PROPERTIES OF EXTRUDED SNACKS SUPPLEMENTED WITH AMARANTH GRAIN GRITS

Ljubica P. Dokić, Marija I. Bodroža-Solarov, Miroslav S. Hadnađev and Ivana R. Nikolić

Extruded amaranth grain products have specific aroma and can be used as snack food, supplement in breakfast cereals, or as raw material for further processing. Extruded products of corn-amaranth grits blends, containing 20% or 50% amaranth grain grits, were produced by extrusion-cooking using a laboratory Brabender single screw extruder 20 DN. Extrudates with various texture were obtained.

During extrusion process starch granules are partially degraded, hence rheological properties were examined. All samples exhibited thixotropic flow behavior. Those samples in which part of the corn grits was replaced with amaranth one had lower viscosity and exhibited lower level of structuration during storage.

KEY WORDS: Amaranth, extrudate, proteins, starch, rheological, properties

INTRODUCTION

Amaranth grain has significant nutritional value. Its protein, mineral meters, fat and cellulose percentage are higher compared to cereals (1, 2). Since this plant has similar application as cereals, it is classified as pseudocereal (2). The origin of Amaranthus sp. is from middle and south America, but for the last few decades this cultivar was introduced in European countries as Austria, Poland, Hungary, Serbia and Montenegro (2, 3).

Extruded amaranth grain products have specific aroma and can be used as snack food, supplement in breakfast cereals, or as raw material for further processing (4). Sanches–Marroquim et al. investigated extruded blends of Amaranth with wheat and outs flour. The optimal combination of these components, to their opinion is 50:50, or 60:40, respectively (5).

Starch is an important industrial raw material for food products as well as for technical products. Corn starch is relatively easily isolated by wet-milling procedure. Amaranth
starch is interesting because of its small granular size, 1–2 \( \mu m \), which provides specific functional properties, as good freeze–thaw stability and resistance to mechanical shear. Amaranth starch content is approximately 63%, while protein content is 15%. The starch has “waxy” characteristics and specific molecular composition, while proteins have high quality and major content of S–amino acids and lysine (6).

There is no effective and easy method to isolate the starch from amaranth seed because of its small granules and high protein content. Considering the fact that starch and protein are of high quality, some other methods were developed, like dry milling and separation or extrusion process with the aim to provide products useful for food or non-food purposes. During extrusion process, properties of native starch granules are modified and pregelatinized starch with changed rheological characteristics is obtained (7).

Numerous products with starch undergo thermal treatments during production and application, when starch gels with specific rheological characteristics are formed. Modification of rheological properties can be achieved by mixing different starches. The aim of this work was to investigate rheological characteristics of gels of amaranth and corn grits blends, before and after extrusion process.

**EXPERIMENTAL**

Amaranth and corn were acquired from local commercial sources. Grits was obtained by milling whole grain in laboratory mill (Bühler 202, Germany). Blends were prepared in the following ratios: amaranth:corn, 20:80, 50:50 and 0:100, respectively. Particle size distribution of grits is presented in Table 1.

<table>
<thead>
<tr>
<th>Sample</th>
<th>850 ( \mu m )</th>
<th>650 ( \mu m )</th>
<th>450 ( \mu m )</th>
<th>350 ( \mu m )</th>
<th>250 ( \mu m )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn grits</td>
<td>1.2</td>
<td>44.1</td>
<td>50.3</td>
<td>3.7</td>
<td>0.7</td>
</tr>
<tr>
<td>Amaranth grits</td>
<td>0.8</td>
<td>43.0</td>
<td>41.2</td>
<td>9.0</td>
<td>6.0</td>
</tr>
</tbody>
</table>

Grits blends were extruded using a laboratory Brabender single screw extruder 20 DN. Before extrusion, the moisture content of the grits was adjusted to 16%. Such moisture content enables optimal extrusion conditions.

It was fed to the extruder under the following conditions:

- **Compression ratio**: 4:1
- **Temperature of the first zone**: 120°C
- **Temperature of the second zone**: 130°C
- **Temperature of the third zone**: 160°C
- **Die diameter**: 3 mm
- **Screw speed**: 120 rpm

The extruded product (flips) was analyzed for moisture (AOAC, 1984, 8), bulk density and expansion ratio.
Extrudate density was calculated. Six products were randomly selected, weighted (m) and measured (L, D), and the density was calculated as follows:

\[
\text{Density} = \frac{4 \times m}{\pi \times D \times L}
\]

where \( m \) is the mass, \( L \) – length of cooled extrudate with the diameter \( D \) (9).

Expansion ratio was calculated as the ratio of the diameter of extruded simple to that of the extruded die.

Density and expansion ratio are given as average value of six calculations.

**Statistical Analysis.** Analysis of variance (ANOVA) and least significant differences (LSD) were performed by the Statistical Analysis System (Statistical, Tulsa, Oklahoma, USA).

