Influence of Extrusion on Functional Properties of Flour from Selected Wheat and Barley Cultivars Grown in Croatia

Utjecaj estruzije na funkcionalna svojstva odabranih sorti pšenice i ječma uzgojenih u Hrvatskoj

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THE INFLUENCE OF EXTRUSION ON FUNCTIONAL PROPERTIES OF FLOUR FROM SELECTED WHEAT AND BARLEY CULTIVARS GROWN IN CROATIA

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SUMMARY

The aim of this research was to evaluate the effect of extruder die temperature (90, 100, 110 °C) and flour moisture (25, 30, 35%) on properties of extrusion-modified flours from wheat (Kraljica, Olimpija) and hull-less barley (GZ-10, GZ-11) cultivars. Flours were extruded in laboratory single screw extruder and micro viscoamylographic, farinographic properties, sedimentation and falling number were determined. The results showed that viscosity values decreased and stability of flours increased after extrusion, both during shearing at high temperatures and regarding retrogradation. Although barley flours were in B2 and C1 quality category before extrusion, after extrusion all flours were within A1 or A2 category. Sedimentation values significantly decreased after extrusion, and falling number depended largely on extrusion conditions. By careful selection of cultivar, flour moisture, and extrusion conditions flours with desired properties may be produced.

Keywords: wheat and hull-less barley flour, extrusion, rheological properties, sedimentation, falling number

INTRODUCTION

Wheat is a staple food in the large part of the world and wheat flour is the main choice in production of a variety of products from bread and bakery to pasta and biscuits (Aly et al., 2021). Although it has the best baking properties among all cereals, wheat flour is nowadays often partially or fully substituted with other cereals, rich in fiber or without gluten. One of them is hull-less barley, a rich source of ß-glucan and polyphenols, consumption of which is linked to beneficial effects on cardiovascular system. However, barley flour has inferior baking properties to wheat flour. It contains hordeins, which are not so good in creating protein network as gliadins, present in wheat (Punia, 2020). Along with development of specific cultivars and manipulation of growing conditions, properties of flours may be modified by different technological processes, among which extrusion is very popular. By the unique combination of moisture, screw configuration and speed, temperature profile and die diameter, properties of flour are modified due to physical and chemical changes of proteins, starch and fiber induced by high temperature, high shear and pressure (Jafari et al., 2017).

The aim of the present research was to evaluate the influence of moisture and die temperature on baking properties of flours from two cultivars of wheat and two cultivars of barley.

MATERIALS AND METHODS

Sample preparation

Flours of two wheat cultivars, Kraljica and Olimpija and two hull-less barley cultivars, GZ-10 and GZ-11,

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selected at Agricultural Institute Osijek (Croatia) were used in the research.

In the first part of the research, samples were equilibrated to moisture level of 30%. Extrusion was performed in the laboratory single screw extruder (Do-Coder, Brabender 19/20 DN, GmbH, Duisburg, Germany), consisting of three independent zones of controlled temperature in the barrel. Extrusion parameters were as follows: screw: 1:1; die: 5 mm; temperature profile: 70/90 °C in the first two zones and with changing temperature at the exit of the extruder: 90, 100 and 110 °C.

In the second part of the research, samples were equilibrated to three moisture levels: 25, 30 and 35%. Extrusion was performed at the same parameters, with temperature profile 70/90/110 °C.

Obtained extrudates were air-dried, milled (IKA MF10) to pass 2 mm sieve and stored in a cool and dark place until the analysis.

Analysis of extruded products

Viscosity of flours was determined using micro-viscoamylograph (Brabender GmbH, Duisburg, Germany). 100 g of 10% suspension of flour in distilled water was heated at the following program:

- Heating from 30 °C to 92 °C at 7.5 °C/min
- Keeping at 92 °C for 5 min
- Cooling from 92 to 50 °C at 7.5 °C/min
- Keeping at 50 °C for 1 min.

Falling number was determined using Falling Number 1500 (Perten Instruments AB, Sweden), according to method AACC 56-81.B.

Sedimentation test was done using Zeleny shaking device (Brabender GmbH, Duisburg, Germany), according to method AACC 56-61.02.

Rheological properties of flour were determined by Farinograph (Brabender GmbH, Duisburg, Germany), according to method AACC 54-21.01.

