Effect of Extrusion Procedure on Selected Grain Parameters in Contrast Wheat Cultivars

Václav Dvořáček[1*], Vladimír Plachý[2], Lenka Štěrbová[1], Eva Matějová[1], Michal Kaválek[3], Boris Hučko[2]

[1]*Crop Research Institute, Drnovská 507, Prague 6–Ruzyně, 161 06, Czech Republic*
[2]*Czech University of Life Sciences Prague, Department of Microbiology, Nutrition and Dietetics, Kamýcká 129, 160 00-Prague, 6, Czech Republic*
[3]*Farmet a.s. Jiřinková 276, Česká Skalice, Czech Republic*

Abstract

In spite of the fact that the majority of registered wheats (*Triticum aestivum* L.) belonging to cultivars suitable for baking applications, more than 60% of annual Czech wheat production is utilized for feeding. Regarding this fact, a proper extrusion process may offer an improvement of grain feeding quality. The study was aimed at monitoring of grain quality parameter changes in extruded wholemeal from three technologically contrasting cultivars (Elixer, Bodyček, Cimrmanova raná) obtained after 8 different combinations of extrusion processes with variation in water dosage and insertion diameter. Technologically different wheat cultivars significantly changed extrusion temperature. Simultaneously, the extrusion process significantly increased RDS content in starch (from 36 to 86%). On the contrary, the parameters CP and ADF content showed minimal changes after extrusion. The mild reduction of CF and NDF after extrusion probably included hemicellulose degradation. It is possible to conclude that the applied extrusion processes showed comparable effect in all 3 contrasting wheat cultivars on the one hand. On the other hand, the selection of a proper wheat cultivar with suitable grain composition can also bring a further progress in the final quality of extrudates.

Keywords: chemical composition, cultivars, digestibility, extrusion, wheat grain

1. Introduction

The main aims of wheat breeding are permanently focused on yield efficiency, abiotic and biotic resistance and grain quality optimizing. The grain quality in the case of wheat includes the group of parameters generally aimed at baking applicability of wheat. In spite of this fact, common wheat in north-western Europe (42%) including the Czech Republic (even 60%) is predominantly used for farm animal feeding [1, 2]. The explanation of this situation is connected with strict demands of baking industry on wheat grain quality which in combination with instable weather conditions conduce to the reduction of proper wheat cultivars for baking. These cultivars are further used for feeding only. It is evident that this fact doesn't increase quality of a final feeding rate especially for monogastric animals (poultry and pigs) where wheat can be represented by more than 50% in their feeding rate.

Therefore, new progressive and economically efficient procedures are developed for improvement of feed digestibility and a total weight gain of animals on basis of enzymatic supplements and a physical treatment including grinding pelletizing and thermal modifications [3]. In recent years, the extrusion technique is extensively used in feed of animals, because this technology has numerous advantages, including the possibility of wide application, high productivity, energy efficiency and high quality of

* Corresponding author: Václav Dvořáček,
Tel. +420 233022418, Email: dvoracek@vurv.cz

the resulting product [4, 5]. Gelatinization of starch, structural changes in protein and amino acid, denaturation of anti-nutritional factors along with sterilization of ingredients are the main features of extrusion process which should lead to the better digestibility, intake, feed conversion ratio and production especially in poultry birds [6]. On the other hand, extruded ingredients may not have any effect or they even have adverse effect on performance of the chicken [7] or piglets [8]. There are a lot of factors which may influence the extrusion process and its final impact on the feeding quality of grain. Animal related factors are breed, age, sex, feed intake and passage rate of feed in gastrointestinal tract of the animal. The great influences on starch and protein structures of grain are achieved by a different extrusion processing as well (input moisture, screw speed, temperature and pressure, retention time etc.). The individual chemical composition of the ingredients (grain) is the next factor affecting on final feeding value. For example, a fast retrogradation of amylose or starch–lipid interactions have been described after extrusion of cereal mixtures and significantly decreased starch digestibility [6].

It must be said that there is still a lack of information about the use of extruded wheat in monogaster diets and information especially about reaction of individual wheat cultivars on individual extrusion procedures are not known us yet. Therefore, the aim of our work focused on the specific effect of extrusion procedures on selected chemical and technological parameters in three wheat cultivars contrasting in baking quality.