Strength, hardness and plasticity were determined on a universal instrument for texture analysis INSTRON 4301. Determination of hardness was performed with head with 1.6 mm diameter running at speed of 60 mm/min. Softness of sample by cutting was examined using knife with 1 mm blade and at head speed of 60 mm/min. Probe for compression with 30 mm diameter was used to examine the force needed to compress extrudate from 1 cm length to 0.5 cm at the Instron head speed of 48 mm/min. The measurements were performed in the six replicates and average value for strength, hardness and plasticity were calculated.

The gels for rheological measurements were obtained by heating 6.25% suspension of grits, in a Brabender viscoamylograph up to 95°C and then held at 95°C for 30 min. Gels were made from grits blends as well as from extruded products milled to grits on a laboratory mill. The obtained paste was cooled to room temperature and rheological measurements of the gels were carried out at 20°C. Measurements were carried out right after the cooling (0h) and 24 hours later (24h). Rheometer RheoStress 600HP (Haake, Germany) with measurement set plate–plate (PP60Ti), with 60 mm diameter and 1 mm distance, was used. Flow curves were obtained by hysteresis loop method by the following cycle:

- ramp up 0-500 1/s in 4 min
- constant \( \gamma \) 500 1/s in 2 min
- ramp down 500-0 1/s in 4 min.

Micrographs were taken on a scanning electron microscope (JEOL–JSM–6460LV).

**RESULTS AND DISCUSSION**

Results of the determination of expansion index and density of extrudates are presented in Table 2.

The initial moisture level drop from 16% to the final average level of 7.5% for extrudates, was within the expected range of 4-8%, reported by Koeppel (1987) as characteristic for an extruded snack products. The difference in moisture content of extrudates is not statistically important (Table 2).
Table 2. Extrudate properties

<table>
<thead>
<tr>
<th>Sample</th>
<th>Moisture content (%) (db)</th>
<th>Expansion index</th>
<th>Density (g/cm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100% corn grits</td>
<td>7.6 ± 0.09&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.03 ± 0.21&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.095 ± 0.02&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>80% corn : 20% amaranth grits</td>
<td>7.4 ± 0.03&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.83 ± 0.11&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.132 ± 0.01&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>50% corn : 50% amaranth grits</td>
<td>7.6 ± 0.05&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.83 ± 0.18&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.346 ± 0.04&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Results are mean ± SD of six measurements

<sup>a</sup> Means with different letters in the same column for each sample are significantly different at the 5% level

Addition of amaranth grits to extrusion blend proportionally reduced extrusion index and increased density of extrudates, due to its reduced expansion properties compared to corn. Reduced expansion resulted in a denser product with smaller air cell diameters as shown in Figure 1.

Fig. 1. Scanning electron micrographs of amaranth:corn 50:50 (A) and corn extrudate (B)

It is difficult to produce expanded products by extrusion cooking of amaranth grain alone, due to its high fat content (6-8% in whole grain). Fat provides a powerful lubricant effect in extrusion cooking and reduced product expansion (11). Flips of 100% corn grits have the highest expansion (4.03) and lowest density (0.095 g/cm³), which provides demanded crispy structure during eating.

Blend of 50% corn and 50% amaranth grits resulted in a decreased expansion index (1.83) compared to control 100% corn grits by 2.2 times, but in increased density (0.346 g/cm³) by 3.6 times.

Table 3. Texture of extrudates measured by Instron 4301

<table>
<thead>
<tr>
<th>Sample</th>
<th>Compression force (N)</th>
<th>Penetration force (N)</th>
<th>Cutting force (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100% corn grits</td>
<td>13.2 ± 0.23&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.2 ± 0.09&lt;sup&gt;a&lt;/sup&gt;</td>
<td>19.2 ± 0.20&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>80% corn : 20% amaranth grits</td>
<td>20.8 ± 0.32&lt;sup&gt;b&lt;/sup&gt;</td>
<td>5.1 ± 0.11&lt;sup&gt;b&lt;/sup&gt;</td>
<td>18.8 ± 0.18&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>50% corn : 50% amaranth grits</td>
<td>24.5 ± 0.15&lt;sup&gt;b&lt;/sup&gt;</td>
<td>11.6 ± 0.08&lt;sup&gt;c&lt;/sup&gt;</td>
<td>18.4 ± 0.14&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>a</sup> Means with different letters in the same column for each samples are significantly different at the 5% level

Table 3 represents the differences in compression, penetration and cutting force (N) for the extrudate with amaranth grits supplement compared to the control with 100% corn
grits. Increasing the amount of amaranth grits in flips increased the resistance of extrudates, thus the difference in force for compression and penetration compared to corn grits flips is significant. Cutting force which imitates biting, is not statistically much different among treatments.

Hardness of flips with 50% amaranth grits represented by penetration force (11.6 N) is by 3.6 times higher than the penetration force for sample with 100% corn grits (3.2N), which is a major difference.

