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Effect of screw configuration, moisture content and particle size of corn grits on properties of extrudates

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Summary

Extrusion is a modern procedure for processing different types of raw materials and production of wide range of food products, where the corn grits are often used as main raw materials. Therefore the aim of this study was to determine the effect of screw configuration (4:1 and 1:1), moisture content (15% and 20%) and particle size of corn grits (>500 µm and <500 µm) on properties of extrudates. Samples were extruded in the laboratory single screw extruder Brabender 19/20 DN, at temperature profile 135/170/170 °C, using die with 4 mm diameter. Physical and rheological properties, digestibility and starch damage of the obtained extrudates were determined, and results were compared with control samples of non-extruded corn grits. Lower moisture content and usage of screw with compression ratio 4:1 increased expansion ratio and fracturability, but decreased bulk density and hardness of extrudates, regardless of granularity. After extrusion process water absorption index increased, but peak, hot and cold viscosity of all samples decreased, with more pronounced effect in grits extruded with lower moisture content and with screw 4:1. Extrusion caused a reduction of the resistant starch content and increase starch damage of all samples.

Keywords: extrusion, corn grits, particle size, moisture content, screw configuration

Introduction

Extrusion cooking of cereals is a very important process in food industry, since it regards a wide range of products such as snack-foods, baby-foods, breakfast cereals, noodle, pasta and cereals based blends (Semaska et al., 2010). Extruders minimize the operating costs and higher productivity than other cooking process, combining energy efficiency and versatility (Ficarella et al., 2004). Corn meal is a major ingredient for extruded foods, such as ready-to-eat breakfast cereals and snacks (Gujral et al., 2001). The effect of various process variables (moisture content, particle size, screw configuration) on extrusion behavior of corn grits and other flours have been extensively studied (Onwulata and Konstace, 2006; Delgado-Licon et al., 2009; Garber et al., 1997; Curic et al., 2009; Hood-Niefer and Tyler, 2010; Qi and Onwulata, 2011; Altan et al., 2009; Chuang and Yeh, 2004; Desrumaux et al., 1998; Carvalho et al., 2010). Rayas-Duarte et al. (1998) reported that samples prepared and extruded with the lowest moisture content have the largest water absorption and expansion index. Altan et al. (2009) investigated effect of screw configuration on properties of barley extrudates and reported that severe screw

configuration produced more expanded product with low bulk density than that of medium screw configuration. Desrumaux et al. (1998) reported that increase in particle size for a given biochemical composition gave extrudates that were harder, with a modified expansion and lower cell density. Onwulata and Konstace (2006) reported that smaller particle size fractions exhibited increased solubility and significantly higher viscosity. Kebede et al. (2010) reported that increased barrel temperature, reduced feed moisture content and a higher screw speed showed a significantly ($P < 0.01$) higher radial expansion, reduced bulk density and less compression resistance of teff flour extrudates. Carvalho et al. (2010) reported that extrudates produced with corn meal of higher particle sizes expanded more than extrudates produced with smaller particle sizes, and that increasing corn meal particle size decreased water absorption index (WAI) values.

The aim of this research was to determine the effect of screw configuration (4:1 and 1:1), moisture content (15% and 20%) and particle size of corn grits (>500 µm and <500 µm) on properties of extrudates – physical and rheological properties, digestibility and starch damage.

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Materials and methods

Corn grits used in this study, with different particle size ($>500 \mu\text{m}$ and $<500 \mu\text{m}$), were obtained from the mill „Đakovo“ of the „Žito“ Company Ltd. Osijek. Particle size of grits was determined by sifting grits through series of sieves on analytical sieve shaker model AS200, Retsch GmbH.

Moisture content of corn grits was set to 15% and 20%, and then samples were extruded in the laboratory single screw extruder Do-Coder, Brabender 19/20 DN, GmbH, Duisburg, Germany. *Extrusion parameters* were as follows: screw: 4:1 and 1:1; die: 4 mm; temperature profile: 135/170/170 °C. Obtained extrudates were air-dried at ambient temperature over night to achieve moisture content $90 \pm 2\%$.