Statistical analysis was performed using Statistica 12 (StatSoft, TIBCO Software, Palo Alto, CA, USA) by analysis of variance (ANOVA), Tukey HSD test ($p<0.05$) and correlation matrices ($p<0.05$).

RESULTS AND DISCUSSION

The influence of temperature of extrusion

Results obtained by micro-viscoamylograph are shown in Table 1 (for wheat) and Table 2 (for barley). Peak viscosity, hot and cold paste viscosities of extruded flours were reduced by extrusion. For wheat Olimpija and barley GZ-11 the increase of extrusion temperature resulted in more pronounced drop of the peak viscosity, however, other two samples did not follow the same trend.

Breakdown values are indicators of stability during shearing at high temperatures. Extruded wheat flours had significantly lower values of breakdown compared to unmodified flour. For Kraljica variety, flour extruded at 90 °C had the most stable viscosity, whereas flour extruded at 110 °C was the most stable among Olimpija flours.

Pasting properties are mainly a result of starch properties (Hou et al., 2020), and extrusion causes damaging of starch granules and the loss of granular structure, which are responsible for drop of viscosity values (de la Rosa-Millan et al., 2019). However, increased starch damage also results in a larger absorption of the water (Shang et al., 2021) which, in turn, increases viscosity of the paste due to larger swelling of the granules. Absorption increased proportionally to the increase of the die temperature for all analysed samples in the present research (Table 3). This may be the reason for unestablished trends in viscosity reduction with the rise of the die temperature during extrusion.

Table 1. Viscosity of wheat flours determined by Brabender micro visco-amylograph.

Tablica 1. Viskoznost brašna pšenice određena Brabenderovim mikro viskoamilografom.

