UPLC System (Waters, USA), coupled with the tandem mass spectrometer LCT Premier XE (Waters, USA) with analyzer time-of-flight MS (TOFMS) was used for the identification and detection of analytes. Wider scale of *Fusarium* mycotoxins was determined—deoxynivalenol (DON) and its conjugated forms, zearalenone (ZON) and its metabolites, enniatins, and so forth, but some of them only in trace amount. Only the mycotoxins, which were detected most frequently in our wheat grain samples—DON, deoxynivalenol-3-β-D-glucoside (D3G), 3-acetyldeoxynivalenol (3-ADON), and ZON—are presented in this study.

2.4. Standard technological quality parameters

Crude protein content (CP) in grain dry matter according to the Kjeldahl method (EN ISO 20483; ICC-Standard No. 105/2), wet gluten content (WG) in grain dry matter and gluten index (GI) using the apparatus Glutomatic Perten (ISO 5531), falling number (FN)—ISO 3093, sedimentation index—Zeleny test (ZS)—ISO 5529, volume weigh (VW)—ISO7971-2, and TKW (thousand kernels weight) were determined with the frame of the baking quality.

2.5. Rheological characteristics

Protein and starch characteristics of the wheat flour (dough development, protein weakening, starch gelatinization, diastatics activity, and anti-stalling effect) were determined by the apparatus Mixolab (Chopin, Tripette et Renaud, Paris, France) according to the Mixolab protocol Chopin+ [16]. Evaluated flour was obtained by milling the cereal grain samples on a Bühler mill automat MLU 202.

A typical Mixolab curve, which is shown in **Figure 1**, is separated to the five stages represented by five (C1–C5) points [16].

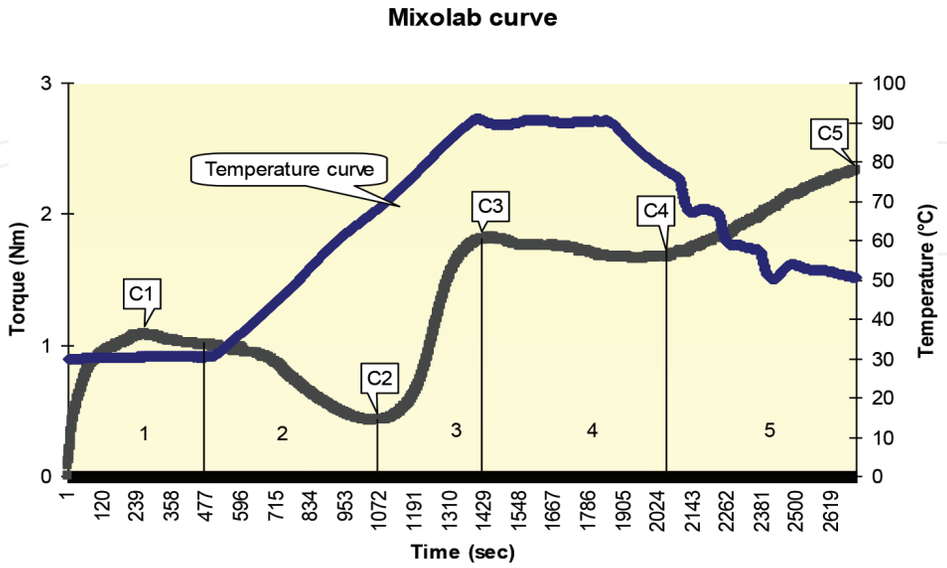

Figure 1. Standard Mixolab curve.

The two first stages of the Mixolab curve correspond to the rheological characteristics of proteins—stability, elasticity, and water absorption, whereas the other stages relate mainly to the starch and amylolytic activity. Evaluated characteristics from measured Mixolab curve are C1 (Nm) marks maximum torque during mixing, used to determine water absorption; C1 (min) time required to achieve the maximum torque; C2 (Nm) measures the weakening of the protein based on the mechanical work and the increasing temperature; C3 (Nm) indicates the rate of starch gelatinization; C4 (Nm) represents the stability of the hot-formed gel; C5 (Nm) expresses starch retrogradation during the cooling period; difference C1–C2 represents the protein network strength under the increasing heating; difference C3–C4 shows diastatic activity and relates with falling number; difference C5–C4 correlates with the anti-stalling effects, represents the shelf life of end products; and DS indicates the stability of the dough before weakening [16].

Results were statistically evaluated by the analysis of variance (ANOVA) and correlation analysis with the statistical significance expression on the level $\alpha = 0.05$ and $\alpha = 0.01$ in the "Statistica 9.0 CZ".

3. Results

3.1. Content of mycotoxins and standard technological quality parameters

An average content of evaluated *Fusarium* mycotoxins in grain is summarized in **Table 1**. Our results show significant differences in evaluated mycotoxins content between variants with natural contamination and artificial *Fusarium* spp. inoculation; on the other hand, differences between organic and conventional growing systems were statistically insignificant. Content of deoxynivalenol (DON) in grain was several times higher than content of other evaluated mycotoxins for both wheat species. Content of mycotoxins in *Triticum aestivum* grain was generally higher in comparison with grain of *Triticum spelta*.