Extrudate diameter and *expansion ratio (ER)* were measured according to Brnčić et al. (2008), where expansion ratio was calculated as follows (Eq. 1):

$$ER = \text{extrudate diameter (mm)} / \text{die diameter (mm)} \quad (1)$$

Bulk density (BD) of extrudates was measured according to Pan et al. (1998) and calculated according to Eq. 2:

$$BD = \text{extrudate mass (g)} / \text{extrudate volume (cm}^3\text{)} \quad (2)$$

Texture analysis was performed on texturometer TA.XT2 Plus, Stable Microsystem using method „Measurement of the hardness and fracturability of pretzel sticks“ with following settings: Pre-Test Speed: 1.0 mm/s; Test Speed: 1.0 mm/s; Post-Test Speed: 10.0 mm/s; Distance: 3 mm; Trigger Type: Auto – 5 g.

Water absorption index (WAI) was determined according to Sosulski (1962).

Pasting properties of extrudates (10% d. m., 100 g total weight) were measured using a Micro Visco-Analyser (Model 803202, Brabender GmbH & Co KG, Duisburg, Germany) according to standard method supplied with the apparatus. The flour suspensions were heated at 7.5 °C/min from 32 to 92 °C, held at 92 °C for 10 min, cooled at 7.5 °C/min to 50 °C, and held at 50 °C for 1 min.

Starch damage was determined according to AACC Method 76-31, and *resistant starch content* according to AOAC 2002.02 method.

Experimental data were analyzed by analysis of variance (ANOVA) and Fisher's least significant difference (LSD) with significance defined at $P < 0.05$. All statistical analyses were carried out using software program STATISTICA 10.0 (StatSoft, Inc, USA).

Results and discussion

Effect of screw configuration, moisture content and particle size of corn grits on properties of extrudates is shown in Fig. 1. Extrudates prepared at lower moisture content and with screw configuration 4:1 were more expanded, regardless of corn grits granularity. These results are in accordance with other researches (Kebede et al., 2010; Onwulata and Konstance, 2006; Altan et al., 2009). The cross-sectional expansion index (SEI) was increased with a decrease in water injection rate and/or an increase in barrel temperature (Ryu and Ng, 2001). Extrudates produced with corn meal of higher particle sizes expanded more than extrudates produced with smaller particle sizes (Carvalho et al., 2010).

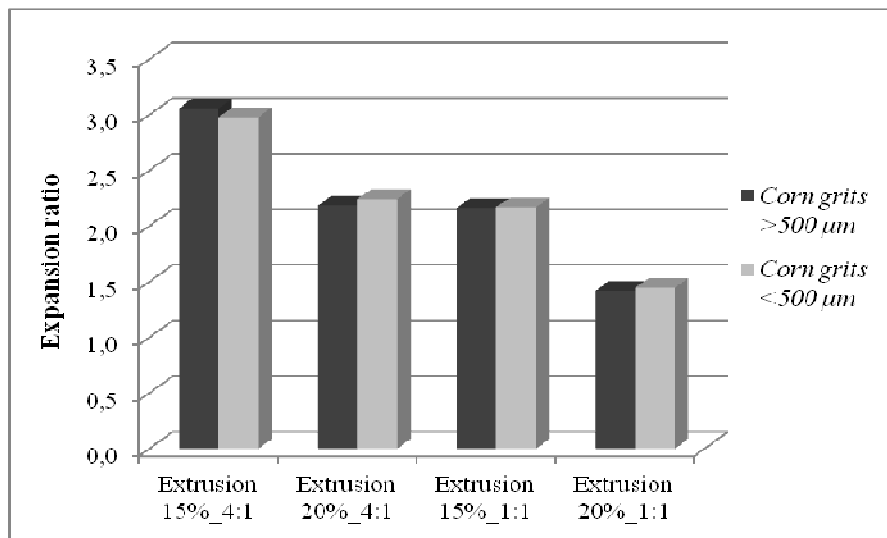


Fig. 1. Expansion ratio of corn grits extrudates

Bulk density (BD) of extrudates was higher when samples were extruded at higher moisture content and with usage screw configuration 1:1 (Fig. 2). The results obtained by measuring the bulk density are in accordance with the results of measurements of the expansion ratio i.e. extrudates with lower values of the diameter and expansion ratio had higher bulk density. The lowest BD value was obtained when rice flour was extruded at lower

