Effect of fat and sugar replacement on cookie properties

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Abstract: Fat mimetics, namely Raftiline, Simplesse, C*deLight and polydextrose, diluted in water to give a gel with 200 g kg\(^{-1}\) concentration, were used for partial fat replacement and polyols, namely lactitol, sorbitol and maltitol, for sugar replacement in low-fat, sugar-free cookies. Raftiline, Simplesse or C*deLight combined with lactitol or sorbitol in 35% fat-reduced, sugar-free cookies resulted in products with hardness and brittleness comparable to those of the control. Polydextrose as fat mimetic and maltitol as sugar substitute resulted in very hard and brittle products. Further fat replacement to 50% was achieved using Raftiline, Simplesse or C*deLight combined with a blend of lactitol and sorbitol; however, the final products were hard, brittle and did not expand properly after baking. Cookies prepared with Simplesse had the least acceptable flavour, while cookies prepared with C*deLight were rated as the most acceptable by a sensory panel. The textural properties were improved by either decreasing the amount of alternative sweetener or increasing the concentration of fat mimetic in the gel which was added to the cookies. All fat-reduced, sugar-free cookies prepared in this study had higher values of moisture content and water activity than the control, but these values were below the upper limit that affects cookie shelf-life.

Keywords: fat replacement; sugar replacement; fat mimetics; polyols; cookie properties

INTRODUCTION

One of the major nutritional problems today is the consumption of high quantities of fat and sugar, which has been associated with serious health problems. In the USA and Europe, daily fat consumption represents about 40% of total caloric intake; however, health specialists recommend that it should not exceed 30% of the total calories in a diet.\(^1\) On the other hand, the consumption of sucrose is considered as one of the factors which cause obesity and dental illnesses. Despite these problems, fat and sugar cannot be easily replaced, especially in a complex food system such as biscuits. Cookies, especially, are soft-type biscuits whose textural characteristics are mostly provided by their high fat content. Fat provides flavour and mouthfeel; it also contributes to appearance, palatability, texture and lubricity. Sucrose is one of the most important ingredients of bakery products, providing volume, texture and sweetness.

Studies of fat replacement by several fat mimetics suggested only partial replacement in order to produce bakery goods with acceptable properties. Thus the replacement of shortening by polydextrose (Litesse) or a blend of mono- and diglycerides in crisp oatmeal cookies showed that the sensory characteristics and physicochemical properties of the prepared cookies were affected and that polydextrose appeared to be a suitable replacer for up to 25% of shortening.\(^4\) Other experiments with polydextrose and several starch-based fat replacers showed that the replacement of 35% of fat had the least negative effects on the physical properties of cookies, compared with replacement by 45 or 55%.\(^5\) Also, oat fibres were successfully used in order to produce soft-type cookies with one-third fewer calories; the low-fat product presented a colour and flavour comparable to those of the standard product.\(^6\) Other oat-derived fat mimetics (Oattrim and Z-Trim) gave cookies and some bakery products with acceptable sensory characteristics when they replaced fat by 50%, but higher levels of replacement resulted in lower overall quality.\(^4,7\) Through a study on several fat replacers in biscuits, Conforti et al\(^8\) concluded that an increase in fat replacement resulted in increases in moisture content and colour lightness and a decrease in tenderness of the product; however, consumers rated the biscuits with up to 66% fat replacement as acceptable, with no significant differences compared with control biscuits. Increases in water activity and hardness were the major effects of an increase in fat replacement in cookies as well, while flavour was not significantly affected by fat replacement up to 35%.\(^9\) The type of fat mimetic seemed also

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to affect texture and flavour. However, some reports suggested that higher fat replacement could be used successfully in some bakery products. Hippelheuser et al. used Amerimaize 2210, a modified, pre-gelatined starch, in order to produce a low-fat muffin (with a fat content of 50 g kg^{-1}) which had sensory and textural properties similar to those of the control (fat content 270 g kg^{-1}). Also, Simplesse bakery blends, which consist of whey microparticulates and selected emulsifiers, were reported not to affect the full-fat taste when they replaced fat up to 93% in cakes, muffins and brownies. On the contrary, experimental results for cookies showed that the replacement of 50 or 75% of fat by protein- or carbohydrate-based fat mimetics negatively affected the flavour of the products.

Unlike fat which was partially replaced, sugar was totally removed in bakery products. The substances used to replace sucrose in low-calorie products were polyols or fructose to provide mainly volume and intense sweeteners to provide sweetness. Olinger and Velasco investigated the effects of specific polyols, ie sorbitol, lactitol, isomalt and maltitol, on the textural, physical and sensory characteristics of cookies. The cookies with polyols were notably softer than the sucrose ones, except for the lactitol cookies, whose instrumental and perceived hardness were similar to those of sucrose cookies. Peck reported that the use of sorbitol as the sole bulking agent for sugar replacement in cookies would result in very soft products and suggested that a portion of sorbitol could be replaced by isomalt or polydextrose to give the desirable texture.