Significant decrease of volume weight and thousand kernels weight but increase of protein and wet gluten content was observed in artificially inoculated variants for both wheat species—higher protein content in smaller grain is expectable. At the same time, general reductions of Zeleny sedimentation and gluten index in artificially inoculated variants were observed (**Table 2**). Similar situation—decreased falling number values were determined in artificially inoculated variants too.

Above mentioned findings were also confirmed by determined correlations between mycotoxins content and evaluated technological parameters (**Table 3**). Negative correlation coefficients were found between content of mycotoxins and most of the technological parameters for both wheat species. The most evident negative effect of mycotoxins content was seen on VW and TKW for the spelt wheat (correlation: −0.95**; −0.97**). On the other hand, positive correlation coefficients were found between content of mycotoxins, crude protein content, and wet gluten content in grain.

Treatment	Growing system	DON (μg kg^{-1})	D3G (μg kg^{-1})	3-ADON (μg kg^{-1})	ZON (μg kg^{-1})
Triticum aestivum L.					
Artificial inoculation	Organic	19411.1^{b}	2704.6^{b}	472.3^{ab}	2965.3^{b}
	Conventional	26729.4^{b}	4141.3^{b}	1051.9^{b}	3191.4^{b}
Natural contamination	Organic	304.7^{a}	153.8^{a}	7.5^{a}	19.0^{a}
	Conventional	257.5^{a}	66.5^{a}	7.5^{a}	22.3^{a}
Triticum spelta L.					
Artificial inoculation	Organic	12648.7^{b}	2154.5^{b}	149.8^{b}	117.1^{b}
	Conventional	14433.7^{b}	2797.8^{b}	169.8^{b}	237.0^{b}
Natural contamination	Organic	25.6^{a}	22.6^{a}	7.5^{a}	4.0^{a}
	Conventional	260.1^{a}	142.4^{a}	7.5^{a}	7.1^{a}

Values with different letter combinations are statistically significant at $p \leq 0.05$; DON—deoxynivalenol; D3G—deoxynivalenol-3-β-D-glucoside; ZON—zearalenone; 3-ADON—3-acetyldeoxynivalenol.

Table 1. Content of mycotoxins in the wheat grain of evaluated wheat species (average data of both cultivars).

Treatment	Growing system	CP (%)	WG (%)	GI	ZS (ml)	FN (s)	VW (kg hl^{-1})	TKW (g)
Triticum aestivum L.								
Artificial inoculation	Organic	13.7^{ab}	30.0^{a}	42.0^{a}	34.0^{a}	250.5^{a}	50.4^{a}	23.9^{a}
	Conventional	14.1^{b}	32.5^{a}	58.5^{ab}	33.1^{a}	259.3^{ab}	47.2^{a}	22.4^{a}
Natural contamination	Organic	12.0^{a}	26.1^{a}	88.3^{b}	49.3^{b}	283.8^{b}	72.8^{b}	47.3^{b}
	Conventional	12.5^{ab}	27.3^{a}	83.8^{b}	54.8^{b}	279.8^{b}	74.1^{b}	49.5^{b}
Triticum spelta L.								
Artificial inoculation	Organic	19.6^{b}	52.5^{a}	24.5^{a}	25.7^{a}	307.0^{a}	54.1^{a}	22.1^{a}
	Conventional	20.6^{b}	53.2^{a}	21.0^{a}	27.1^{a}	321.0^{a}	50.1^{a}	20.9^{a}
Natural contamination	Organic	16.7^{a}	49.1^{a}	38.0^{a}	39.1^{b}	343.0^{a}	73.0^{b}	40.9^{b}
	Conventional	18.8^{ab}	52.8^{a}	33.0^{a}	34.7^{b}	313.5^{a}	74.0^{b}	41.2^{b}

Values with different letter combinations are statistically significant at $p \leq 0.05$; CP—crude protein content in grain dry matter; WG—wet gluten content in grain dry matter; GI—gluten index; ZS—Zeleny sedimentation; FN—falling number; VW—volume weight; TKW—thousand kernels weight.

Table 2. Technological quality parameters of evaluated wheat species (average data of both cultivars).

3.2. Mixolab

3.2.1. Triticum aestivum L.

Resulted common wheat Mixolab parameters confirmed that *Fusarium* spp. infection markedly worsenes both protein and starch characteristics (**Table 4**). Average value of C2, which positively correlates with dough strength, was more than half lower after *Fusarium* spp.

