SPELT PASTA WITH INULIN AS A FUNCTIONAL FOOD

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Spelt wheat growing without use of pesticides is a suitable raw material for whole meal products. The aim of this study was to enhance the fiber content in spelt pasta by adding inulin HPX. Inulin HPX replaced the spelt farina in the quantity of 0%, 5%, 10% and 20%, thus contributing to a decrease in the toughness, and improving color of the pasta. The presence of inulin can be clearly distinguished from other polysaccharides components by 13C MAS NMR spectroscopy. A simultaneous increase in the area of the peaks at 81, 74, 64 and 58 ppm, obtained during the deconvolution analysis of the NMR spectra, is directly associated with the increase in the inulin content. Inulin contributes positively to the nutritive and technological characteristics of the pasta. Spelt pasta with 20 % of inulin is a new functional product with modified nutritional properties and with decreased digestible carbohydrates in the amount of 43.2% and reduced energy of 27.2%.

KEY WORDS: pasta, inulin, nutritive value, texture color, 13C MAS NMR

INTRODUCTION

The relationship between food and health has an increasing impact on food innovation due to the popularity of the concept of functional food. Dietary fibers in pasta are versatile functional food ingredients, which are beneficial to human health (1-4). One of dietary fibers used by food industry is inulin, a non-digestible fructo-oligosaccharide. It acts as a prebiotic by stimulating the growth of healthy bacteria in the colon. Inulin is a linear polydisperse carbohydrate material consisting mainly of D – fructose joined by β-(2/1) linkages (1, 3, 5). Pasta containing inulin alters nutritive and sensory properties, has a positive effect on certain functions in the organism, and improves psychical condition. The functionality of the food with increased content of inulin can be seen in the positive effect of reducing the risk from numerous non-infectious diseases (1, 2, 6). The aim of this study was to investigate the quality of pasta with inulin, in an effort of obtaining new products with alte-
red nutritional properties, to classify and discriminate the analyzed samples by principal component analysis (PCA) using $^{13}$C MAS NMR spectroscopy data and presented technological data. Pattern recognition technique was applied within assay descriptors, to characterize and differentiate various samples.

**EXPERIMENTAL**

**Material and methods**

Wholemeal flour of spelt grown in the year 2012 in Serbia was used for pasta production. Chemical analyses (protein, starch, lipid, sugar, cellulose, and total dietary fiber) of pasta were determined according to the official methods of AOAC (7) and AOAC (8). Inulin HPX is a commercial product obtained from the root of Jerusalem artichoke, produced by "ORAFTI Active Food Ingredients", Tienen, Belgium, with average DP ≥ 23. Pasta with inulin HPX (0, 5, 10 and 20%) was made using the La Parmigiana D45 MAC 60 procedure described by Filipović et al, (9). Textural properties of cooked pasta and pasta color were measured using Texture analyzer TA.HD plus (Stable Micro System, U.K.) and colormeter Chroma meter (CR-400, Konica, Minolta, Japan), respectively, as described by Filipović et al, (9, 10). The $^{13}$C MAS NMR spectra were recorded at 100.627 MHz using a Bruker MSL 400 NMR spectrometer with a TecMag console upgraded (Texas, USA), according to the procedure described by Filipović et al, (11). Descriptive statistical analyses for all the obtained results were expressed as the mean ± standard deviation (SD), one-way ANOVA and principal component analysis (PCA) analyses were described by Filipović et al, (10). Furthermore, PVA was applied successfully to classify and discriminate the different samples based on the NMR spectra (peak width) and technological parameters.

**RESULTS AND DISCUSSION**

**Quality of spelt pasta with different quantities of inulin.** Based on chemical properties of the pasta with different quantities of inulin, ANOVA, coupled with Tukey’s HSD test, were evaluated for a comparison of the parameters. These tests showed statistically significant differences in protein content among the values of pastas with 0 and 5% inulin and pasta with 10% and 20% inulin (Table 1).