Sample / *Uzorak*	**Peak viscosity /** *Viskoznost vrha* (BU)	**Viscosity at 92 °C /** *Viskoznost na 92 °C* (BU)	**Viscosity after shearing at 92 °C /** *Viskoznost nakon miješanja na 92 °C* (BU)	**Viscosity at 50 °C /** *Viskoznost na 50 °C* (BU)	**Viscosity after shearing at 50 °C /** *Viskoznost nakon miješanja na 50 °C* (BU)	**Breakdown /** *Kidanje* (BU)	**Setback /** *Setback* (BU)
Kraljica							
Unmodified flour	568.5 ± 4.95 ^{d}	560.5 ± 2.12 ^{d}	423.5 ± 4.95 ^{d}	808.5 ± 6.36 ^{c}	804.5 ± 2.12 ^{c}	144.5 ± 0.71 ^{b}	376.0 ± 11.31 ^{c}
Extruded at 90 °C/30%	322.0 ± 28.28 ^{a}	293.0 ± 31.11 ^{a}	287.0 ± 21.21 ^{a}	605.0 ± 18.38 ^{a}	584.5 ± 33.23 ^{a}	39.0 ± 43.84 ^{a}	315.5 ± 0.71 ^{a}
Extruded at 100 °C/30%	413.0 ± 0.00 ^{b}	313.0 ± 1.41 ^{a}	354.0 ± 2.83 ^{b}	701.5 ± 7.78 ^{b}	693.5 ± 16.26 ^{b}	61.0 ± 7.07 ^{a,b}	342.5 ± 2.12 ^{b}
Extruded at 110 °C/30%	407.0 ± 0.00 ^{b}	392.0 ± 9.90 ^{b}	340.0 ± 1.41 ^{b,c}	688.0 ± 2.83 ^{b}	683.5 ± 7.78 ^{b}	65.5 ± 2.12 ^{a,b}	338.5 ± 0.71 ^{b}
Extruded at 110 °C/25%	492.0 ± 0.00 ^{c}	484.0 ± 4.24 ^{c}	392.5 ± 0.71 ^{c,d}	775.0 ± 4.24 ^{c}	784.5 ± 6.36 ^{c}	99.5 ± 0.71 ^{a,b}	375.0 ± 5.66 ^{c}
Extruded at 110 °C/35%	315.5 ± 16.26 ^{a}	243.0 ± 29.70 ^{a}	280.0 ± 11.31 ^{a}	585.5 ± 13.44 ^{a}	562.0 ± 15.56 ^{a}	34.0 ± 26.87 ^{a}	296.5 ± 2.12 ^{a}
Olimpija							
Unmodified flour	500.0 ± 12.73 ^{D}	329.5 ± 65.76 ^{B}	422.5 ± 13.44 ^{D}	797.0 ± 8.49 ^{C}	796.5 ± 9.19 ^{C}	77.0 ± 1.41 ^{C}	366.0 ± 21.21 ^{C}
Extruded at 90 °C/30%	359.0 ± 9.90 ^{B}	307.0 ± 0.00 ^{A,B}	329.5 ± 10.61 ^{B}	667.5 ±19.09 ^{B}	666.5 ± 31.82 ^{B}	29.0 ± 1.41 ^{B}	330.5 ± 7.78 ^{B,C}
Extruded at 100 °C/30%	349.5 ± 7.78 ^{B}	268.5 ± 6.36 ^{A,B}	325.5 ± 3.54 ^{B}	655.5 ± 3.54 ^{B}	653.0 ± 1.41 ^{B}	23.5 ± 4.95 ^{B}	322.5 ± 2.12 ^{A,B,C}
Extruded at 110 °C/30%	343.5 ± 2.12 ^{B}	271.5 ± 0.71 ^{A,B}	332.5 ± 2.12 ^{B}	647.5 ± 17.68 ^{B}	636.0 ± 12.73 ^{B}	11.5 ± 4.95 ^{A}	309.0 ± 15.56 ^{A,B}
Extruded at 110 °C/25%	417.5 ± 19.09 ^{C}	342.5 ± 14.85 ^{B}	376.0 ± 14.14 ^{C}	743.0 ± 35.36 ^{C}	747.0 ± 19.80 ^{C}	41.5 ± 6.36 ^{B}	364.5 ± 16.26 ^{C}
Extruded at 110 °C/35%	255.5 ± 4.95 ^{A}	197.5 ± 26.16 ^{A}	251.5 ± 0.71 ^{A}	534.5 ± 0.71 ^{A}	513.0 ± 5.66 ^{A}	4.5 ± 4.95 ^{A}	276.0 ± 1.41 ^{A}