	DON (μg kg^{-1})	D3G (μg kg^{-1})	3-ADON (μg kg^{-1})	ZON (μg kg^{-1})
Triticum aestivum L.				
CP (%)	0.48	0.37	0.44	0.22
WG (%)	0.30	0.21	0.27	0.06
GI	−0.26	−0.36	−0.15	−0.14
ZS (ml)	−0.60*	−0.75**	−0.58*	−0.64*
FN (s)	−0.53*	−0.56*	−0.56*	−0.64*
VW (kg hl^{-1})	−0.63*	−0.71*	−0.56*	−0.47
TKW (g)	−0.61*	−0.70*	−0.55*	−0.45
Triticum spelta L.				
CP (%)	0.69*	0.64*	0.64*	0.35
WG (%)	0.18	0.18	0.22	0.17
GI	−0.66*	−0.66*	−0.68*	−0.51
ZS (ml)	−0.68*	−0.78*	−0.77**	−0.72*
FN (s)	−0.11	−0.27	−0.27	−0.50
VW (kg hl^{-1})	−0.95**	−0.88**	−0.88**	−0.48
TKW (g)	−0.97**	−0.92**	−0.93**	−0.54

Statistically significant for $p \leq 0.05^{(*)}$ and for $p \leq 0.01^{(**)}$.

DON—deoxynivalenol; D3G—deoxynivalenol-3-β-D-glucoside; ZON—zearalenon; 3-ADON—3-acetyldeoxynivalenol; CP—crude protein content in grain dry matter; WG—wet gluten content in grain dry matter; GI—gluten index; ZS—Zeleny sedimentation; FN—falling number; VW—volume weight; TKW—thousand kernels weight.

Table 3. Correlation between mycotoxins content and technological parameters of evaluated wheat species.

Treatment	Growing system	C1 (min)	C2 (Nm)	C3 (Nm)	C4 (Nm)	C5 (Nm)
Artificial inoculation	Organic	2.40^{a}	0.18^{a}	2.04^{a}	1.66^{a}	2.12^{a}
	Conventional	1.77^{a}	0.15^{a}	1.99^{a}	1.70^{a}	2.28^{a}
Natural contamination	Organic	3.21^{a}	0.44^{b}	2.66^{b}	1.96^{a}	2.50^{a}
	Conventional	3.00^{a}	0.40^{b}	2.63^{b}	1.97^{a}	2.59^{a}
Treatment	Growing system	C1C2 (Nm)	C3C4 (Nm)	C5C4 (Nm)	DS (min)	
Artificial inoculation	Organic	0.90^{b}	0.38^{a}	0.46^{a}	6.3^{a}	
	Conventional	0.93^{b}	0.29^{a}	0.57^{a}	5.0^{a}	
Natural contamination	Organic	0.69^{a}	0.66^{b}	0.54^{a}	9.9^{b}	
	Conventional	0.74^{a}	0.70^{b}	0.62^{a}	9.5^{b}	

Values with different letter combinations are statistically significant at $p \leq 0.05$; C1—time required for maximum torque during mixing; C2—protein weakening; C3—starch gelatinization; C4—stability of gel; C5—starch retrogradation; C1C2—fall of protein strength; C3C4—diastatic activity; C5C4—anti-stalling effect; DS—time of dough stability before weakening.

Table 4. Mixolab characteristics of *Triticum aestivum* L. (average data of both cultivars).

inoculation for both growing systems. Therefore, higher rate of protein thermal weakening (C1C2) and visible shorter time of dough stability were found for inoculated variants.

It is evident from **Figure 2** that the inferior effect of infection on protein part of curve is especially obvious for variety Bohemia in 2011, where after dough development, there is rapid fall of the curve which implies low quality of gluten.

Dough heating and thus swelling of starch granules and increasing viscosity cause the increase of the curve—point C3. It was evident from our results that values of artificially inoculated variants were markedly lower than values of variants with natural *Fusarium* spp. contamination. Supposedly, this is due to damaged starch granules of inoculated variants. There was no statistical difference between organic and conventional growing systems. Although C5 parameters in the last section of the curve were slightly higher for naturally contamined variants than for inoculated variants, differences C5C4 representing retrogradation and consequently shelf life of end products were statistically comparable (**Table 4**).

Deteriorated rheological quality of inoculated variants was also confirmed by rated strong negative correlation coefficients between mycotoxins content and Mixolab parameters (**Table 5**).

3.2.2. Triticum spelta L

Final Mixolab characteristics of *T. spelta* L. (**Table 6**) imply slightly better resistance to *Fusarium* spp. infection compare to the reaction of *T. aestivum* variants. It is evident especially in case of Mixolab characteristics, representing protein part of curve (values of C2 and C1–C2).