moisture contents and higher temperatures, whereas the highest value was obtained at higher moisture contents and lower temperatures (Hagenimana et al., 2006). Other researches also show the same trend, where is concluded that an increase of moisture content increased bulk density of extrudates (Ding et al., 2005, 2006; Thymi et al., 2005; Garber et al., 1997), which confirms the results obtained in this investigation.

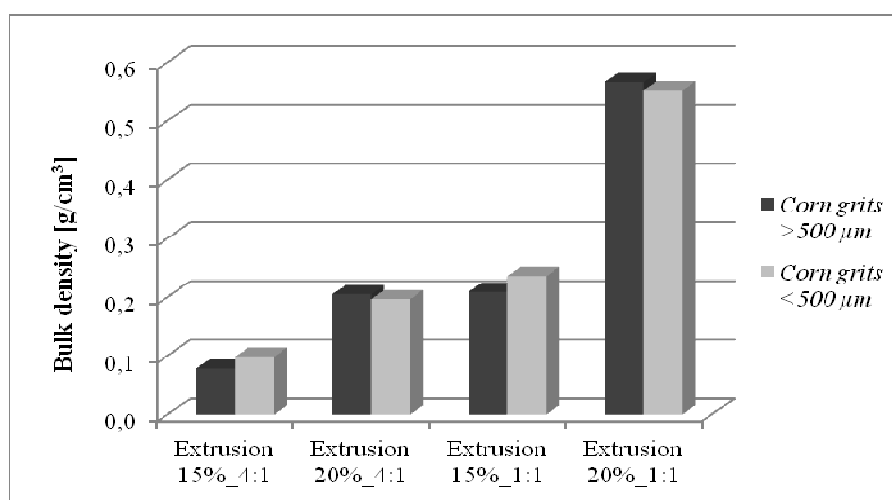


Fig. 2. Bulk density of corn grits extrudates

Texture properties of extrudates are highly influenced by expansion degree (Anton et al., 2009). This is in accordance with this research, since extrudates with lower expansion ratio had higher hardness and lower fracturability (Fig. 3, Fig. 4). Extrudates extruded at higher moisture content and with usage screw 1:1 had higher hardness and lower fracturability, regardless of corn grits granularity. Many studies have shown

that the greatest impact on the texture of extrudates has moisture content (Brnčić et al., 2006; Petrova et al., 2010), but also other parameters (temperature, screw configuration, screw speed,...) are very important and were subjects of many papers (Lazou and Krokida, 2010; Mendonca et al., 2000; Saeleaw et al., 2012; Wu et al., 2007).