Intense sweeteners, namely aspartame, cyclamates, acesulphame-K and saccharin, or fructose were used to replace sugar in cookies. Combinations of two or three of these sweeteners with and without the addition of polydextrose (as a bulking agent) showed that most of the resulting cookies had a sweetness similar to that of the control. Although cookies prepared with polydextrose were harder and more fragile than cookies prepared without it, they showed, in general, properties which were closer to those of sucrose cookies. The results of sensory analysis showed that a bitter aftertaste was present in cookies containing acesulphame-K, saccharin and cyclamates. Sweetness-time curves showed that no alternative sweetener behaved exactly as sucrose did. Nevertheless, cookies prepared with acesulphame-K or saccharin gave sweetness intensity profiles similar to those of sucrose cookies. Aspartame was considered unacceptable since it is not stable at high temperatures.

Our previous work on fat mimetics indicated that polydextrose, maltodextrins (C*deLight) and protein microparticulates (Simplesse) were the most appropriate as far as cookie properties were concerned. The main problem noted was the high hardness of the products. Additional research on the replacement of sucrose by polyols in low-fat cookies (35% of shortening replaced by polydextrose) showed that maltitol, lactitol and sorbitol resulted in cookies with acceptable properties, and especially lactitol and sorbitol improved the texture, while maltitol improved the flavour of the products. The sweetness of the cookies was adjusted by the addition of acesulphame-K.

The present work was undertaken to prepare sugar-free cookies with up to 50% fat replacement and acceptable properties. Combinations of various fat mimetics with lactitol, sorbitol and maltitol were used. The effects of the quantity of polyol added to the formulation and of the concentration of the fat mimetic preparation were also studied.

**MATERIALS AND METHODS**

**Materials and cookie formula**

Four types of fat mimetic were used: an improved polydextrose, Litesse (Pfizer, Inc, New York, NY, USA); a maltodextrin with low dextrose equivalent (DE = 3), C*deLight MD 01970 (Cerestar, Brussels, Belgium); an inulin, Raftiline (Orrafti Active Food Ingredients, Oreaye, France); and a blend of microparticulate whey proteins and emulsifiers, Simplesse Dry 100 (The Nutrasweet Kelco Co, Tadworth, Surrey, UK). Polydextrose, C*deLight MD 01970 and Raftiline were dissolved in cold water at a concentration of 200 g kg^{-1}. Simplesse Dry 100 was dissolved in cold water at a concentration of 330 g kg^{-1}, because at 200 g kg^{-1} concentration it gave a solution with low viscosity. The solutions were stored at 4°C overnight. Cold storage resulted in gel formation for all the formulations except polydextrose solution. C*deLight MD 01970 was also used at concentrations of 100, 150 and 300 g kg^{-1}. In low-fat formulations, 35 or 50% of shortening was replaced by an equal weight of the fat mimetic formulation.

The polyols used to replace sucrose were maltitol (MALTISORB P200, Roquette Freres SA, Lestrem, France), lactitol (LACTY-M LB-839 DN, PURAC Biochem, Gorinchem, The Netherlands) and sorbitol (NEOSORB P600, Roquette Freres SA). Intense sweeteners were not used for sweetness adjustment, in order to avoid masking any flavour induced by the additives.

The control cookie formulation contained the following ingredients at the indicated levels: flour, 200 g; powdered sugar, 81 g; shortening (Artisan, ELAIS SA, Athens, Greece), 88 g; cold soluble starch (C*Top 126E1, Cerestar), 10 g; cheese whey, 3.5 g; ammonium bicarbonate, 2.6 g; sodium bicarbonate, 1.7 g; tartaric acid, 0.6 g; sodium stearoyl lactate (SSL), 2.0 g; water, 36 g.

**Experimental procedure**

Cookies were prepared according to the following procedure. All ingredients except the fat mimetic formulation were equilibrated overnight in an oven at 25°C. Shortening was mixed with water, starch, emulsifier, whey, sugar and the fat mimetic formulation in a mixer (Kenwood Chef A901, Kenwood...
Manufacturing Co Ltd, New Lane, Hampshire, UK) for 2 min at low speed and then for 5 min at high speed until a cream was formed. Flour, sodium bicarbonate, ammonium bicarbonate and tartaric acid were sifted together and added to the cream. The dough was formatted to cookies of 4 cm diameter and 3 mm thickness, using a frame of 3 mm height and a cutter of 4 cm diameter. The cookies were baked in an air circulation oven at 160°C for 30 min. The samples were allowed to cool at room temperature for 2 h. Some cookies were set aside for the measurement of physical characteristics. The rest were packaged in metallised polypropylene bags for 24 h and then texture and sensory analyses and water activity measurements were conducted.