Average value of C2, which represents the weakening of the protein, was lower in artificially inoculated variants for both wheat species, but in spelt, the difference between naturally contamined and artificially inoculated variants was not so high. At the same time, higher rate of protein thermal weakening (C1C2) and thus shorter time of dough stability were found in

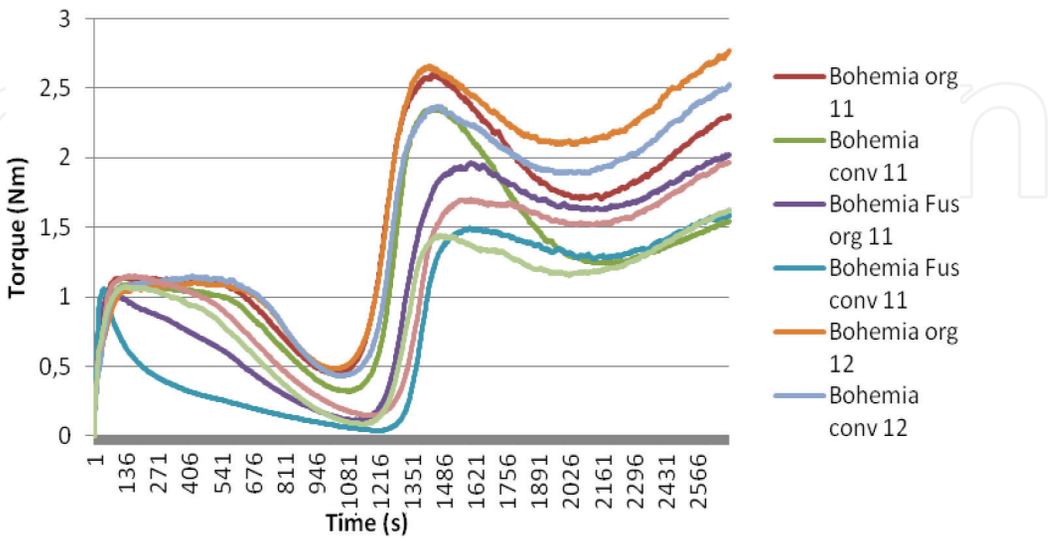

Figure 2. An example of Mixolab curve—common wheat cultivar Bohemia.

	DON (μg kg^{-1})	D3G (μg kg^{-1})	3-ADON (μg kg^{-1})	ZON (μg kg^{-1})
C1 (min)	−0.38	−0.40	−0.36	−0.36
C2 (Nm)	−0.82**	−0.85**	−0.77**	−0.67*
C3 (Nm)	−0.74**	−0.66*	−0.72*	−0.54*
C4 (Nm)	−0.50*	−0.40	−0.50*	−0.35
C5 (Nm)	−0.43	−0.35	−0.44	−0.31
C1–C2 (Nm)	0.73**	0.74**	0.69*	0.56*
C3–C4 (Nm)	−0.49	−0.52*	−0.45	−0.38
C5–C4 (Nm)	−0.22	−0.20	−0.26	−0.18
DS (min)	−0.89**	−0.93**	−0.90**	−0.89**

Statistically significant for $p \leq 0.05^{(*)}$ and for $p \leq 0.01^{(**)}$; DON—deoxynivalenol; D3G—deoxynivalenol-3-β-D-glucoside; ZON—zearalenone; 3-ADON—3-acetyldeoxynivalenol; C1—time required for max. torque during mixing; C2—protein weakening; C3—starch gelatinization; C4—gel stability; C5—starch retrogradation; C1C2—fall of protein strength; C3C4—diastatic activity; C5C4—anti-stalling effect; DS—dough stability time.

Table 5. Correlation between Mixolab parameters and mycotoxins content for *Triticum aestivum* L. in both growing systems.

inoculated variants for both wheat species, but in spelt, the difference between naturally contamined and artificially inoculated variants was slightly lower compared to common wheat.

Correlation between Mixolab parameters and mycotoxins content for *T. spelta* shows **Table 7**. Although there was a deflection of inoculated variants particularly evident for parameters C2 and C1–C2, affirmed by significant negative correlation between mycotoxins content and C2

Treatment	Growing system	C1 (min)	C2 (Nm)	C3 (Nm)	C4 (Nm)	C5 (Nm)
Artificial inoculation	Organic	5.12^{a}	0.14^{a}	1.64^{a}	1.25^{a}	1.83^{a}
	Conventional	4.20^{a}	0.14^{a}	1.65^{a}	1.33^{a}	1.89^{a}
Natural contamination	Organic	4.82^{a}	0.30^{b}	2.33^{b}	1.10^{a}	1.70^{a}
	Conventional	3.72^{a}	0.28^{b}	1.78^{a}	0.85^{a}	1.30^{a}
Treatment	Growing system	C1C2 (Nm)	C3C4 (Nm)	C5C4 (Nm)	DS (min)	
Artificial inoculation	Organic	0.97^{a}	0.39^{a}	0.58^{a}	6.3^{c}	
	Conventional	0.95^{a}	0.32^{a}	0.56^{a}	4.3^{a}	
Natural contamination	Organic	0.83^{b}	1.23^{b}	0.60^{a}	6.0^{bc}	
	Conventional	0.83^{b}	0.93^{b}	0.45^{a}	4.9^{ab}	

Values with different letter combinations are statistically significant at $p \leq 0.05$; C1—time required for max. torque during mixing; C2—protein weakening; C3—starch gelatinization; C4—stability of gel; C5—starch retrogradation; C1C2—fall of protein strength; C3C4—diastatic activity; C5C4—anti-stalling effect; DS—dough stability time.