2. Materials and methods

The certified seeds of three contrasting wheat cultivars–*Triticum aestivum* L. registered in the Czech Republic (Elixer, Bodyček, Cimrmanova raná) were obtained and used for 8 combinations of extrusion processes with 4 variations in water dosage and 2 diameters of final insertion. The cultivar Elixer is classified as wheat of C-category (poor baking quality) suitable for animal feeding. The next cultivars Bodyček (A-category) and Cimrmanova raná (E-category) are baking wheats, where the last one is declared as the best baking (elite) material.

The selected wheat cultivars (1000 kg) were grinded using the hammer mill (Taurus VM 4, screen 2 mm) and wheat meal was extruded using pilot extruder device (Farmet FE 100). The four input water dosages 6, 8, 10 and 12 l . 100 kg^{-1} and two diameters of final insertions (80.5 and 82.5 mm) in the extrusive chambers were applied for each of wheat cultivars. Other extrusion parameters such as screw speed (615 rpm) and mass flow rate (82 kg/h) stayed constant.

The following grain parameters were tested in wheat meal as well as in final extrudates in two repetitions: content of dry matter (DM) according to ČSN 56 0512–7, crude protein content (CP)–Kjeldahl method according to ČSN EN ISO 5983-1 and content of starch (ST)–Ewers polarimetric methods according to ČSN EN ISO 10520. Fiber analyses included assessment of contents of crude fiber (CF) according to Commision Regulation No 152/2009, neutral detergent fiber according to Commission Regulation No 152/2009 and acid detergent fiber (ADF) according to Commission Regulation No 152/2009.

The determination of rapidly digestible starch (RDS) was carried out according to the method developed by Englyst et al. (1999) [9] with a slight simplification. The method was miniaturized with a sample weight 50 mg only and the enzymatic digestion was stopped after 20 minutes. In this way, the rapidly available glucose (RAG) is detected, that includes a major ratio of RDS and typically (in case of wheat) very low contents of free glucose (FG) and the glucose moiety of sucrose [10]. Regarding this fact both free saccharides were ignored and results were expressed as content of RDS.

The bulk weight of extrudates was assessed in 3 repetitions using a standard grain tester determined for the test weight of seeds ČSN ISO 7971-2.

Statistica 9.0 CZ was used for statistical analyses of variance (ANOVA) and Tukey post-hoc comparison.

3. Results and discussion

The summary of specific extrusion characteristics measured during individual extrusion combinations are presented in the Table 1. Whereas a rising of water doses regularly increased outlet humidity of extrudates, the achieved temperature in the last chamber 3 was more varietal dependent. The cultivar Bodyček showed evidently lower temperature in the all extrusion combinations compared to both next cultivars (Cimrmanova raná and Elixer). It seems to be evident that the lower extrusion temperature

Table 1. Extrusion characteristics during processing of individual wheat cultivars

Combinations	Engine load [N.m]	Power input [kW]	Chamber temp.1 [°C]	Chamber temp.2 [°C]	Chamber temp.3 [°C]	Outlet humidity [%]
Elixer 1	169.3	14.6	23	38	108	9.3
Elixer 2	183.2	15.7	25	42	132	9.8
Elixer 3	169.3	14.5	26	45	131	11.5
Elixer 4	166.3	14.6	26	45	134	12.8
Elixer 5	166.3	14.3	30	44	126	8.9
Elixer 6	159.4	13.7	30	44	128	9.4
Elixer 7	167.3	14.4	29	46	130	11.1
Elixer 8	160.4	13.8	28	46	133	12.8
Bodyček 1	174.2	15.0	30	46	124	9.3
Bodyček 2	174.2	15.0	33	46	116	8.9
Bodyček 3	168.3	14.5	33	48	111	9.9
Bodyček 4	156.4	13.5	32	47	109	10.2
Bodyček 5	194.0	16.7	28	45	120	8.2
Bodyček 6	189.1	16.3	28	45	117	8.4
Bodyček 7	169.3	14.6	28	45	111	10.0
Bodyček 8	165.3	14.2	29	44	108	10.3
Cimrmanova r. 1	171.3	14.7	28	47	129	6.6
Cimrmanova r. 2	153.5	13.2	31	48	112	9.7
Cimrmanova r. 3	160.4	13.8	33	49	133	11.4
Cimrmanova r. 4	155.4	13.3	33	44	134	12.1
Cimrmanova r. 5	166.3	14.3	33	47	115	8.7
Cimrmanova r. 6	160.4	13.8	33	47	110	9.2
Cimrmanova r. 7	167.3	14.4	31	45	131	11.1
Cimrmanova r. 8	161.4	13.9	31	48	127	12.2

