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The fatty acid profile in different wheat cultivars depending on the level of contamination with microscopic fungi

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ABSTRACT

Analyses were conducted on 30 winter wheat samples growing under controlled conditions and following inoculation with fungi *Fusarium culmorum*. In inoculated samples the mean concentration of 30 analysed fatty acids was significantly higher in relation to the control and amounted to 1396 mg/kg *vs.* 1046 mg/kg in the control kernels. Recorded concentrations for individual cultivars were significantly correlated with the concentration of fungal biomass.

Higher concentration in the control was recorded only for the acid *trans* C18:2*n*–6. It was also found that the acid profiles are characteristic of individual cultivars. Statistical analysis showed that *trans* C18:2*n*–6, C18:1, C18:3*n*–3 and C18:3*n*–6 were the acids with the greatest discriminatory power in distinguishing inoculated samples from the control. Discriminatory analysis separated individual cultivars into quality classes of winter wheat cultivars depending on the presence of a specific fatty acid profile.

1. Introduction

In Poland wheat is a staple cereal with the greatest cropped area and the highest production. Wheat grain contains on average 13.2% water, 11.5% protein, 59.4% available carbohydrates, 10.6% dietary fibre, 1.8% minerals and 1.9% fats (Prabhasanar & Haridas Rao, 1999). Lipids are a quantitatively minor, but significant component of wheat grain, amounting to 0.9–3.3% (Price & Parsons, 1995). Content of these compounds in wheat grain is connected with its maturity, classification of cultivars into quality classes and cultivation conditions. Lipids from wheat germ isolated on a commercial scale are important oils for direct human consumption, containing polyenic fatty acids and tocopherols of high nutritive value (Sahasrabudhe, 1989). Lipid composition determines strength of wheat flour, while the fatty acid fraction plays a significant role in cereal storage practice (Daftary, Pomeranz, & Sauer, 1970). Changes in the latter initiate processes leading to the deterioration of grain (Olsson, 1999). The action of microflora colonising kernels results in the production of toxic metabolites, while quality changes occur in grain in its individual fractions, i.e., the protein, fatty acid and carbohydrate fractions (Morrison, 1977).

Pathogenic fungi from the genus *Fusarium* cause huge economic losses in cereal crops worldwide. The biggest disease caused by these microorganisms is *Fusarium* head blight (FHB), the main carriers of which worldwide include *Fusarium graminearum*, *Fusarium culmorum* and *Fusarium avenaceum*, whose distribution and occurrence in individual species are closely related to climatic conditions (Parry, Jenkinson, & MacLeod 1995). Isolates of these fungi produce primarily group B trichothecenes, particularly deoxynivalenol (DON), nivalenol (NIV), 3-Ac-DON, 15-Ac-DON and fusarenon X (Fus-X), with the first two metabolites found most commonly. Group A trichothecenes, which include T-2 toxin, HT-2 toxin, scirpentriol (STO), diacetoxyscirpenol (DAS), neosolaniol (NEO), T-2 triol, T-2 tetraol and their other derivatives, are produced e.g., by such *Fusarium* species as *Fusarium sporotrichioides*, *Fusarium poae* and *Fusarium langsethiae* (Chełkowski 1989; Imathiu, 2010). Mycotoxins formed in grain exhibit toxic properties towards both humans and animals, causing several diseases called mycotoxicoses (Langseth, Bernhoft, Rundberget, Kosiak, & Gareis 1999). Moreover, infestation by fungi from the genus *Fusarium* results in deterioration of seed quality (Veisz, Szunics, & Szunics, 1997) and contributes to reduced technological quality of grain (Jackowiak, Packa, Wiwart, & Perkowski 2005).

Lipid oxidation processes, next to hydrolysis, are the most frequently occurring changes observed during metabolic processes in microscopic fungi colonising wheat grain. Lipid oxidation processes occur with the participation of microbial enzymes showing specificity typical of lipoxygenases. The presence of such enzymes was found in the following microbial genera: *Aspergillus*, *Penicillium*, *Rhizopus* and *Pseudomonas*. Lipoxygenases catalyse oxidation of polyenic fatty acids to their hydroperoxides. Fatty acid hydroperoxides are compounds of low stability and are transformed in the following reactions: reduction, isomerisation, chain scission,

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etc., (Maggio-Hall, Wilson, & Keller, 2005). It was shown that certain strains of microscopic fungi are capable of hydroperoxide degradation. A considerable role is played by the scission of the carbon chain in hydroperoxide to volatile compounds, which frequently deteriorate the organoleptic value of raw materials and products. The content of volatile carbonyl compounds is an indicator of rancidity in fats and oils.

Model studies conducted by Hamzehzarghani et al. (2005) showed that in wheat grain inoculated with pure cultures of fungi from the genus *Aspergillus* lipid losses amounted to approx. 30%. When analysing lipid composition in grain during culture with microorganisms it was found that losses of individual fatty acids were not uniform. After 72 h in wheat grain the content of linoleic acid decreased on average by 35%, while losses of palmitic acid ranged from 28% to 36%. Considerable differences in losses of unsaturated acids in comparison to the reduction of the saturated acid may be explained by the fact that unsaturated acids are used more rapidly in metabolic processes of grain and microorganisms. Literature on the subject indicates that under the influence of microorganisms the amount of triacylglycerols, esters, sterols and fractions of polar lipids (the sum of phospholipids and glycolipids) is reduced in wheat grain, while the content of free fatty acids increases. The reduction of triacylglycerol contents in grain is caused by the action of microbial lipases.