Table 6. Mixolab characteristics of *Triticum spelta* L. (average data of both cultivars).

	DON (μg kg^{-1})	D3G (μg kg^{-1})	3-ADON (μg kg^{-1})	ZON (μg kg^{-1})
C1 (min)	0.18	0.12	0,20	0,02
C2 (Nm)	−0.94**	−0.92**	−0.90**	−0.56*
C3 (Nm)	−0.69*	−0.68*	−0.66*	−0.40
C4 (Nm)	0.28	0.25	0.30	0.19
C5 (Nm)	0.19	0.17	0.22	0.13
C1–C2 (Nm)	0.94**	0.90**	0.91**	0.54*
C3–C4 (Nm)	−0.51	−0.49	−0.52	−0.32
C5–C4 (Nm)	0.05	0.03	0.08	0.03
DS (min)	−0.13	−0.21	−0.11	−0.27

Statistically significant for $p \leq 0.05^{(*)}$ and for $p \leq 0.01^{(**)}$; DON—deoxynivalenol; D3G—deoxynivalenol-3-β-D-glucoside; ZON—zearalenone; 3-ADON—3-acetyldeoxynivalenol; C1—time for maximum torque during mixing; C2—protein weakening; C3—starch gelatinization; C4—gel stability; C5—starch retrogradation; C1C2—fall of protein strength; C3C4—diastatic activity; C5C4—anti-stalling effect; DS—dough stability before weakening.

Table 7. Correlation between Mixolab parameters and mycotoxins content for *Triticum spelta* L. in both growing systems.

and C1–C2 values, generally *Fusarium* effect was less pronounced in comparison with common wheat.

It is evident from **Figure 3** that despite the shifts of individual curves for variety Ceralio, majority of resulting Mixolab parameters for various type of treatment were statistically insignificant. Just characteristics C2 and dough stability for the control from organic treatment were preferable to the conventional variant.

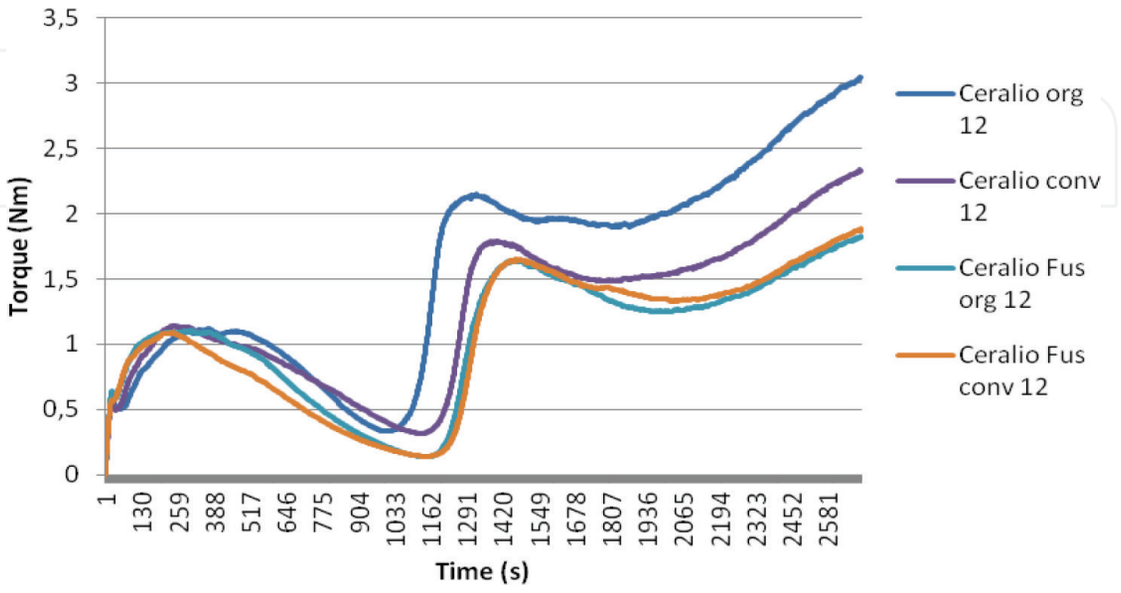

Figure 3. An example of Mixolab curve—spelt wheat cultivar Ceralio.

