POSSIBILITY OF PARTIAL REPLACEMENT OF FAT BY INULINE IN COOKIES IN ORDER TO DECREASE THEIR CALORIC VALUE

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INTRODUCTION

Many cookies and other sweet baked goods contain high amounts of sugar and fat. From the point of view of nutritive properties, excessive consumption of bakery products is not recommended for it is linked with the intake of SFA and TFA [Balas, 2001; Erp-Baart et al., 1998; Daniewski, 1998] which are known to provoke an increase of LDL/HDL-cholesterol ratio, with a consequent increase in the risk of cardiovascular diseases [Mensik et al., 2003; Juttelstad, 2004].

The consumption of sweet bakery products in Poland amounted nearly 8 kg/person/year (2002-2006 years) and evidence suggests that this will remain stable, because these products are important dietary components of mid-morning and afternoon snacks and also their sweetness and marked palatability are elements which promote their consumption [Gouveia et al. 2007].

Inuline is a storage polymer composed of β-2,1-linked fructosyl moieties mostly with a terminal glucosyl residue. It occurs in many plants such as in banana, wheat, onions and chicory [Van Loo et al., 1995]. Inuline content ranges from less than 1% in banana to more than 15% in chico ry roots with the number of fructosyl residues (degree of polymerisation, DP) extending from 3 to 250, depending on the plant species and the plants’ life cycle [Kip et al., 2005].

For about 20 years, inuline has also been available as an ingredient for application in the food industry, where it is used in a large variety of food products, both for their technological and nutritional benefits. Its nutritional benefits arise from the fact that inuline is a dietary fibre [Flamm et al., 2001] and consequently has a low caloric value and that it resists gastric acid and digestion in the human small intestine [Roberfroid, 1999]. Consumption of inulins also leads to an increase in the number of Bifidobacterium and Lactobacillus species in the human fecal colon microbiota [Gibson et al., 1995]. Based on a combinations of these properties inuline finds applications in, for instance, dairy products, beverages, spreads, ice cream, confectionery, bread and other bakery products.

The aim of this study was to examine the effect of partial replacement of some fats with inuline in cookies on their sensory and instrumental quality indices.

MATERIALS AND METHODS

EXPERIMENTAL

Experimental cookies were prepared using a recipe containing high amount of fat (55% with respect to flour). It is a typical formula of short-dough biscuits mostly used in manufacturing cookies in Poland. Three different shortenings were used for the preparation of reference cookies: Akobake K, Akobake P (Karshamns, Sweden) and Cargill shortening (Cargill, the Netherlands). All are based on fractions of palm oil. In low fat formulation 50% of fat was replaced with inuline.
**Ingredients for preparing cookies**

The reference cookie formulation contained the following ingredients: 240 g of wheat flour, 133 g of fat, 90 g of powdered sugar, 76 g of egg yolks, 10 g of dried milk. In low fat formulation 50% fat was replaced with 17 g inuline (Hortinex). This corresponds to Hortinex recommendations according to which 1 g of inuline replaces 4 g of fat.

**Preparation of cookies**

All ingredients were blended in a Philips mixer for 6 min. Inuline was added directly to the blended fat and mixed with other ingredients. Thereafter, the mixed dough was rolled out and cut in square pieces 55 mm in length and 4 mm in thickness. The cookies were placed into baking cups and baked at 190°C for 12 min in a Sveba Duhlin Fristad Sveden oven. The prepared cookies were subjected to instrumental and sensory analysis 24 h after baking.

**METHODS**

**Analysis of fats**

Gas chromatography (GC) was used to determine FA composition of the investigated fats according to the Polish Standard [PN-EN ISO 5508:2000]. Methyl esters were prepared according the Polish Standard [PN-ISO 5509:2000]. The composition of FA was expressed as the peak area percentage of total FA. Instrument: HP 6890 GC System with autosampler; SGE Capillary BPX 70, column: 60 m x 0.25 mm ID; oven: temperature program from 160 to 210°C, rate: 2.5°C/min; carrier gas: helium, air: 300 mL/min; injector: Split-Splitless 240°C; detector: FID 250°C; software: HP Chemstation v. 3.11. Method validation was carried out with a reference sample CRM-163 EEC-EAEC (Brussels, 1993). SFC of fats was determined by means of pulsed nuclear magnetic resonance spectroscopy using NMS 120 Minispec NMR Analyzer Bruker instrument at 25°C. Melting point (MP) was estimated with the capillary method following the Polish Standard [PN-EN ISO 6321:2004]. According to the standards, analyses of fats were conducted in two replications.