Values with different superscripts are statistically different within the same wheat variety ($p<0.05$)

Table 2. Viscosity of barley flours determined by Brabender micro visco-amylograph.

Tablica 2. Viskoznost brašna ječma određena Brabenderovim micro viskoamilografom.

Sample / *Uzorak*	**Peak viscosity /** *Viskoznost vrha* (BU)	**Viscosity at 92 °C /** *Viskoznost na 92 °C* (BU)	**Viscosity after shearing at 92 °C /** *Viskoznost nakon miješanja na 92 °C* (BU)	**Viscosity at 50 °C /** *Viskoznost na 50 °C* (BU)	**Viscosity after shearing at 50 °C /** *Viskoznost nakon miješanja na 50 °C* (BU)	**Breakdown /** *Kidanje* (BU)	**Setback /** *Setback* (BU)
GZ-10							
Unmodified flour	781.0 ± 7.07 ^{d}	770.5 ± 17.68 ^{c}	506.0 ± 4.24 ^{e}	913.5 ± 4.95 ^{d}	893.0 ± 5.66 ^{d}	273.5 ± 12.02 ^{d}	397.5 ± 0.71 ^{c}
Extruded at 90 °C/30%	694.0 ± 1.41 ^{c}	452.0 ± 74.95 ^{b}	467.5 ± 0.71 ^{c}	846.0 ± 8.49 ^{c}	835.5 ± 3.54 ^{c}	222.5 ± 2.12 ^{c}	366.0 ± 7.07 ^{b,c}
Extruded at 100 °C/30%	654.0 ± 4.24 ^{b}	248.5 ± 0.71 ^{a}	460.0 ± 2.83 ^{b,c}	797.0 ± 8.49 ^{b}	796.5 ± 7.78 ^{b}	192.0 ± 1.41 ^{a,b}	328.5 ± 7.78 ^{a,b}
Extruded at 110 °C/30%	690.0 ± 5.66 ^{b}	289.0 ± 31.11 ^{a}	489.0 ± 1.41 ^{d}	842.0 ± 11.31 ^{c}	835.5 ± 10.61 ^{c}	200.5 ± 4.95 ^{b,c}	345.5 ± 12.02 ^{a,b}
Extruded at 110 °C/25%	658.5 ± 6.36 ^{c}	594.0 ± 45.25 ^{b}	454.0 ± 2.83 ^{b}	825.0 ± 16.97 ^{b,c}	816.5 ± 0.71 ^{b,c}	206.0 ± 7.07 ^{b,c}	363.5 ± 17.68 ^{b,c}
Extruded at 110 °C/35%	534.5 ± 2.12 ^{a}	531.5 ± 6.36 ^{b}	360.0 ± 2.83 ^{a}	691.5 ± 2.12 ^{a}	686.5 ± 0.71 ^{a}	172.5 ± 2.12 ^{a}	321.5 ± 2.12 ^{a}
GZ-11							
Unmodified flour	766.5 ± 0.71 ^{D}	738.0 ± 21.21 ^{C}	483.0 ± 9.90 ^{C}	852.0 ± 7.07 ^{C}	850.0 ± 2.83 ^{C}	283.0 ± 11.31 ^{C}	360.0 ± 4.24 ^{A}
Extruded at 90 °C/30%	724.0 ± 2.83 ^{C}	393.0 ± 35.36 ^{A}	490.5 ± 3.54 ^{C}	865.0 ± 5.66 ^{C}	849.0 ± 1.41 ^{C}	232.5 ± 6.36 ^{B}	366.0 ± 2.83 ^{A}
Extruded at 100 °C/30%	698.5 ± 0.71 ^{B}	430.5 ± 53.03 ^{A}	481.5 ± 4.95 ^{C}	847.0 ± 1.41 ^{C}	838.0 ± 0.00 ^{C}	215.0 ± 5.66 ^{B}	355.5 ± 3.54 ^{A}
Extruded at 110 °C/30%	692.0 ± 2.83 ^{B}	389.0 ± 5.66 ^{A}	479.5 ± 0.71 ^{C}	847.0 ± 19.80 ^{C}	831.5 ± 12.02 ^{C}	212.5 ± 3.54 ^{B}	360.5 ± 21.92 ^{A}
Extruded at 110 °C/25%	699.5 ± 2.12 ^{B}	697.0 ± 2.83 ^{C}	433.0 ± 2.83 ^{B}	790.5 ± 2.12 ^{B}	783.5 ± 7.78 ^{B}	264.5 ± 0.71 ^{C}	349.0 ± 0.00 ^{A}
Extruded at 110 °C/35%	563.5 ± 2.12 ^{A}	560.0 ± 7.07 ^{B}	387.0 ± 2.83 ^{A}	728.0 ± 9.90 ^{A}	737.0 ± 9.90 ^{A}	175.0 ± 1.41 ^{A}	332.5 ± 10.61 ^{A}

*Values with different superscripts are statistically different within the same barley variety ($p<0.05$)

Along with starch, the important component of flour is gluten, properties of which are reflected through farinographic parameters. The results of farinograph analysis are presented in Table 3. Unextruded wheat flour had larger values of absorption, dough development, stability, resistance and Farinograph quality number than barley flour. Olimpija flour is in the quality group A1 and Kraljica in A2, while barley flours fall within B2 (GZ-11) and C1 (GZ-10) quality groups according to Hankoczy table. Olimpija flour may be used to improve properties of less quality flours, while Kraljica is an excellent flour for bread-making.

Table 3. Farinographic properties of wheat (Kraljica, Olimpija) and barley (GZ-10, GZ-11) flours.

Tablica 3. Farinografska svojstva brašna pšenice (Kraljica, Olimpija) i ječma (GZ-10, GZ-11).