http://dx.doi.org/10.5772/67657

4. Discussion

4.1. Content of mycotoxins and standard technological quality parameters

There are contradictory reports on the relationship between the *Fusarium* infection grade and content of mycotoxins in the cereals grain. Some authors did not confirm positive correlation between the infection grade and DON content [17, 18], while others found a high-positive significant correlation [19]. Despite relationship between the *Fusarium* spp. infection grade and mycotoxins content does not have to be too close [18], in the case of a strong infection pressure evoked by artificial inoculation, it is possible to suppose also high mycotoxins content [4, 14–20]. This observation is in accordance with our results, which show significant differences in evaluated mycotoxins content between variants with natural contamination and artificial *Fusarium* spp. inoculation. Differences between organic and conventional growing systems were statistically insignificant, which indicates low dependence of *Fusarium* spp. infestation on cropping system (in the case when fungicidal treatment against FHB was not used). Our results also confirmed, in accordance to [5], that DON was the most occurred *Fusarium* mycotoxin for both evaluated wheat species. According to findings of [21], DON is the most frequent *Fusarium* mycotoxin even in the rye grain.

Several authors mentioned negative effects of *Fusarium* spp. infection on baking quality of wheat [6–22]. On the other hand, there are some contradictory studies where a strong *Fusarium* spp. contamination did not significantly influence the bread making properties [23, 24]. Some authors mentioned an increase of protein content of the wheat grain after the *Fusarium* spp. contamination [25], others mentioned slight decrease of it [2, 6] and [26] concluded that the crude protein content in the wheat grain was not affected by the *F. culmorum* infection. In our case, increase of protein and wet gluten content occurred in artificially inoculated variants. This fact is probably connected with low TKW and volume weight of artificially inocluated variants—in the case of small grains, we can presuppose higher protein concentration.

Zeleny sedimentation index and gluten index measure swelling potential of kernel protein. At the same time, general reductions of Zeleny sedimentation and gluten index in artificially inoculated variants were observed. This indicates that *Fusarium* spp. infection may alter protein quality in grain, in accordance with findings of [6, 14–25].

Decrease of falling number value in artificially inoculated variants was observed too. According to Refs. [27] and [14], fungal infection is expected to increase the degradation of starch due to the activity of enzymes as α—amylase in kernels, which is measurable by means of falling number.

Our results showed negative correlation between content of the most mycotoxins and technological quality parameters for both wheat species. The most evident negative effect of mycotoxins content was seen on volume weight and thousand kernels weight. These results are in accordance with [28]—these authors mentioned that FHB can lead to the production of small-sized grains.

4.2. Mixolab

Mixolab parameters show, based on the results published up to now, high compatibility with standard rheological analysis (for example, farinograph, extensograph, or amylograph).

Consequently, it is possible to anticipate a potential prediction of bread making quality of wheat from these parameters [10]. But there are not many studies on the efficiency of this Mixolab system to predict rheological parameters of wheat with changed characteristics caused by fungi species, which have become a serious problem in the wheat cultivation during recent years.

4.2.1. Triticum aestivum L

Some authors [14, 17–20] mentioned that *Fusarium* spp. infection markedly worsens both protein and starch characteristics. Also in our case, average value of C2, which positively correlates with dough strength, was, in accordance with findings of [29], more than half lower after *Fusarium* spp. inoculation for both variants of growing system. Therefore, higher rate of protein thermal weakening (C1C2) and visible shorter time of dough stability were found for these inoculated variants. According to Ref. [30], dough heating and thus swelling of starch granules and increasing viscosity cause the increase of the curve—point C3. It was evident from our results that values of artificially inoculated variants were markedly lower than values of variants with natural *Fusarium* spp. contamination. Supposedly, this is due to damaged starch granules of inoculated variants. The dough with such results is usually stickier and can give a poor baking quality [31]. Mixolab characteristic C5, which represents the rate of starch retrogradation [30], was slightly lower for artificially inoculated variants and verifies the worse quality of the starch part of the wheat grain.

4.2.2. Triticum spelta L

Despite the fact that common wheat is the most widespread of all cultivated wheat species, at the present time, spelt wheat has growing popularity thanks to the nutritive and pro-health properties. The consummation of spelt products helps to reduce the cholesterol level in blood and fosters the circulatory system [32]. This wheat species has been also known for the high resistance to unsupportive environmental factors. Due to a higher stalk and hard adherent husks, spelt has poor fungal infestation in comparison with common wheat (*T. aestivum* L.) and nowadays is grown mostly by organic methods [33].

Final Mixolab characteristics of *T. spelta* L. show similar trends but imply better resistance to *Fusarium* spp. infection compare to the reaction of *T. aestivum* variants. For example, average values of C2, which represent the weakening of protein, were in spelt as same as in common wheat lower in artificially inoculated variants, but in spelt, the difference between naturally contamined and artificially inoculated variants was not so high. Slightly lesser *Fusarium* effect than common wheat showed correlation coefficients between Mixolab characteristics and mycotoxins content too. This fact was reported by Ref. [33] as well.