**Sensory evaluation of cookies**

Sensory analysis of cookies was carried out using the scaling method by a sensory panel according to Polish Standard [PN ISO 4121:1998]. The sensory panel of ten members, habitual consumers of bakery products (students and faculty staff members: 24–46 years of age), made each evaluation in duplicate. They scored all sensory attributes on a 100 mm rating scale anchored at extreme “not at all…” and “extremely….” Only with respect to the greasiness the scales were anchored at extreme “low…” and “high….” The subjects rated acceptability of appearance and attributes of cookies texture: hardness, crispness and greasiness and overall quality. The scales were anchored at extreme “not at all…” and “extremely…” measured using a linear scale. Samples of cookies were coded and given to each assessor in individual random order.

**Instrumental analysis of cookies**

Texture measurements were carried out using Texturometrika TTA-XT2 (Stable Micro Systems, UK) by a bending-snapping test according to Baltsavias et al. [1999]. Procedure: broken shear force of each cake was determined as an indication of hardness and crispness. A 10 kg load cell was used and crosshead speed set at 1 mm/min, temperature 23°C. Volume of cookies (in cm³) was determined using Jakubczyk & Haber method [1983]. Data were analysed with the use of Statgraphics plus 4.1. Duncan’ s test was used to assess the differences between means at p<0.05.

**RESULTS AND DISCUSSION**

**Fats**

The results of GC analysis of fats are presented in Table 1. Shortenings differed in the content of SFA which ranged from 29.9 to 57.5%. Generally, the levels of SFA in all used fats were high, which is typical of bakery fats because SFA are resistant to oxidation and on the whole have excellent technological properties [Krygier & Żbikowska, 2002]. Shortenings differed greatly in TFA content which are regarded as especially undesirable in the diet [Pedresen, 2001]. However, TFA have an excellent effect on the structure of bakery products. Many studies revealed that bakery and confectionery fats are the crucial sources of TFA [Balas, 2001; Daniewski et al., 1998; Erp-Baart et al., 1998; Parcerisa et al., 1999].

From the three shortenings studied Cargill fat was characterised by both the lowest content of TFA (0.9%) and the highest content of SFA (57.5%). As expected, the studied fats contained low amount of polyunsaturated FA (PUFA) (5.9 to 0.5%) (Table 1). Unsaturated FA are undesirable in bakery fats because they are not resistant to environmental stress during the baking process (high temperature). At high temperature unsaturated FA, especially α-linolenic acid (C 18:3) are the main source of undesirable oxidation products.

There were no significant differences in MP between shortenings. In contrast, fats differed in SFC content (13.6-31.6%), (Table 1).

**Sensory and instrumental evaluation of cookies**

Flavour, texture and appearance are the main quality attributes of cookies. Fat is a very important ingredient of cookies because it contributes to the texture and pleasing mouthfeel and additionally positively impacts flavour intensity and perception [Zoulias et al., 2002]. Sensory intensity of aroma, **Table 1. Characteristics of examined fats.**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Akobake K</th>
<th>Akobake P</th>
<th>Cargill</th>
</tr>
</thead>
<tbody>
<tr>
<td>SFA (%)</td>
<td>29.9±0.89</td>
<td>49.1±4.23</td>
<td>57.5±4.10</td>
</tr>
<tr>
<td>TFA (%)</td>
<td>23.1±0.90</td>
<td>3.2±0.10</td>
<td>0.9±0.21</td>
</tr>
<tr>
<td>PUFA (%)</td>
<td>2.3±0.30</td>
<td>5.9±0.71</td>
<td>0.5±0.20</td>
</tr>
<tr>
<td>Sum of cis isomers (%)</td>
<td>53.0±3.89</td>
<td>52.3±3.85</td>
<td>56.4±4.12</td>
</tr>
<tr>
<td>SFC at 25°C (%)</td>
<td>13.6±0.85</td>
<td>18.2±0.92</td>
<td>31.6±0.91</td>
</tr>
<tr>
<td>SMP (°C)</td>
<td>34.6±0.92</td>
<td>35.8±0.98</td>
<td>35.5±0.93</td>
</tr>
</tbody>
</table>
intensity of taste, acceptability of appearance and overall ratings averaged over the six types of cookies are presented in Table 2. The statistical comparison was made between the control cookies containing three different fats and the three with the lower fat content containing inuline.

The lowest intensity of buttery aroma was rated in cookies containing shortening with 57.5% SFA and 0.9% TFA (Cargill) for both inuline-containing and control recipes. Replacement 50% of fat with inuline had significant (p<0.05) impact on the intensity of buttery aroma of cookies containing shortening with 49% SFA and 3.2% TFA (Akobake P) (from 2.5 to 2.0). In the case of Akobake K or Cargill shortenings, the effect of fat replacement with inuline was not statistically significant (p<0.05). Generally, the sensory panel found low intensity of buttery aroma in all samples.