Sample / *Uzorak*	**Absorption** / *Apsorpcija* (%)	**Dough development** / *Razvoj tijesta* (min)	**Stability** / *Stabilnost* (min)	**Resistance** / *Otpor* (min)	**Degree of softening** / *Stupanj omekšanja* (FJ)	**Farinograph Quality Number** / *Farinografski broj kvalitete* (FQN)	**Quality Group** / *Skupina kvalitete*
Wheat Kraljica							
Unmodified flour	60.8	5.8	0.5	6.3	74	87	A2
Extruded at 90 °C	87.4	8.4	8.1	16.5	0	200	A1
Extruded at 100 °C	89.2	17.1	0.2	17.3	34	200	A1
Extruded at 110 °C	91.6	7.6	3.8	11.3	0	200	A1
Extruded at 25% moisture	77.6	6.3	8.9	15.2	0	200	A1
Extruded at 30% moisture	91.6	7.6	3.8	11.3	0	200	A1
Extruded at 35% moisture	115	6.3	7.3	13.6	87	200	A1
Wheat Olimpija							
Unmodified flour	60.4	6.7	2.1	8.8	5	168	A1
Extruded at 90 °C	88.8	15.4	3.1	18.5	24	200	A1
Extruded at 100 °C	91.1	18.5	1.2	19.7	32	200	A1
Extruded at 110 °C	93.1	10.5	0	10.5	58	109	A1
Extruded at 25% moisture	74.7	14.7	4.7	19.3	11	200	A1
Extruded at 30% moisture	93.1	10.5	0	10.5	58	109	A1
Extruded at 35% moisture	112.6	9.8	1.1	10.8	91	156	A1
Barley GZ-10							
Unmodified flour	59.1	1.2	0.4	1.6	110	21	C1
Extruded at 90 °C	77.9	8.9	0	8.9	50	89	A2
Extruded at 100 °C	79.7	15.5	1.3	16.8	48	170	A1
Extruded at 110 °C	89.2	9.1	0.1	9.2	67	93	A2
Extruded at 25% moisture	87	15.7	0	15.7	84	157	A1
Extruded at 30% moisture	89.2	9.1	0.1	9.2	57	93	A2
Extruded at 35% moisture	102.1	10.9	0.4	11.3	52	130	A1
Barley GZ-11							
Unmodified flour	61	1.1	0.4	1.5	105	24	B2
Extruded at 90 °C	72.5	15.7	0	15.7	0	158	A1
Extruded at 100 °C	73.8	14.7	0.1	14.9	0	153	A1
Extruded at 110 °C	82.5	20	0	20	0	200	A1
Extruded at 25% moisture	88.4	5.7	1.5	7.2	37	107	A2
Extruded at 30% moisture	82.5	20	0	20	0	200	A1
Extruded at 35% moisture	103	18.6	1.3	20	115	200	A1

After the extrusion, dough development time increased for analysed samples, along with Farinograph quality number and all samples fall into A1 quality group, except GZ-10 flours extruded at die temperature 90 °C and 110 °C, which fall into A2 category. Overall, these results indicate that extrusion improves gluten quality. However, stability of the dough is not reflecting this – according to Diosi et al. (2015) minimum stability for A quality group is 10 min, for B1 6 min and for B2 4 min. Considering this, none of the flours investigated in the present research can be considered quality enough. All of them have a very low stability, barley flours even below 1.5 min. Aly et al. (2021) ascribed the low stability of barley flour to its large contents of fiber and "dilution" of starch-gluten network due to it, and Rolandelli et al. (2021) reported agglomeration and denaturation of protein and gelatinisation of starch after extrusion of maize flour. All these changes on molecular level induce changes in dough properties.

The low stability of proteins determined by farinograph is supported with the results for sedimentation (Fig. 1), which is also an indicator of protein quality (Keceli et al., 2021). While unmodified wheat flours had sedimentation values of 40 and 46 mL, showing a good quality of proteins, extruded flours had values below 10 mL, showing weak gluten properties. Takač et al. (2021) reported sedimentation values 20 – 60 mL for different wheat cultivars grown in Serbia and Hungary, and Nadeem et al. (2021) reported values 24.99 – 25.85 mL for wheat varieties grown in Pakistan. Barley flours, both non-extruded and extruded had very low sedimentation values, indicating poor gluten properties, which is due to presence of hordeins which have inferior properties to gliadins (Rosentrater and Evers, 2017). Extrusion had a more pronounced effect on sedimentation values of GZ-10 cultivar than on GZ-11, with linear decrease of the values with the increase of the die temperature. This indicates that proteins of GZ-10 cultivar underwent more severe changes induced by heat and pressure, however, as Rolandelli et al. (2021) have reported, the changes on molecular level are more complex and should be investigated more thoroughly in the present case.

