The effect of thermal processing on soluble dietary fibre fraction in wheat

Adrian Caprita and Rodica Caprita *
Banat University of Agricultural Sciences and Veterinary Medicine, Calea Aradului 119, 300645-Timisoara, Romania.
*e-mail: rodi.caprita@gmail.com

Received 27 June 2011, accepted 16 October 2011.

Abstract
Dietary fibre (DF) includes all non-starch polysaccharides resistant to digestion in the small intestine and fermentable in the large intestine, and consists of a mixture of components with a varying degree of solubility. Wheat contains substantial amounts of both soluble (SDF) and insoluble (IDF) dietary fibre. The predominant water SDF in wheat is arabininoxylan (6-8%). The main polysaccharide constituents of wheat endosperm cell walls are arabinoxylans, whereas arabinoxylans and β-glucans predominate in wheat aleurone layers, arabinoxylan and cellulose predominate in cell walls of pericarp/testa. Soluble polysaccharides give viscous aqueous solutions. The viscous properties depend on molecular weight and molecule size (linear or branched), ionically charged groups, surrounding structures, and concentration of DF. In aqueous solutions, water molecules penetrate the amorphous regions of soluble DF. The increase in viscosity is explained by formation of Ca$^{2+}$ bridges and hydrogen bonds, resulting in a loose network that can hold considerable amounts of water. Most food processing methods are essentially based on heating. Thermal processing of plant tissues alters the physical and chemical properties of plant cell wall and modifies fibre solubilization, which modifies the water extract viscosity (WEV). The study had in view the effect of thermal processing on WEV of wheat flour. Wheat samples were heated for 5, 10 and 15 min at 150 and 180°C in a forced air oven, or by exposing for 30, 60, 90 and 120 seconds to microwave radiations. The water-soluble fraction was obtained using a single extraction at 1:2 flour: water ratio, for 60 min at 40°C. The experimental data revealed that thermal processing has a marked effect on the viscosity of water extracts. Heat treatment at 150°C increased WEV demonstrating an increase in the proportion of SDF in the total DF content of the cooked flour with cooking time. These observations suggest a redistribution of the total DF content from insoluble to soluble components. WEV increased up to 3.09 cP (20% increasing) when heating at 150°C for 15 min. Thermal processing at 180°C did not induce a significant increase in WEV. WEV increased slightly with heating in microwave, up to 8% after 90 s. Further heating decreased WEV to 2.17 cP.

Key words: Dietary fibre, non-starch polysaccharides, wheat, arabinoxylans, water extract viscosity, thermal processing.

Introduction
A very important aspect of food quality is related to the nutritional quality and the effect on consumers’ health. As a result of processing, many foods are deprived of some substances having great importance for health, among which is the dietary fibre (DF). DF has some beneficial physiological effects, such as improving the bulk motility, decreasing blood cholesterol and glucose, preventing constipation and cancer and prebiotic acting.

The American Association of Cereal Chemists defined DF as the edible parts of plants or analogous carbohydrates that are resistant to digestion and absorption in the human small intestine with complete or partial fermentation in the large intestine. DF includes polysaccharides, oligosaccharides, lignin and associated plant substances.

Based on their water solubility, DF is classified as soluble dietary fibre (SDF) and insoluble dietary fibre (IDF). The predominant water SDF in wheat is arabininoxylan (6-8%). The main polysaccharide constituents of wheat endosperm cell walls are arabinoxylans, whereas arabinoxylans and β-glucans predominate in wheat aleurone layers, and arabinoxylan and cellulose predominate in cell walls of pericarp/testa. The arabinoxylans are composed of arabinose and xylose in a branched structure. Soluble polysaccharides give viscous aqueous solutions. The viscous properties depend on molecular weight or molecule size (linear or branched), ionically charged groups, surrounding structures, and concentration of DF. In aqueous solutions, water molecules penetrate the amorphous regions of soluble DF. The increase in viscosity is explained by formation of Ca$^{2+}$ bridges and hydrogen bonds, resulting in a loose network that can hold considerable amounts of water.

Most food processing methods are essentially based on heating. Thermal processing of plant tissues alters the physical and chemical properties of plant cell wall and modifies fibre solubilization, which modifies the water extract viscosity (WEV).

Our study had in view the effect of thermal processing on WEV of wheat flour.