Appearance and taste are highly relevant to the consumer preference of foods and are particularly important, in the case of health-promoting foods, in those groups most inclined to unhealthy diets [Neumark-Sztainer et al., 1999]. This conclusion may be extrapolated to functional foods and therefore, in our study, an assessment has been made of sensory intensity in sweet and buttery taste in control cookies and cookies with 50% of fat replaced with inuline. The intensity of sweet taste was sharply reduced by reducing the fat content of cookie recipes (Table 2). It was particularly evident when shortening with the lowest TFA content (0.9%) was utilized (decreasing intensity of sweetness of cookies from 5.3 to 3.7 was attained). Similar results were presented by Drewnowski et al. [1998] in cookies with 25% reduced sugar content and confirmed that the key sensory attribute for this class of food products is sweetness and that consumers are very sensitive to any variations in sugar content.

Replacement of 50% of fat with inuline had a little impact on the decreasing intensity of buttery taste of cookies. The lowest intensity of buttery taste was scored in cookies containing shortening Cargill (with the lowest content TFA).

With respect to using shortening Akobake K, the sensory panel did not find differences (p<0.05) in the appearance between control cookies and those containing inuline. Replacement of 50% of Cargill with inuline significantly (p<0.05) decreased the scoring of appearance, whereas the cookies containing inuline with shortening Akobake P attained higher scores with respect to acceptability of appearance than the control samples (5.1 and 6.2, respectively).

With respect to cookies containing Akobake K and Cargill, the estimation of overall sensory quality (Table 2) confirmed lower acceptability of cookies in the case when 50% of fat was replaced with inuline. With respect to Akobake P no significant differences were found between control cookies and those containing inuline. Generally, the averaged scores were high and ranged from 7.1 to 9.1 (on the scale 0-10 cm).

### Texture of cookies

The importance of cookies texture in consumer acceptance is increasingly recognized. Fat is one of the principal ingredients that affect cookies texture. Substitution of fat with other ingredients had a greater impact on textural attributes of cookies than the replacement of sugar or flour [Campbell et al., 1994]. It can be seen (Table 3) that reducing the fat content by 50% and replacing it with inuline in cookie recipes led to higher ratings of hardness. The same results were obtained during instrumental measurement of texture (Table 4).

In all samples replacement of fat with inuline resulted in 2-fold increase of instrumental values of texture. For example, the lowest hardness was rated in Akobake K + inuline (3.1) in comparison to Akobake K (5.3).

### Table 2. Results of sensory evaluation of cookies (scale 0-10).

<table>
<thead>
<tr>
<th>Sample</th>
<th>Buttery aroma</th>
<th>Sweet taste</th>
<th>Buttery taste</th>
<th>Appearance acceptability</th>
<th>Overall quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Akobake K</td>
<td>2.7a</td>
<td>5.1b</td>
<td>4.1c</td>
<td>6.6c</td>
<td>9.1c</td>
</tr>
<tr>
<td>Akobake K + inuline</td>
<td>2.1a</td>
<td>3.6a</td>
<td>3.6a</td>
<td>6.8a</td>
<td>7.8a</td>
</tr>
<tr>
<td>Akobake P</td>
<td>2.5a</td>
<td>5.7a</td>
<td>3.9a</td>
<td>5.1a</td>
<td>8.1a</td>
</tr>
<tr>
<td>Akobake P + inuline</td>
<td>2.0a</td>
<td>4.6b</td>
<td>3.4a</td>
<td>6.2b</td>
<td>8.1a</td>
</tr>
<tr>
<td>Cargill</td>
<td>1.8a</td>
<td>5.3bc</td>
<td>2.8a</td>
<td>7.3d</td>
<td>8.9b</td>
</tr>
<tr>
<td>Cargill + inuline</td>
<td>1.2a</td>
<td>3.7a</td>
<td>2.5a</td>
<td>6.7a</td>
<td>7.1a</td>
</tr>
<tr>
<td>NIR</td>
<td>0.81</td>
<td>0.79</td>
<td>0.69</td>
<td>0.74</td>
<td>0.50</td>
</tr>
</tbody>
</table>

The same letters denote non-significant differences (p<0.05) between mean values in the same column.