5. Conclusions

The negative effect of *Fusarium* spp. contamination on the baking quality of wheat (*T. aestivum* L. and *T. spelta* L.) grain and flour was confirmed not only by the standard methods for technological quality determination but also by the rheological system Mixolab. This system

reflected a good sensitivity to the quality changes evoked by *Fusarium* spp. infection. The significantly worsened rheological quality and the negative effect on the protein as well as starch part of the Mixolab curves were observed in wheat artificially inoculated by *Fusarium* spp. compared to wheat with natural *Fusarium* spp. contamination. No significant statistical differences were determined for both growing systems—organic and conventional. There were only visible contrasts between the monitored years.

Our results confirmed that some of the problems related to the rheological properties of flour during processing, which regularly occur in some years and in some areas may be caused by *Fusarium* spp. contamination. However, if the *Fusarium* spp. contamination is not too high and the content of mycotoxins in the kernels does not exceed the allowed hygienic limit, this wheat can be used (after any modification of the processing technology, if necessary).

Acknowledgements

Supported by the Ministry of Agriculture of the Czech Republic, Project NAZV QI111B154.

Author details

Ivana Capouchová[1]*, Ludmila Papoušková[2], Petr Konvalina[3], Zdenka Vepříková[4], Václav Dvořáček[2], Monika Zrcková[1], Dagmar Janovská[2], Alena Škeříková[1] and Kateřina Pazderů[1]

*Address all correspondence to: capouchova@af.czu.cz

1 Czech University of Life Sciences Prague, Czech Republic

2 Crop Research Institute Prague, Czech Republic

3 University of South Bohemia, České Budějovice, Czech Republic

4 University of Chemistry and Technology Prague, Czech Republic

References

[1] Mauler-Machnik A, Suty A. New findings on the epidemiology, importance and control of *Fusarium* ear blight on wheat. Cereal Research Communications. 1997; 25:705–709

[2] Dexter JE, Marchylo BA, Clear RM, Clarke JM. Effect of *Fusarium* head blight on semolina milling and pasta-making quality of durum wheat. Cereal Chemistry. 1997; 74:519–525. DOI: 10.1094/CCHEM.1997.74.5.519

[3] Bailey KL, Gossen BD, Gugel RK, Morrall RAA. Diseases of field crops in Canada. 3rd ed. Saskatoon: University Extension Press; 2007. 205 p.

[4] Smith KP, Evans CK, Dill-Macky R, Gustus C, Xie W, Dong Y. Host genetic effect on deoxynivalenol accumulation in *Fusarium* head blight of barley. Phytopathology. 2004; 94:766–771. DOI: 10.1094/PHYTO.2004.94.7.766

[5] Juan C, Ritieni A, Mañes J. Determination of trichothecenes and zearalenones in grain cereal, flour and bread by liquid chromatography tandem mass spectrometry. Food Chemistry. 2012; 134:2389–2397. DOI: 10.1016/j.foodchem.2012.04.051

[6] Gärtner BH, Munich M, Kleijer G, Mascher F. Characterisation of kernel resistance against *Fusarium* infection in spring wheat by baking quality and mycotoxin assessments. European Journal of Plant Pathology. 2008; 120:61–68. DOI: 10.1007/s10658-007-9198-5

[7] Nightingale MJ, Marchylo BA, Clear RM, Dexter JE, Preston KR. *Fusarium* head blight: effect of fungal proteases on wheat storage proteins. Cereal Chemistry. 1999; 76:150–158. DOI: 10.1094/CCHEM.1999.76.1.150

[8] Dobraszczyk B, Morgenstern MP. Rheology and the breadmaking process. Journal of Cereal Science. 2003; 38:229–245. DOI: 10.1016/S0733-5210(03)00059-6

[9] Rosell CM, Collar C, Haros M. Assessment of hydrocolloid on the thermomechanical properties of wheat using the Mixolab. Food Hydrocolloids. 2007; 21:452–462. DOI: 10.1016/j.foodhyd.2006.05.004

[10] Cato L, Mills C. Evaluation of the Mixolab for assessment of flour quality. Food Australia. 2008; 60:577–581

[11] Ozturk S, Kahraman K, Tiftik B, Koksel H. Predicting the cookie quality of flours by using Mixolab. European Food Research and Technology. 2008; 227:1549–1554. DOI: 10.1007/s00217-008-0879-x

[12] Hrušková M, Švec I, Jurinová I. Changes in baking quality of composite wheat/hemp flour detected by means of Mixolab. Cereal Research Communications. 2013; 41:150–159. DOI: 10.1556/CRC.2012.0033

[13] Chen F, Li H, Li X, Dong Z, Zuo A, Shanga X, Cuia D. Alveograph and Mixolab parameters associated with puroindoline-D1 genes in Chinese winter wheats. Journal of the Science of Food and Agriculture. 2013; 93:2541–2548. DOI: 10.1002/jsfa.6073

[14] Papoušková L, Capouchová I, Kostelanská M, Škeříková A, Prokinová E, Hajšlová J, Salava J, Faměra O. Changes in baking quality of winter wheat with different intensity of *Fusarium* spp. contamination detected by means of new rheological system Mixolab. Czech Journal of Food Sciences. 2011; 29:420–429

[15] Džuman Z, Zachariášová M, Lacina O, Vepříková Z, Slavíková P, Hajšlová J. A rugged high-throughput analytical approach for the determination and quantification of multiple mycotoxins in complex feed. Talanta. 2014; 121:263–272. DOI: 10.1016/j.talanta.2013.12.064

[16] Mixolab applications handbook. Rheological and enzymatic analysis. Chopin Applications Laboratory. 2008; 86 p.