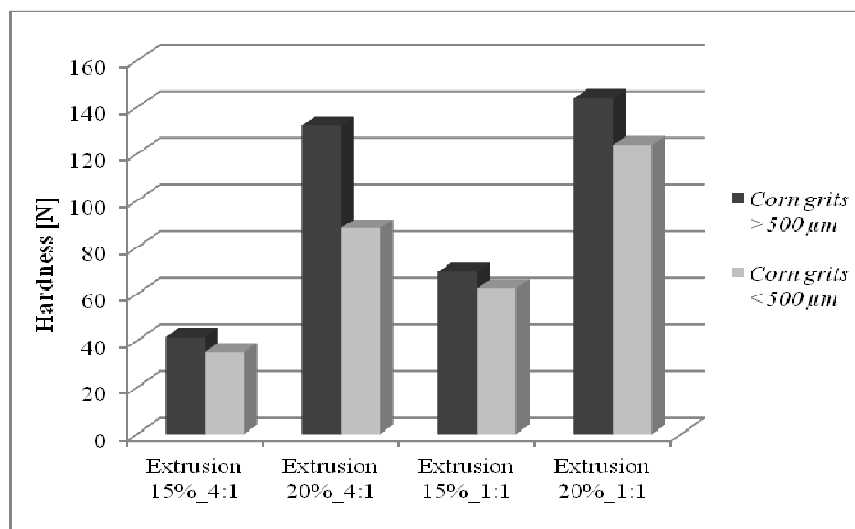


Fig. 3. Hardness of corn grits extrudates

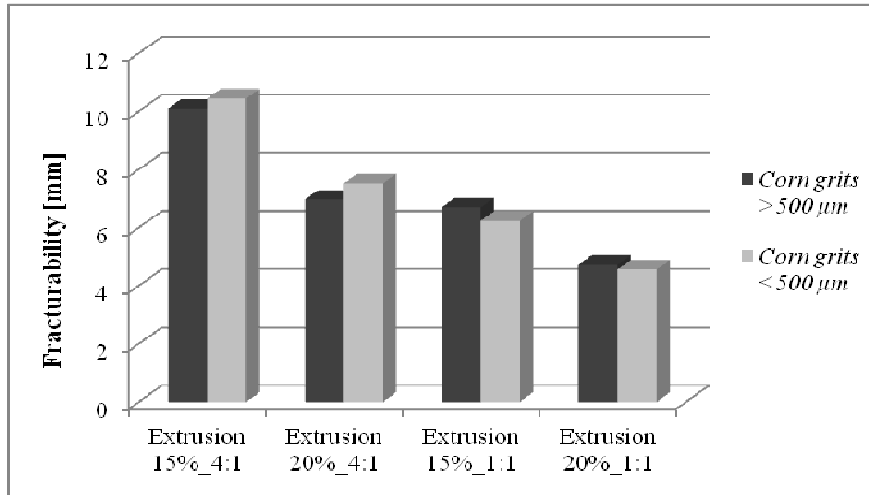


Fig. 4. Fracturability of corn grits extrudates

Water absorption index (WAI) values of all extruded samples were significantly higher compared to non-extruded corn grits, and the greater values were in more expanded extrudates (Fig. 5). Ding et al. (2005, 2006) concluded that the increase in moisture content results in extrudates with lower water absorption

index values. Increasing corn meal particle size decreased WAI values (Carvalho et al., 2010). One more study, which is in accordance with the results obtained in this work, concluded that extrusion causes an increase in water absorption index (Larrea et al., 2005).

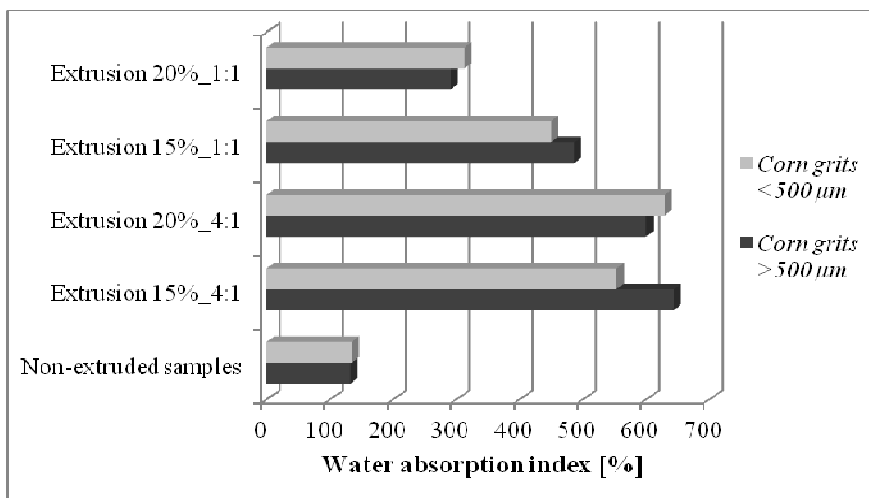


Fig. 5. Water absorption index (WAI) of non-extruded and extruded corn grits

In Table 1 pasting properties of non-extruded and extruded corn grits are shown. Extrusion resulted in decrease of peak, hot and cold viscosity of all samples. Decrease of peak viscosity is correlated to effect of extrusion on higher degradation and gelatinisation of starch (Hagenimana et al., 2006). Peak viscosity was lower at higher moisture content in extrusion using screw 4:1, but on the other hand, in extrusion using screw 1:1 peak viscosity was lower at lower moisture