Combinations 1 – 4: insertion diameter 80.5 mm with gradual input of water 6, 8, 10 and 12 $l.100kg^{-1}$ of seed
Combinations 5 – 8: insertion diameter 82.5 mm with gradual input of water 6, 8, 10 and 12 $l.100kg^{-1}$ of seed

in the case of cv. Bodyček (chamber 3) increased dimension parameters of final extrudates and showed (except the two extrusion combinations 1 and 5) the lowest bulk density (Figure 1).

Simultaneously, cv. Bodyček showed the lowest dimension changes (bulk density) depending on the particular extrusion combinations. The lower effect of water dosage can be connected with a higher ability of the Bodyček flour to bind water compared to cv. Cimrmanova raná and Elixer. The water absorption is significantly influenced by interactions of the genotype and external factors as reported by e.g. Zecevic et al. (2013) [11] and it seems to be one of the important input flour parameters, which can influence efficiency of extrusion.

The detected changes of tested grain parameters after extrusion were also specific (Table 2). The extrusion process (especially high temperature) significantly increased RDS content in all cultivars. The significant decrease of the parameters CF and NDF was detected after extrusion as well. On the other hand, the significant changes of CP, ST and ADF contents were not detected.

The extrusion process confirmed the essential effect on content of rapidly digestible starch (RDS) which increased after extrusion more than 2 times compared to the initial whole meal (Table 2). The particular extrusion combinations did not play a significant role in RDS changes. The insignificant trend of a mild decrease of RDS content was detected in the extrusion combinations with higher water doses (10 and 12 l . 100 kg^{-1} of seed) only. The ratio of RDS in starch varied among the individual extrusion combinations in the close range 82–86%. It is in accordance with results of many authors who also confirmed digestibility increase of starch by starch gelatinization, melting, fragmentation and making starch easily accessible to digestive enzymes [12-14]. The fiber changes after extrusion can be connected with hemicellulose degradation, which is additionally included in NDF compared to ADF including lignin and cellulose predominantly [15]. The frequent detection of unfavorable viscosity increase in extrudates, which is caused by increasing of pentosans, can support this fact as well [8], because xyloses and arabinoses are just basic components of hemicellulose chains in cereals [15].

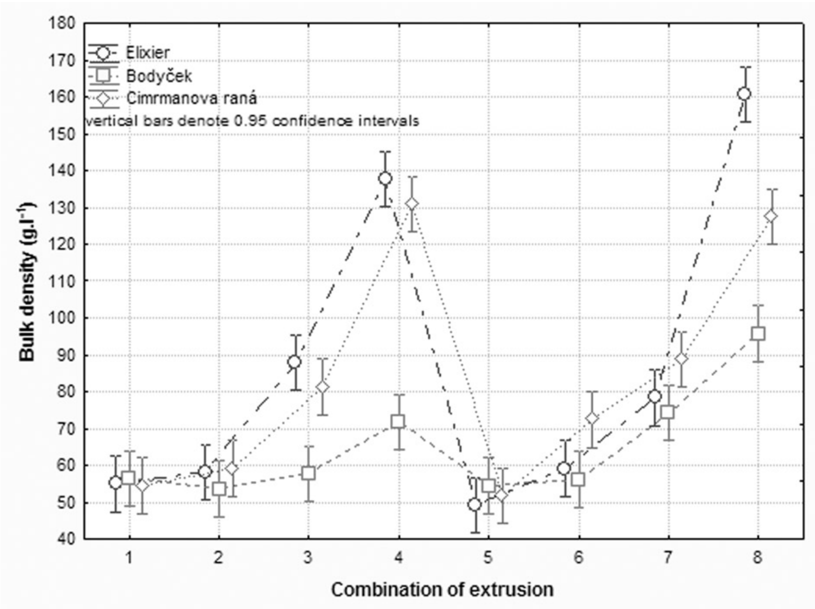

Figure 1. The bulk density of extrudates depending on tested cultivars and extrusion combinations