The addition of inulin (5%, 10% and 20%) to pasta also results in a statistically significant difference in the starch content, because one part of flour is replaced by inulin and the quantity of available starch is reduced. Tukey’s HSD test showed statistically significant differences in the values of cellulose in pasta with inulin (5%, 10% and 20%) and pasta without inulin, since inulin is a macromolecule with chemical structure containing the same molecules as cellulose.

Table 1 shows that the increase in the inulin content indicates a statistically significant increase in the sugar content and a statistically significant decrease of the lipid content. Tukey’s HSD test indicates statistically significant differences in dietary fiber content in pasta with 0%, 5%, 10% and 20% inulin, which confirms that inulin is one type of non-digestible carbohydrates.
Table 1. Chemical properties of pasta with different contents of inulin

<table>
<thead>
<tr>
<th>Chemical property</th>
<th>Content of inulin (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Protein content (% d. m)</td>
<td>15.87±0.21^c</td>
</tr>
<tr>
<td>Starch content (% d. m)</td>
<td>56.49±0.39^d</td>
</tr>
<tr>
<td>Cellulose content (% d. m)</td>
<td>2.0±0.04^a</td>
</tr>
<tr>
<td>Sugars content (% d. m)</td>
<td>2.42±0.02^a</td>
</tr>
<tr>
<td>Lipids content (% d. m)</td>
<td>2.70±0.02^a</td>
</tr>
<tr>
<td>Dietary fibers content (% d. m)</td>
<td>5.62±0.13^a</td>
</tr>
</tbody>
</table>

Values with the same letter are not statistically different at the p<0.05 level (according to post-hoc Tukey’s HSD test).

By increasing the quantity of inulin from 0 to 20, sugar contents of lipid and dietary fibers can be calculated as follows:

Sugars content = (2.42±0.00) + (0.03±0.00) × Inulin (r^2=0.999, p<0.05)
Lipids content = (2.70±0.00) - (0.04±0.00) × Inulin (r^2=0.999, p<0.05)
Dietary fibers content = (5.62±0.22) + (0.52±0.0) × Inulin (r^2=0.999, p<0.05).

Table 2 shows a significant reduction of digestible carbohydrates, which contributes to the reduction of the energy value and increase in the functionality of food. By daily average consumption of 100 g pasta with inulin 0% and 20% inulin, the intake of fiber is 7.7 and 18.9 g per day, respectively. Therefore, this kind of pasta can have positive long-term effects in the prevention of non-infectious diseases caused by irregular diet (12). It is worth to point out that pasta with 20% inulin is a product with a significant decrease of digestible carbohydrates (by 43.2%) and significant reduction of energy (by 27.2%).

Table 2. Nutritive properties of pastas with different contents of inulin

<table>
<thead>
<tr>
<th>Nutritive properties</th>
<th>0</th>
<th>5</th>
<th>10</th>
<th>20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decrease of digestible carbohydrates (%)</td>
<td>-</td>
<td>10.0±0.16^a</td>
<td>18.8±0.12^b</td>
<td>43.2±0.11^c</td>
</tr>
<tr>
<td>Content of non-digestible carbohydrates (g) in 100 g of pasta</td>
<td>7.7±0.21^a</td>
<td>10.9±0.21^b</td>
<td>13.5±0.21^c</td>
<td>18.9±0.21^d</td>
</tr>
<tr>
<td>Energy (kJ)</td>
<td>1373.9</td>
<td>1315.9</td>
<td>1258.8</td>
<td>1000.7</td>
</tr>
<tr>
<td>Decrease in the energy of pasta (%)</td>
<td>-</td>
<td>4.2</td>
<td>8.4</td>
<td>27.2</td>
</tr>
</tbody>
</table>

Values with the same letter are not statistically different at the p<0.05 level (according to post-hoc Tukey’s HSD test).