content. Gutkoski and El-Dash (1999) reported that initial viscosity of the paste increased with the increase of raw material moisture and extrusion temperature, while the maximum viscosity (at a constant temperature) decreased with the increase of temperature. Peak viscosity of corn grits with higher particle size was lower in non-extruded samples, but higher in all extruded samples. After heating and mixing on 92 °C viscosity of all samples decreased, and

then after cooling on 50 °C viscosity of all samples marked increased, as a result of starch retrogradation during cooling. Viscosity values at 50 °C of non-extruded samples were higher in regards to all extruded samples. This is in accordance to other researches

(Hagenimana et al., 2006; McPherson et al., 2000). Extrusion process partially damages starch granules, thus obtained gels of extruded products have lower viscosity than the initial grits (Dokić et al., 2009).

Table 1. Pasting properties of non-extruded and extruded corn grits

Sample	Peak viscosity [BU]	Viscosity at 92 °C [BU]	After mixing at 92 °C [BU]	Viscosity at 50 °C [BU]
Non-extruded samples				
<i>Corn grits >500 µm</i>	484.5 ± 18.5 ^a	112 ± 4.0 ^a	477.5 ± 21.5 ^a	809 ± 21.0 ^a
<i>Corn grits <500 µm</i>	502 ± 1.0 ^a	342.5 ± 1.5 ^b	475.5 ± 1.5 ^a	877 ± 2.0 ^a
Extrusion 15% 4:1				
<i>Corn grits >500 µm</i>	253 ± 36.0 ^a	154.5 ± 6.5 ^a	153 ± 9.0 ^a	242 ± 6.0 ^a
<i>Corn grits <500 µm</i>	230.5 ± 9.5 ^a	141 ± 3.0 ^a	137 ± 1.0 ^a	209 ± 4.0 ^a
Extrusion 20% 4:1				
<i>Corn grits >500 µm</i>	212 ± 18.0 ^a	191 ± 20.0 ^a	185 ± 3.0 ^a	293.5 ± 6.5 ^a
<i>Corn grits <500 µm</i>	181.5 ± 9.5 ^a	155 ± 2.0 ^a	165 ± 4.0 ^a	279 ± 4.0 ^a
Extrusion 15% 1:1				
<i>Corn grits >500 µm</i>	130 ± 5.0 ^a	107.5 ± 3.5 ^b	116.5 ± 7.5 ^a	172.5 ± 3.5 ^b
<i>Corn grits <500 µm</i>	128 ± 2.0 ^a	89 ± 0.0 ^a	91 ± 1.0 ^a	145 ± 2.0 ^a
Extrusion 20% 1:1				
<i>Corn grits >500 µm</i>	255.5 ± 1.5 ^a	213.5 ± 0.5 ^a	254.5 ± 1.5 ^a	474 ± 3.0 ^a
<i>Corn grits <500 µm</i>	250 ± 1.0 ^a	233 ± 2.0 ^a	246 ± 0.0 ^a	444 ± 1.0 ^a

Starch damage significantly increased and resistant starch (RS) content decreased after extrusion of all samples (Fig. 6, Fig. 7). This is in accordance to conclusion of Mendoza and Bresaani (1987) and

Hagenimana et al. (2006). RS content was higher, before and after extrusion, in corn grits with higher particle size.