Table 2. Effects of extrusion procedures on tested parameters of selected wheat cultivars

Factor		RDS (mg kg^{-1})	ST (%)	CP (%)	CF (%)	NDF (%)	ADF (%)
Cultivars	Elixer	527.4^{a}	66.3^{a}	13.0^{a}	2.3^{b}	12.2^{a}	2.0^{b}
	Bodyček	506.4^{b}	66.5^{a}	13.1^{a}	2.4^{c}	13.4^{a}	2.1^{b}
	Cimrmanova raná	526.1^{a}	67.7^{b}	13.7^{b}	2.0^{a}	10.0^{c}	1.7^{a}
Extrusion combinations	Native wheat meal	243.2^{a}	67.0^{abc}	13.3^{a}	2.8^{c}	15.5^{b}	1.8^{a}
	E1	574.9^{b}	66.2^{a}	13.3^{a}	2.0^{a}	11.3^{a}	2.0^{a}
	E2	573.8^{b}	67.0^{abc}	13.2^{a}	2.1^{ab}	11.0^{a}	1.8^{a}
	E3	552.0^{b}	67.3^{bc}	13.3^{a}	2.1^{ab}	10.8^{ab}	2.0^{a}
	E4	547.9^{b}	67.5^{b}	13.2^{a}	2.1^{ab}	12.0^{ab}	2.0^{a}
	E5	559.4^{b}	66.1^{a}	13.3^{a}	2.1^{ab}	12.4^{ab}	1.9^{a}
	E6	546.2^{b}	67.4^{b}	13.3^{a}	2.2^{ab}	10.9^{a}	2.0^{a}
	E7	542.0^{b}	66.7^{abc}	13.3^{a}	2.3^{ab}	10.9^{a}	2.0^{a}
	E8	540.1^{b}	66.2^{ac}	13.3^{a}	2.3^{b}	10.5^{a}	2.0^{a}
Parameter variability depending on	Cultivar (%)	0.9*	38.1**	76.1**	39.3**	26.7**	53.0**
	Extrusion (%)	95.0**	30.0**	1.3^{ns}	44.8**	27.7**	8.8^{ns}
	Interactions (%)	0.8^{ns}	31.7**	2.9^{ns}	9.9**	37.8**	21.7*

Combinations E1–E4: insertion diameter 80.5 mm with gradual dose of water 6, 8, 10 and 12 l.100 kg^{-1} of seed
Combinations E5–E8: insertion diameter 82.5 mm with gradual dose of water 6, 8, 10 and 12 l.100kg^{-1} of seed
*Statistically significant at $p \leq 0.05$; ** Statistically significant at $p \leq 0.01$
Values with different letter indexes are statistically significant at $p \leq 0.05$

Regarding these facts and declared effect of the wheat cultivar on arabinoxylans content [16], input monitoring of arabinoxylans in wheat grains with a further selection of proper wheat cultivars could also improve the final quality of extrudates. On the contrary, the high genotype stability and low extrusion effect were mainly found in the parameter CP (Table 2 and Figure 2). It was the expected result, because the extrusion process mainly changes the protein structure by denaturation of protein, modification of side chains of amino acids and subsequently protein digestibility [6], which the Kjeldahl mineralization method cannot reveal. The adverse extrusion effect on protein quality is often connected with lysine loss caused by the maillard condensation. It is reaction between NH_2 groups of lysine residues and C=O groups of reducing sugars (≥3% glucose, fructose, maltose, lactose) [8]. Nevertheless, the very low concentration of free reducing sugars declared in wheat should eliminate the risk [10]. The final graphical result specified the above discussed relationship between a lower temperature effect of extrusion and a lower RDS content detected in cv. Bodyček (Figure 3). It is evident that this insignificant trend showed the extrusion with the size insertion 80.5 mm only. On the contrary, the trend of RDS reduction depending on a water dose increasing was found out in both insertion sizes.