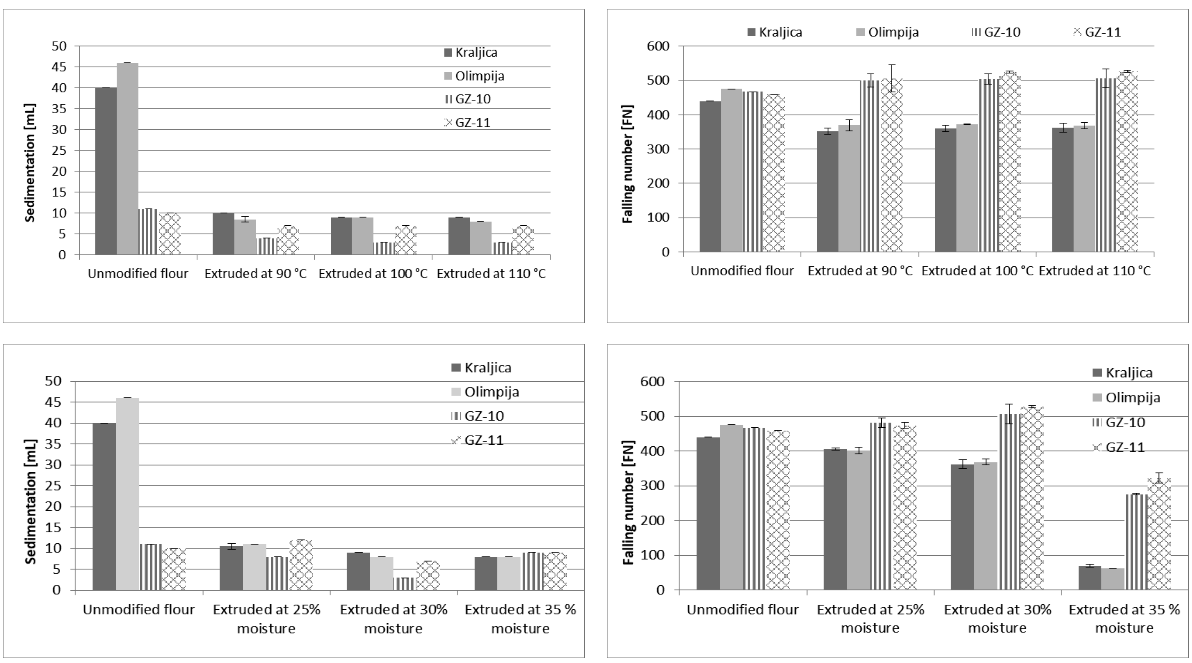

Figure 1. Sedimentation and Falling number of wheat (Kraljica, Olimpija) and barley (GZ-10, GZ-11) flours.
Grafikon 1. Sedimentacija i broj padanja brašna pšenice (Kraljica, Olimpija) i ječma (GZ-10, GZ-11).

Another property important for the quality of flour is enzyme activity, measured through falling number. According to Rosentrater and Evers (2017), values of 329 – 334 are suitable for production of wheat breads, whereas rye flour with values 80 – 110 may be used in combination with additives for improving dough quality. The results of determination of falling number in this research are shown in Fig. 1. Unmodified flours had falling number values between 440 and 475. While extrusion caused decrease of falling number for wheat (352 – 369.5), the values of barley flours were increased by the process (500 – 527), without major influence of the die temperature. Rosentrater and Evers (2017) state that extrusion may be used for the inactivation of alpha-amylase in flours for production of flatbread, snacks and biscuits and the results for barley obtained in this research are confirming this. The results for wheat, however, may not necessarily be the result of higher amylase activity, but reflect the decrease of viscosity instead, as according to the same authors, hydrolysis of proteins and cell-wall components may also be reflected in the results, although comparatively small.

The influence of flour moisture

To explore the influence of flour moisture on properties of extruded flours, the moisture of the flours was set to 25%, 30% and 35%, and flours were extruded at the die temperature 110 °C. All measured viscosities of wheat flours (Table 1) decreased as moisture of the flours increased. Breakdown values of wheat flours were significantly lower, proportionally to the increase of the moisture content, with the Olimpija flour extruded at 35% moisture being the most stable during shearing at high temperatures (breakdown value 4.5 ± 4.95 BU). The differences in setback values of wheat flours were not as large as in the breakdown, however, extruded flours were less prone to starch retrogradation than the unmodified one.

For barley, however, the highest values of the viscosities were determined for the flour extruded at 30% of moisture, and the differences between values of viscosities of extruded and the unmodified flours were not so marked (Table 2). Breakdown and setback values were lower for extruded flours in both cultivars, with the most stable GZ-10 flour extruded at 35% moisture.