### Table 3. Results of sensory assessment of texture attributes of cookies (scale 0-10).

<table>
<thead>
<tr>
<th>Samples</th>
<th>Hardness</th>
<th>Crispness</th>
<th>Greasiness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Akobake K</td>
<td>5.3a</td>
<td>5.7b</td>
<td>3.4c</td>
</tr>
<tr>
<td>Akobake K + inuline</td>
<td>8.3a</td>
<td>3.1b</td>
<td>5.6c</td>
</tr>
<tr>
<td>Akobake P</td>
<td>3.9b</td>
<td>6.8c</td>
<td>3.9b</td>
</tr>
<tr>
<td>Akobake P + inuline</td>
<td>8.2a</td>
<td>2.9a</td>
<td>5.5b</td>
</tr>
<tr>
<td>Cargill</td>
<td>4.0a</td>
<td>7.5b</td>
<td>5.5b</td>
</tr>
<tr>
<td>Cargill + inuline</td>
<td>7.6b</td>
<td>3.3b</td>
<td>6.1b</td>
</tr>
<tr>
<td>NIR</td>
<td>0.78</td>
<td>0.83</td>
<td>0.85</td>
</tr>
</tbody>
</table>

The same letters denote non-significant differences (p<0.05) between mean values in the same column.

### Table 4. Results of instrumental measurements of physical properties of cookies.

<table>
<thead>
<tr>
<th>Physical property</th>
<th>Sample</th>
<th>Volume (cm³)</th>
<th>Texture (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Akobake K</td>
<td>30.1b</td>
<td>15.6a</td>
</tr>
<tr>
<td></td>
<td>Akobake K + inuline</td>
<td>28.9b</td>
<td>37.4a</td>
</tr>
<tr>
<td></td>
<td>Akobake P</td>
<td>33.3a</td>
<td>14.0a</td>
</tr>
<tr>
<td></td>
<td>Akobake P + inuline</td>
<td>31.6a</td>
<td>39.9a</td>
</tr>
<tr>
<td></td>
<td>Cargill</td>
<td>35.5a</td>
<td>12.6a</td>
</tr>
<tr>
<td></td>
<td>Cargill + inuline</td>
<td>30.4a</td>
<td>29.8a</td>
</tr>
</tbody>
</table>

The same letters denote non-significant differences (p<0.05) between mean values in the same line.
instrumental texture of cookies containing shortening Akobake K was 15.6 N and after replacement of 50% of fat with inuline it increased to 37.4 N. In several studies it is pointed that high values of shear force (which indicated hardness) is an unpleasant attribute for such type of product [Zoulias et al., 2002; Rutkowska, 2003].

Crispness can be considered as a pleasant sensory property of cookies as far as it does not become extremely great [Zoulias et al., 2002]. Sensory panel found reference cookies crispy (5.7–7.5 points), which was strongly reduced after replacing 50% fat with inuline (2.9–3.3 points).

Decrease in crispness was associated with higher hardness. The above results obtained are similar to those described in the literature. For example, Maache-Rezzoug et al. [1998] investigated the effect of fat content on biscuit texture and found that an increase in fat content in biscuits resulted in more friable and crispy products. Reduction of fat in cookies resulted in a chewy texture and decreasing moisture content [Sanchez et al., 1995]. Greasiness is a texture attribute of cookies perceived during mastication. For cookies containing shortenings Akobake K or Akobake P replacement of 50% of fat with inuline significantly increased the scoring of greasiness. In the studies on the texture of crackers Martinez et al. [2002] found that high intensity of greasiness was not acceptable by consumers.

Instrumental estimation of the volume of cookies revealed decreasing values as a result of replacing 50% fat with inuline. The differences in volume between two types of cookies studied did not exceed 15%. During evaluation of the acceptability of appearance the analytical panel highly scored the lower volume of cookies containing inuline (from 6.2 to 6.7 scores).

**CONCLUSIONS**

Reduction of fat in the formulations led to samples with higher instrumental values of texture, therefore resulted in cookies which were estimated as more hard.

On the other hand, the replacement of 50% of fat with inuline had various effects on the sensory properties of the samples depending on the shortening used:

- Intensity of sweet taste was significantly reduced by decreasing the fat content of cookie recipes. It was particularly evident when shortening with the lowest TFA content (0.9% Cargill) was utilized.
- Replacement of 50% of fat with inuline had a significant impact on intensity of buttery aroma of cookies containing shortening with 49% SFA and 3.2% TFA (Akobake P). Generally, the sensory panel found low intensity of buttery aroma of all samples.
- Replacement of 50% of fat with inuline had a little impact on the intensity of buttery taste of cookies. The lowest intensity of buttery taste was scored in cookies containing shortening with the lowest content of TFA.
- The replacement of 50% of fat with inuline resulted only in a moderate decrease of the acceptability of overall sensory quality.

These data have some implications for designing acceptable lower-energy cookies. Sweetness is a desirable sensory attribute in this group of food products. As a result, any manipulations that reduce the sweetness level of cookies will result in their diminished acceptance. On the other hand, reducing the fat content in cookies will decrease the total and fat calories, and replacing part of fat with inuline will influence the nutritional benefits.

**REFERENCES**


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