For the increase of the inulin content from 0 to 20, the content of non-digestible carbohydrates can be calculated as follows:

Non-digestible carbohydrates content = (7.75±0.18) + (0.61±0.05) × Inulin (r^2=0.999, p<0.05)
The textural characteristics and color of pasta play an essential role in determining the final acceptance by consumers (6). The ANOVA and the following post-hoc Tukey’s HSD tests (Table 3) showed that the addition (5%, 10% and 20%) of inulin statistically significantly decreased the hardness and toughness of the pasta in comparison to pasta without inulin, which indicates that inulin weakens the structure of pasta dough, which is due to the gluten dilution. Tukey’s HSD test showed that inulin statistically significantly increased the adhesiveness of pasta, because inulin hydrates faster than the starch and protein components of flour, in turn leading to starch and fiber fractions of the pasta being less incorporated in the matrix. If the starch is not encapsulated within a protein matrix, cooking contributes to a sticky layer at the surface of the product, resulting in higher levels of adhesiveness (6, 13, 14).

Table 3. Textural and color properties of pasta with different contents of inulin

<table>
<thead>
<tr>
<th>Textural property</th>
<th>Content of inulin (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Hardness (g)</td>
<td>3117.5±13.1&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Adhesiveness (gsec)</td>
<td>2.02±0.05&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Work of Shear - toughness</td>
<td>13.44±0.14&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Pasta color</td>
<td></td>
</tr>
<tr>
<td>L Brightness</td>
<td>76.00±0.32&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>a* Share of red color</td>
<td>2.27±0.08&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>b* Share of yellow color</td>
<td>13.35±0.00&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>C* Differences in coloration</td>
<td>13.35±0.14&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Values with the same letter are not statistically different at the p<0.05 level (according to post-hoc Tukey’s HSD test)

For the increase in the inulin content from 0 to 20, the toughness can be calculated as follows:

\[
\text{Toughness} = (13.39±0.17) - (1.01±0.44) \times \text{Inulin} + (0.03±0.00) \times \text{Inulin}^2 \quad (r^2=0.999, p<0.05)
\]

The use of a tristimulus colorimeter permits the simultaneous measurements of brightness and yellowness, the most appreciated pasta attributes. Table 3 shows that there is a statistically insignificant difference in the brightness, share of red color and yellow color, and differences in the coloration in pasta with the addition of 20% of inulin and pastats with 0%, 5% and 10% of inulin. The content of inulin increased the brightness, reduced the proportion of red color and increased the differences in coloration of the product. The share of yellow color decreased with the increased content of inulin in pasta, since one part of wholemeal flour was replaced by inulin, so that the quantity of available flour was reduced.

The $^{13}$C MAS NMR characterization of spelt pasta with different quantities of inulin. As stated in our previous study (11), due to a similar chemical environment of detectable groups, the NMR analysis of the most polysaccharides, shows that the shifts overlap to a large extent. The positions of the peaks of inulin and spelt pasta samples, reveal the possibility of obtaining discrimination of the inulin component from other pre-
sent components in the spectrum. The distinction of the peak position of inulin compared to other polysaccharides (such as starch) enables also the evaluation of their content in the sample. This difference in the peak position of inulin in comparison to the position of the dominant peaks originated from the starch is especially pronounced for peaks positioned at 81, 64 and 58 ppm. Furthermore, based on the results of deconvolution analysis of polysaccharides region in the 13C MAS NMR spectra, the peak at 75 ppm (basically originated from the C(4) carbon in the starch structure) also provides the continual gain in the values of the area ascribed to this peak, which is consistent with the added amount of inulin. Generally, a continuous increase of the area for any of particular peak mentioned above can be observed, which can be clearly correlated with the amount of added inulin for each of the samples shown. During the deconvolution analysis, the peaks at 64 and 58 ppm are incorporated only in the case of the samples with inulin (samples 2 and 3), whereas the peaks positioned at 81 and 74 ppm are overlapped to some extent with neighboring peaks belonging to the starch component. However, the results of deconvolution analysis were not affected substantially for that reason, indicating the same correlation dependence as was observed for other mentioned peaks.