[17] Kushiro M. Effects of milling and cooking processes on the deoxynivalenol content in wheat. International Journal of Molecular Sciences. 2008; 9:2127–2145. DOI: 10.3390/ijms9112127

[18] Garcia D, Ramos AJ, Sanchis V, Marín S. Predicting mycotoxins in food: a review. Food Microbiology. 2009; 26:757–769. DOI: 10.1016/j.fm.2009.05.014

[19] Snijders CHA. Resistance in wheat to *Fusarium* infection and trichothecene formation. Toxicology Letters. 2004; 153:37–46. DOI: 10.1016/j.toxlet.2004.04.044

[20] Capouchová I, Papoušková L, Kostelanská M, Prokinová E, Škeříková A, Hajšlová J, Konvalina P, Faměra O. Effect of different intensities of *Fusarium* infestation on grain yield, deoxynivalenol content and baking quality of winter wheat. Romanian Agricultural Research. 2012; 29:297–306.

[21] Papoušková L, Capouchová I, Dvořáček V, Konvalina P, Janovská D, Vepříková Z, Škeříková A, Zrcková M. Qualitative changes of rye grain and flour after *Fusarium* spp. contamination evaluated by standard methods and system Mixolab. Zemdirbyste-Agriculture. 2015; 102:397–402. DOI: 10.13080/z-a.2015.102.050

[22] Seitz LM, Eustace WD, Nohr HE, Shorgen MD, Yamazaki WT. Cleaning, milling and baking tests with hard red winter wheat containing deoxynivalenol. Cereal Chemistry. 1986; 63:146–150

[23] Antes S, Birzele B, Prange A, Krämer J, Meier A, Dehne HW, Köhler P. Rheological and breadmaking properties of wheat samples infected with *Fusarium* spp. Mycotoxin Research. 2001; 17:76–80

[24] Prange A, Birzele B, Krämer J, Meier A, Modrow H, Köhler P. *Fusarium*-inoculated wheat: deoxynivalenol contents and baking quality in relation to infection time. Food Control. 2005; 16:739–745. DOI: 10.1016/j.foodcont.2004.06.013

[25] Boyacioglu D, Hettiarachchy NS. Changes in some biochemical components of wheat grain that was infected with *Fusarium graminearum*. Journal of Cereal Science. 1995; 21:57–62. DOI: 10.1016/S0733-5210(95)80008-5

[26] Wang JH, Wieser H, Pawelzik E. Impact of the fungal protease produced by *Fusarium culmorum* on the protein quality and breadmaking properties of winter wheat. European Food Research and Technology. 2005; 220:552–559. DOI: 10.1007/s00217-004-1112-1

[27] Hareland GA. Effects of pearling on falling number and alpha-amylase activity of preharvest sprouted spring wheat. Cereal Chemistry. 2003; 80:232–237. DOI: 10.1094/CCHEM.2003.80.2.232

[28] Eggert K, Wieser H, Pawelzik E. The influence of *Fusarium* infection and growing location on the quantitative protein composition of emmer (*Triticum dicoccum*). European Food Research and Technology. 2010; 230:837–847. DOI: 10.1007/s00217-010-1229-3

[29] Stoenescu G, Ionescu VS. Rheological properties of the wheat flour supplemented with different additives. AUDJG – Food Technology. 2011; 35:54–62

[30] Collar C, Santos E, Rosell CM. Significance of dietary fiber on the viscometric pattern of pasted and gelled flour-fiber blends. Cereal Chemistry. 2006; 83:370–376. DOI: 10.1094/CC-83-0370

[31] Dexter JE, Preston KR, Tweed AR, Kilborn RH, Tipples KH. Relationship of flour starch damage and flour protein to the quality of Brazilian-style hearth bread and remix pan bread produced from hard red spring wheat. Cereal Foods World. 1985; 30:511–514

[32] Solarska E, Marzec M, Kuzdraliński A, Muszyńska M. The occurrence of mycotoxins in organic spelt products. Journal of Plant Protection Research. 2012; 52:190–195

[33] Wiwart M, Perkowski J, Budzyński W, Suchowilska E, Buśko M, Matyasik A. Concentrations of ergosterol and trichothecenes in the grains of three *Triticum* species. Czech Journal of Food Sciences. 2011; 29:430–440.