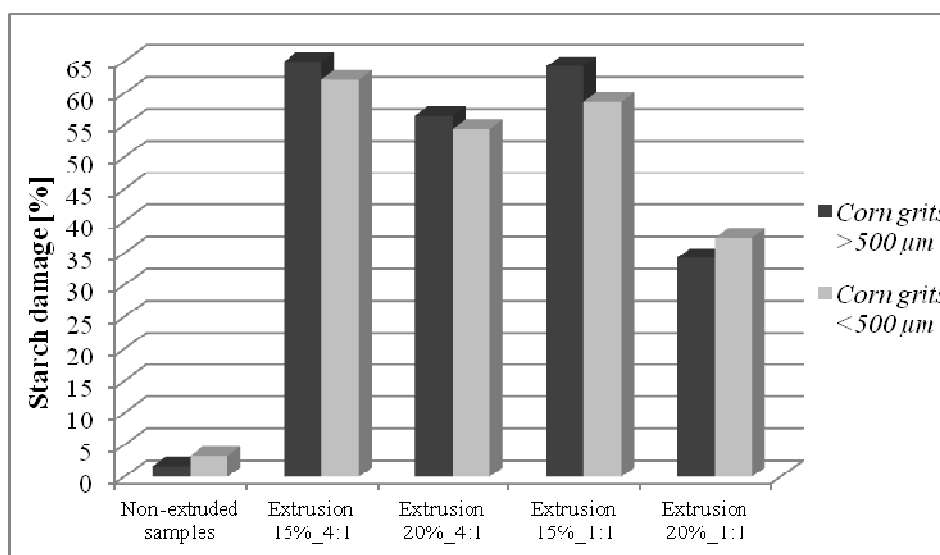


Fig. 6. Starch damage of non-extruded and extruded corn grits

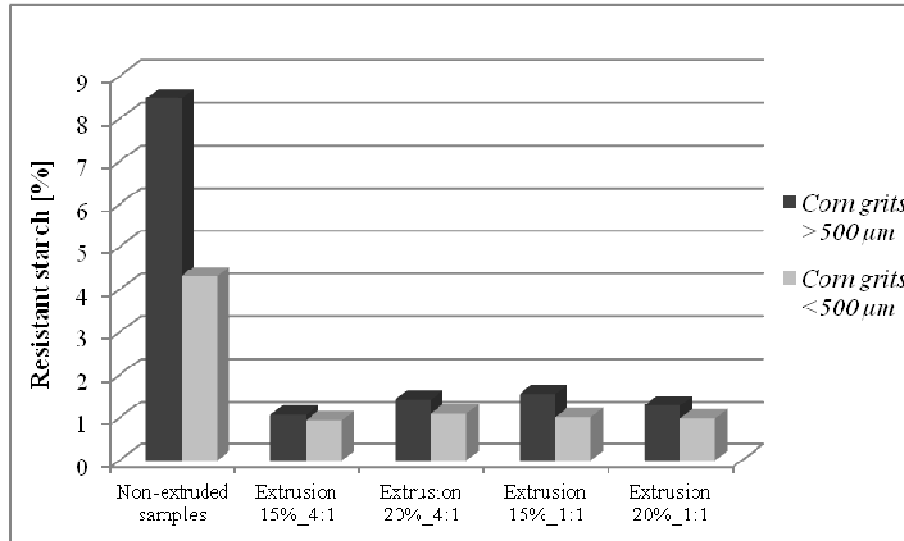


Fig. 7. Resistant starch content of non-extruded and extruded corn grits

Conclusions

This research was conducted to investigate the parameters of extrusion for preparation corn grits „snack“ products with desirable physical properties. Extrudates prepared at lower moisture content and with screw configuration 4:1 were more expanded, regardless of corn grits granularity. The results for bulk density and texture properties are in accordance with the results of measurements of the expansion ratio i.e. extrudates with lower values of the diameter and expansion ratio had higher bulk density and hardness and lower fracturability. Water absorption index values of all extruded samples were significantly higher compared to non-extruded corn grits. Extrusion resulted in decrease of peak, hot and cold viscosity of all samples. Starch damage significantly increased and resistant starch (RS) content decreased after extrusion.

The results obtained in this research indicate that screw with compression ratio 4:1 and corn grits with higher particle size and with lower moisture content results in products with better physical properties in regardless to products obtained with screw 1:1 and with corn grits with smaller particle size and with higher moisture content.

Acknowledgments

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