Figure 1. PCA biplots for: chemical properties of pasta (a), nutritive properties of pasta (b) textural properties and color of pasta (c), biplot for 13C MAS NMR spectra of different samples of pasta (d)
The PCA allows a considerable reduction in the number of variables and the detection of the structure in the relationship between the measured parameters and different samples that give complementary information. In this study, four different data sets were submitted to PCA: chemical properties of pasta (Table 1), nutritive properties of pasta (Table 2), textural properties and color of pasta (Table 3) and 13C MAS NMR spectrum (peak width). For visualizing the data trends and the discriminating the efficiency of the used descriptors, a scatter plot of samples using the first two PCs resulting from the PCA of the data matrix is obtained (Fig. 1).

As can be seen, there is a neat separation of samples according to chemical properties of pasta, nutritive properties of pasta, textural properties and color of pasta and NMR spectra. Chemical data showed that the first two PCs explained 99.63% of the total variability. Protein, starch and cellulose content, as well as lipids and dietary fibers content contributed almost equally to the calculation of the first PC, while sugars content contributed the most to the second PC (75%). The first two PCs of the nutritive properties data (Table 2) accounted for 100% of the total variability. All variables contributed almost equally to the calculation of the first PCs, while the content of non-digestible carbohydrates contributed the most to the second PC. The textural properties (hardness, adhesiveness and toughness) and color of pasta (brightness, shares of red and yellow color and differences in coloration) explained 98.26% of the total variability. The first PC is explained almost equally by all variables (both textural and color properties), while the second PC is mostly calculated by C and toughness. The 13C MAS NMR results showed that the first two PCs accounted for 87.18% of the total variability.

CONCLUSION

Based on the investigation of the influence of inulin content on the nutritive and textural properties of pasta and the possibility of inulin identification by 13C MAS NMR spectrum it can be concluded: that the pasta obtained by adding 5, 10 or 20% of inulin is characterized by a significant decrease of digestible carbohydrates (10.0, 18.8 and 43.2%) and increased content of non-digestible carbohydrates (10.9, 13.5 and 18.9%). An average daily consumption of 100 g of pasta with 20% of inulin contributes to the fiber intake of 18.94 g per day. The pasta with 20% of inulin is a new functional product with modified nutritional properties, with reduced energy in the amount of 27.2%. The addition of inulin influenced adversely the pasta texture (decreased toughness) and positively the pasta color (increased brightness, reduced share of red color and differences in coloration). The presence of inulin can be clearly identified by 13C MAS NMR spectroscopy. The increase in the area of the peak positioned at 81, 74, 64 and 58 ppm, obtained during the deconvolution analysis of the NMR spectra, was directly associated with the increase in the inulin content. PCA appeared to be a useful tool for providing a neat separation of the samples according to chemical, nutritive textural pasta properties, pasta color and 13C MAS NMR spectra.

Acknowledgement

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REFERENCES

ТЕСТЕНИНА ОД СПЕЛТЕ СА ИНУЛИНОМ КАО ФУНКЦИОНАЛНА ХРАНА

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Спелта је погодна сировина за производе од целог зрна јер се узгаја без примене пестицида. Са циљем да се повећа садржај влакна у тестенини од спелте, чија се се узгаја без примењивања пестицида, у овом раду је испитан квалитет тестенине од спелте са додатком инулина НРХ. Количина инулина је додавана у интервалу од 0%, 5%, 10% и 20%, као замена за брашно, при чему долази до смањења жилавости и побољшања боје тестенине. Резултати испитивања су показали да се присуство инулина у тестенини може јасно доказати коришћењем 13С МАС НМР спектроскопије. Пораст површине пикова позиционираних на 81, 74, 64 и 58 ppm, добијене деконволуцијом НМР спектара, директно је повезан са повећањем садржаја инулина у одговарајућим узорцима. Инулин позитивно утиче на сензорне и нутритивне особине тестенине. Тестенина од спелте са 20% инулина представља нов функционални производ са смањеним садржајем сварљивих угљених хидрата од 43,2% и смањеном енергијом од 27,2%.

Кључне речи: тестенина, инулин, нутритивна вредност, текстура, боја, 13С MAS NMR

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