Jafari et al. (2017) reported that starch granules of extruded sorghum flour had absorbed water more slowly. The same could be the reason for lower viscosity and breakdown values of extruded flours in the present research. Unlike in the present research, Luo and Koksel (2020) reported higher setback values with higher moisture for extruded yellow pea flour. They have linked this to the fact that high friction during extrusion caused by lower moisture causes larger degradation of starch molecules.

The changes on proteins due to extrusion are evident from markedly prolonged dough development time for barley flours – from 1.2 min to 9.1 – 15.7 min for GZ-10 and from 1.1 min to 5.7 – 20 min for GZ-11 (Table 3). For wheat flours the changes are not so marked, but they also increased from 5.8 to 6.3 – 7.6 min for Kraljica and from 6.7 to 9.8 – 14.7 min for Olimpija. For Kraljica wheat flour, increased dough stability may be observed as well (0.5 min for unmodified flour in relation to 3.8 – 8.9 min for extruded). Dough stability of other flours was not largely influenced by extrusion, but farinograph quality number increased, with the major changes in barley flours: from 21 to 93 – 157 for GZ-10 and from 24 to 107-200 for GR-11. Again, quality of flour improved to A2 – A1 group according to Hankoczy table, however, minimum dough stability time of 10 min according to Diosi et al. (2015) was not achieved.

Sedimentation values for wheat flour significantly dropped by extrusion. Although there is no marked difference between the values of extruded flours, it may be observed that the increase of moisture decreased sedimentation values. For barley flours, however, there is no such trend. While GZ-10 flour extruded at 25% and 30% moisture had lower values of sedimentation in relation to unextruded flour, flour extruded at 35% moisture had the value close to the unextruded one. The sedimentation value of GZ-11 flour extruded at 25% moisture was higher than for the unextruded counterpart, which was close to flour extruded at 35% moisture. Apparently, proteins are not equally susceptible to changes not only with regard to species, but to variety as well. The complexity of interactions between flour components and the factors influencing the susceptibility of individual proteins should be investigated better.

Falling number of wheat flour extruded at 35% moisture was markedly lower than all other investigated flours, with values below 70, indicating very high amylase activity, but these values should be taken with caution, since the viscosities of these flours were also the lowest and probably had an effect on the measured falling number values. All other flours had a low amylase activity, with values above 250. The inhibitory effect of extrusion on amylase activity may be observed for barley flours extruded at 25% and 30% moisture, which had larger values than unextruded counterparts.

CONCLUSIONS

Extrusion may be used as a tool to modify starch and protein properties of wheat and barley flours. Generally, viscosity of the flours is decreased, absorption and dough development time are increased, along with Farinograph and Hankoczy quality values. With proper selection of flour type, moisture and extrusion conditions, sedimentation values may be adjusted to desired application of flour, and alpha-amylase activity may be inhibited. Additional research is needed to reveal exact mechanisms underlying these changes.

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UTJECAJ EKSTRUZIJE NA FUNKCIONALNA SVOJSTVA ODABRANIH SORTI PŠENICE I JEČMA UZGOJENIH U HRVATSKOJ

SAŽETAK

Cilj ovog istraživanja bio je odrediti utjecaj temperature na izlazu ekstrudera (90, 100, 110 °C) i vlažnosti brašna (25, 30, 35 %) na svojstva brašna pšenice (Kraljica, Olimpija) i golozrnog ječma (GZ-10, GZ-11) modificiranih ekstruzijom. Brašna su ekstrudirana u jednopužnom laboratorijskom ekstruderu te su određena mikro viskoamilografska, farinografska svojstva, sedimentacija i proj padanja. Rezultati su pokazali da se viskoznost brašna smanjuje, a stabilnost brašna povećava nakon ekstruzije, i to i tijekom miješanja na visokim temperaturama i po pitanju sklonosti retrogradaciji. Iako su brašna ječma bila u skupinama kvalitete B2 i C1 prije ekstruzije, nakon ekstruzije sva ispitivana brašna bila su u skupini A1 ili A2. nakon ekstruzije značajno su opale vrijednosti sedimentacije, a broj padanja ovisio je o uvjetima ekstruzije. Pomnim odabirom sorte, vlažnosti brašna i uvjeta ekstruzije mogu se proizvedi brašna željenih svojstava.

Ključne riječi: brašna pšenice i golozrnog ječma, ekstruzija, mikro viskoamilograf, farinograf, sedimentacija, broj padanja.

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