Generally, the addition of grits from whole amaranth grain, as a fiber–rich raw material in extruded product formulations, resulted in increased density and hardness of the product (12).

Figure 2 presents flow curves of gels obtained from corn grits and blends of corn and amaranth grits in the ratios 80:20 and 50:50, determined immediately after the preparation and after 24h.

All systems exhibited thixotropic flow behavior. Gels prepared from corn grits had the greatest value of shear stress, i.e. viscosity, and largest thixotropic loop area. The structure is weak and it was broken–down by low share rates. During storage for 24h the system with 100% corn grits is additionally structured and three–dimensional gel structure is formed as a result of retrogradation of amylase fractions. Since retrogradation is a process of binding by weak hydrogen bonds that are easily broken, the flow curve for 100% corn grits measured after 24 hours shows a peak characteristic for breaking such structures down at very low shear rates. Gels of examined grits blends had lower viscosity than corn grits and during storage they did not build additional structure. This is a result of replacing part of the corn grits, whose starch contains amyllose and amylopectin, with amaranth grits whose starch includes small amount of amyllose and high amount of amylopectin fractions (13).

![Fig. 2. Flow curves of the gels from corn grits and corn–amaranth grits in the ratios 80:20 and 50:50 determined in 0 h and 24 h](image-url)
In such a way fraction which structurate during time (amylose) is partially replaced by non gelling fraction. Increased amount of amaranth grits decreased viscosity and surface of thixotropic flow curves.

From the flow curves, in Figure 2, fitting data in Herschel–Bulkley equation (14):

\[ \tau = \tau_0 + k \gamma^n \]

the values for yield stress \( \tau_0 \) and coefficients \( k \) and \( n \) were calculated. Yield stress decreased with addition of amaranth grits, as part of the corn was replaced. Also, values of yield stress \( \tau_0 \) increased for gel samples after 24 hours of storage due to the structuration. Values of viscosity behavior index \( n \) for all samples are smaller than 1, which is characteristic for thixotropic behavior.

**Table 4.** Values of yield stress, consistency index and viscosity behavior index

<table>
<thead>
<tr>
<th>Sample</th>
<th>Yield stress ( \tau_0 ) (Pa)</th>
<th>Consistency index ( k )</th>
<th>Viscosity behavior index ( n )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0h</td>
<td>24h</td>
<td>0h</td>
</tr>
<tr>
<td>100% corn grits</td>
<td>3.97</td>
<td>4.59</td>
<td>2.78</td>
</tr>
<tr>
<td>80% corn : 20% amaranth grits</td>
<td>1.96</td>
<td>2.75</td>
<td>2.49</td>
</tr>
<tr>
<td>50% corn : 50% amaranth grits</td>
<td>0.72</td>
<td>0.92</td>
<td>2.89</td>
</tr>
<tr>
<td>100% corn extrudate</td>
<td>0</td>
<td>0</td>
<td>0.30</td>
</tr>
<tr>
<td>50% corn : 50% amaran. extrudate</td>
<td>0</td>
<td>0</td>
<td>0.05</td>
</tr>
</tbody>
</table>

Fig 3 presents flow curves of corn grits and grits blends of corn and amaranth in a ratio 50:50, as well as flow curves of obtained extrudated products. Flow curves of gels made from extrudates had lower viscosity than the gels made from corresponding grits.
Starch granules in extrudates after thermal treatment were partly damaged during extrusion process and they built weak gels. The obtained pastes had a lower viscosity, and they can be classified to the category of pregelatinized starch granules.

CONCLUSION

Increasing amount of amaranth grits in the extrusion blend causes increase of density and hardness of the extrudated products and decrease in expansion index. When part of the corn grits is replaced with amaranth grits viscosity of gels decreases compared to pure corn grits. Also, extrusion process partially damages starch granules, thus obtained gels of extrudated products have lower viscosity than the initial grits.

REFERENCES

СВОЈСТВА ЕКСТРУДАТА СА ДОДАТКОМ КРУПИЦЕ ОД СЕМЕНА АМАРАНТУСА

Љубица П. Докић, Марија И. Бодрожа-Соларов, Мирослав С. Хаднађев и Ивана Р. Николић

Поступком екструдирања на лабораторијском Брабендеровом 20 ДН екструдеру добијени су екструдати мешавине кукурузног грiza са додатком 20% и 50% крупице од семена амарантуса. Добијени су екструдати различите текстуре. Повећањем удела грiza од амарантуса у смешти за екструдирање долази до повећања густине, смањења степена експанзије, повећања тврдоће. У процесу екструдирања долази до делимичног оштећења скробне грануле те су испитане и реолошке карактеристике. Сви системи су по типу протицања били тиксотропни. Узорци код којих је део кукурузне крупице замењен амарантусовом имали су ниже вискозитете и показивали низак степен просторног структурирања током стајања.

Received 15 June 2009
Accepted 9 September 2009