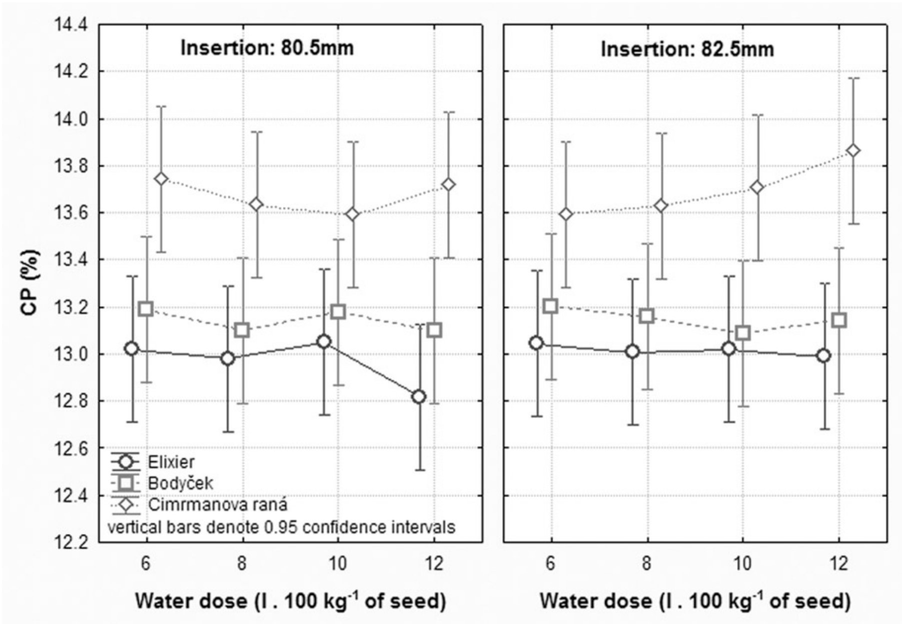

Figure 2. Variability of crude protein depending on cultivar, water dose and size of insertions

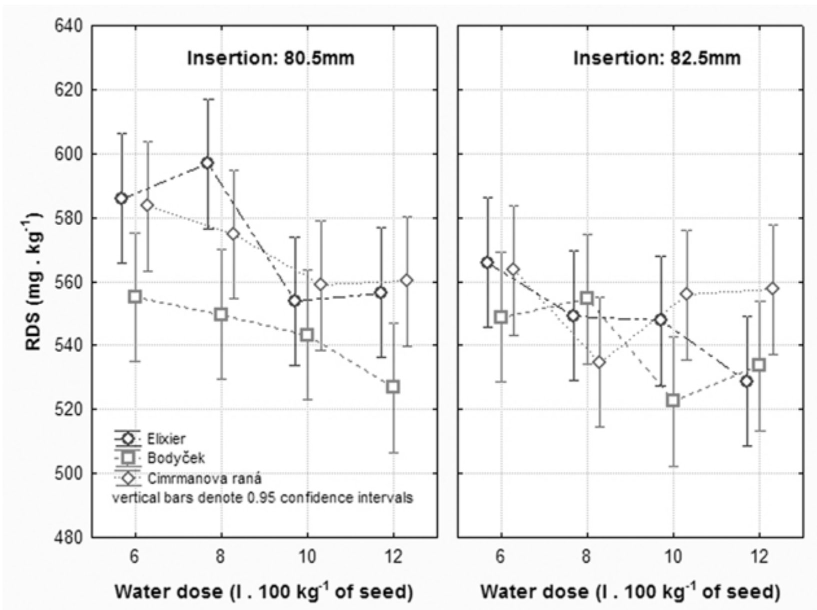

Figure 3. Variability of rapidly digestible starch depending on cultivar, water dose and size of insertions

4. Conclusions

It was confirmed that technologically different wheat cultivars significantly changed extrusion temperature, which is the critical factor especially for starch gelatinization and digestibility. The parameters CP and ADF showed a minimal change after extrusion and the mutual differences of extrudates reflected the parameter values detected in whole meal of the cultivars. Simultaneously, the high extrusion effect was confirmed on starch composition and high increasing of RDS content was found out. The further results also indicated reduction of fiber content after extrusion, which was probably caused by hemicellulose degradation. It is possible to conclude that the applied extrusion processes showed comparable effect in all 3 contrasting wheat cultivars on the one hand. On the other hand, the initial chemical differences among cultivars were also significantly manifested in the extrudate compositions. Thus, a proper wheat cultivar selection can bring further progress in the final quality of extrudates as well.

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