Materials and Methods
Wheat samples were milled by a laboratory grinder to 500 µm granulation, and thermal processed by heating in a forced air oven or by exposing to microwave radiation. Samples were heated for 5, 10 and 15 min at 150 and 180°C in a Froilabo AC60 forced air oven. The microwave treatment was made in a Vortex WD800D-823 oven (800 W and 2450 Hz), for 30, 60, 90 and 120 s.

The water-soluble fractions were obtained using a single extraction at a ratio of flour to water of 1:2, by shaking the tubes at 150 rpm for 60 min at 40°C, using a LabTech LSB-015S water bath. The obtained extracts were centrifuged for 10 min at 5,000 rpm and 25°C, using a Hettich 320R centrifuge.

The dynamic viscosity was determined using a cone/plate viscometer Brookfield Model DVII Cone CP-40, at 100 rpm and 25°C, and the relative viscosity was calculated.
Results and Discussion
Thermal processing of plant tissues alters the physical and chemical properties of plant cell wall. The experimental data reveal that thermal processing increased the soluble dietary fraction in wheat. In general, the changes in the DF composition during cooking may be attributed partly to the redistribution of the insoluble and soluble components of DF, and partly to the formation of resistant starch.

The experimental data (Table 1) show the effect of thermal treatment on the soluble fraction of DF, effect revealed by the determined values of the water extract viscosities. The relative viscosity value of water extract from untreated wheat flour was 2.57 cP.

Table 1. Viscosity of water extracts from thermally treated wheat flour.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Temperature (°C)</th>
<th>Time</th>
<th>Dynamic viscosity (cP)</th>
<th>Relative viscosity (cP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forced air oven</td>
<td>150</td>
<td>5'</td>
<td>2.50</td>
<td>3.01</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10'</td>
<td>2.52</td>
<td>3.03</td>
</tr>
<tr>
<td></td>
<td></td>
<td>15'</td>
<td>2.57</td>
<td>3.09</td>
</tr>
<tr>
<td>Microwave radiations</td>
<td>180</td>
<td>5'</td>
<td>1.96</td>
<td>2.48</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10'</td>
<td>2.28</td>
<td>2.88</td>
</tr>
<tr>
<td></td>
<td></td>
<td>15'</td>
<td>1.60</td>
<td>2.02</td>
</tr>
<tr>
<td>Microwave radiations</td>
<td>30'</td>
<td></td>
<td>2.10</td>
<td>2.66</td>
</tr>
<tr>
<td></td>
<td></td>
<td>60'</td>
<td>2.08</td>
<td>2.63</td>
</tr>
<tr>
<td></td>
<td></td>
<td>90'</td>
<td>2.20</td>
<td>2.78</td>
</tr>
<tr>
<td></td>
<td></td>
<td>120'</td>
<td>1.72</td>
<td>2.17</td>
</tr>
</tbody>
</table>

Thermal treatment at 150°C produced an increase of water extract viscosity. The proportion of SDF from total DF increased with the heating time. The experimental data suggest a conversion of the IDF into SDF. An increased temperature breaks weak bonds between polysaccharide chains and split glycosidic linkages in the DF polysaccharides. As consequence, the architecture of the fibre matrix may be modified and insoluble fibre solubilized.

The relative viscosity of water extract increased to 3.09 cP (20% increasing) when wheat was heated 15 min at 150°C. Heating at 180°C did not induce a remarkable increase of water extract viscosity. A decrease in WEV was observed when heating 15 min at 180°C, suggesting formation of water insoluble resistant starch (Fig. 1).

The microwave radiation treatment produced only a slight modification of water extract relative viscosity: an increase of 8% after 90 s (Fig. 2). Further microwave treatment decreased the water extract relative viscosity (2.17 cP after 120 s).

Conclusions
The increase of the soluble dietary fibre proportion in the total dietary fibre content with the heating time, suggests a redistribution of the total dietary fibre content from insoluble to soluble components.

A decrease in water extract viscosity when heating at 180°C for 15 min and at microwave treatment for 120 s suggests the formation of water insoluble resistant starch.

Acknowledgements
This work was supported by CNCSIS – UEFISCSU, project number 1055/2009 PNII – IDEI code 898/2008.

References
5. Thomson, P. 2005. White breads can also be high fiber. Wellness Foods.