Studies conducted to date, mainly based on model experiments, showed that in the composition of fatty acids in the triacylglycerol fraction during incubation of laboratory cultures on wheat grain no statistically significant differences were found in the percentage amounts of individual fatty acids. In field experiments, when the kernel surface is colonised by several microorganisms, lipases of different fungal strains may exhibit a selective action in relation to individual fatty acids. Model studies conducted on fungal cultures cultured on wheat showed that under the influence of growth of microscopic fungi the fatty acid profile changed. In comparison to the control an increase by 9% and 25% was observed in the content of palmitic (C16:0) and linoleic acids (C18:3), respectively, while the content of oleic acid (C18:1) decreased by 9%. At the same time the content of stearic acid (C18:0) was reduced by 23%. Generally it may be stated that the fatty acid profile changes during infection caused by fungi from the genus *Fusarium*, which results from the modification of the structure of microscopic fungi and their metabolism (Wang, Soansen, Kershaw, & Talbot, 2007).

The aim of this study was to determine the fatty acid profile in grain of 30 representative wheat cultivars. It was decided to attain this aim by analysing samples inoculated with fungi from the genus *Fusarium* and naturally infested samples, denoted as the control samples growing without infection under identical agricultural and climatic conditions. Apart from the determination of the general fatty acid profile the aim of the study was to identify interrelationships between individual fatty acids found in grain, as well as to investigate the effect of infestation with fungi from the genus *Fusarium* on changes in the fatty acid profile in the control and inoculated samples, and also to determine the composition of PUFA and MUFA.

2. Material and methods

2.1. Field experiment

Thirty cultivars of winter wheat (*Triticum aestivum* L.) were evaluated. These cultivars are listed in the Polish National List of the Research Centre for Cultivar Testing (COBORU) and were added to the list between 1998 ('Mewa') and 2009 ('Belenus'). According to the COBORU report (2012) cultivars 'Muszelka', 'Bogatka', 'Tonacja', 'Ostroga', 'Legenda' and 'Akteur' had the largest share

Table 1
Characteristics of 30 winter wheat cultivars, quality code, percentage of *Fusarium* damaged kernels (%FDK) and concentration of ergosterol – ERG (mg/kg).

No.	Cultivar	Pedigree	Quality code	% FDK	ERG (mg/kg)
1	Akteur	(87–308 × Astron) × Astron	A	4.3	45.28
2	Alcazar	Charger × Lynx	A	22.2	26.25
3	Anthus[a]	Greif × (NFC2.192 × Zentos)	B	15.2	11.61
4	Batuta	(Konsul x Korweta) × Kobra	B	21.9	24.56
5	Belenus	Cortez x ST × Hussar	C	26.7	40.15
6	Bogatka	Urban × Kobra	B	9.4	37.05
7	Boomer	Haven × Torfrida × Transit	A	7.6	40.03
8	Dorota	94ST85 × Tambor	B	9.2	15.01
9	Figura	(Juma × G 664/26) × Pegassos	A	10.8	22.48
10	Garantus	Kris × Piko × Tambor	B	13.5	29.48
11	Jenga	98/2574 × Dekan	B	10.8	26.15
12	Kampana	CRT 9 × Kris	C	19.2	28.06
13	Kohelia	(Zentos × Kobra) × (Euris × Kobra)	A	12.1	41.28
14	Legenda	N2015/85 × Astron	A	4.7	35.67
15	Ludwig	Ares × Farmer	A	14.6	31.32
16	Markiza	MIB 295 × Zyta	C	17.9	25.5
17	Meteor	Tarso × Contra × Hadmerslebener 91952-83	B	12.7	29.85
18	Mewa	(CHD 756/78 × FD 303) × Gama	B	15.0	24.56
19	Mulan	Drifter × Maverick	B	13.2	18.01
20	Muszelka	Kris × Rubens	B	18.3	38.99
21	Naridana	Rektor × Kobra	A	12.4	38.06
22	Nateja[a]	(Emika × EGRQ) × Kobra	B	9.0	35.29
23	Ostka St.	Gorbi × STH 48	A	6.9	21.11
24	Ostroga	CEB 9504 × Mewa	A	5.4	22.48
25	Slade	Normann × [584-4-12 × (Haven × Consort)]	K	11.4	19.04
26	Smuga	KOC 1688 × CHD 498/84	A	13.4	26.15
27	Sukces	Jubilatka × SMH 8134	A	7.2	28.01
28	Tonacja	Jubilatka × SMH 8134	A	10.5	25.26
29	Türkis	Tambor × Hadmerslebener 91639-89	A	14.6	22.94
30	Zyta	Jubilatka × SMH 8134	A	7.6	19.81

Quality code: A – quality cultivar, B – bread cultivar, C – non-baking cultivar, K – biscuit cultivar.
[a] Cultivars deleted from the Polish National List in 2012.