All experiments were run in duplicate and the presented results are the average of two trials.

Analytical methods

Physical properties of cookies

The physical properties measured were diameter, moisture content and water activity. In order to measure the diameter of the cookies, the following procedure was followed. Four cookies were placed next to each other and the total diameter was measured. Then all four cookies were rotated by 90° and the new diameter was measured. The average of the two measurements divided by four was taken as the final diameter of a cookie.

Moisture content was determined by drying the samples at 105°C. Water activity was measured in a Ro-tronic A2 Hygromer (Ro-tronic AG, Bassersdorf, Switzerland). Pieces of several cookies of the same sample were exposed to the Hygromer sensor. Measurements of water activity and temperature were taken until the value of water activity was stabilised. The mean value of duplicate measurements was considered as the result for each sample.

Textural properties of cookies

The texture of the samples was evaluated using a TA-XT2 Texture Analyser (Stable Micro Systems, Godalming, Surrey, UK) and conducting a ‘measure force in compression’ test with a sharp blade cutting probe. The analyser was set at a ‘return to start’ cycle, a speed of 1 mm s⁻¹ and a distance of 3 mm. A force/penetration distance plot was made for every test. Hardness and brittleness of the cookies can be estimated by the maximum force (N) and the mean slope (Ns⁻¹) of the force/deformation curve respectively. Measurements were conducted three times and the results are mean values.

Sensory analysis of cookies

Sensory analysis of cookies was conducted by an eight-member trained panel. The sensory characteristics examined were hardness, brittleness, flavour and general acceptance (combination of flavour, appearance and texture). All four sensory attributes were rated on a 1–5 intensity scale where 1 = lowest score and 5 = highest score.

Statistical analysis

Data were analysed by single-factor analysis of variance. Statistical significance is indicated at the 95% confidence level.

RESULTS AND DISCUSSION

Effect of combinations of fat mimetics and polyols on cookie properties

According to our previous work, polydextrose, maltodextrins and protein microparticulates could be used to replace up to 35% of shortening in cookies without adversely affecting the acceptance of a sensory panel. In the present work, in addition to these fat mimetics, inulin was tested, representing a different category of potential fat replacers in cookies. To prepare low-fat, sugar-free cookies, the polyols lactitol, sorbitol and maltitol, which proved the most appropriate in previous experiments, were used. The results of the physical properties of all combinations compared with the control cookies are presented in Fig 1 and Table 1.

Fig 1 presents the diameter increase of the cookies after baking. Cookies usually show a substantial increase in diameter during the late stages of baking that is attributed to gluten properties of the soft wheat flour, which forms a collapsible film rather than an elastic network. The type of fat mimetic added affected the diameter increase more significantly than the polyol did. Control samples showed the greatest diameter expansion, followed by samples prepared with protein microparticulates (Simplesse) and poly-

![Figure 1. Diameter increase of cookies with various sweeteners and 35% of fat replaced by fat mimetics.](image-url)
dextrose. On the other hand, cookies prepared with maltodextrins (C*deLight) or inulin (Raftiline) showed a significantly \((p < 0.05)\) lower diameter increase. Previous experimental results\(^9\) had demonstrated that maltodextrins enhanced elastic shrinkage during baking and therefore resulted in a small diameter increase. Inulin seems to act in the same way. Cookies prepared with lactitol or maltitol showed a greater diameter increase than cookies prepared with sucrose or sorbitol in all cases; the differences were not significant, however. These results were in agreement with previous ones.\(^{17}\)

Table 1 presents the effects of different fat mimetics and alternative sweeteners on moisture content and water activity of the cookies. Cookies should demonstrate low values of moisture content and water activity, as these properties affect shelf-life. All cookies showed significantly greater values of moisture content and water activity than the control. The replacement of fat alone resulted in an increase in both these values.

In particular, samples containing Simplesse and polydextrose demonstrated higher values than samples containing Raftiline and C*deLight. Replacement of sugar by polyols did not increase further the moisture content and water activity, except in the cookies containing Raftiline. Samples prepared with sorbitol showed the highest values, though not statistically significant in most cases. However, all the water activity values measured were below the limit over which growth of micro-organisms or enzymatic or oxidative deterioration is permitted.\(^{20}\)

Hardness and brittleness of the cookies were evaluated by the maximum force (N) and the mean slope (\(\text{Ns}^{-1}\)) of the force/deformation curve respectively, which were obtained from the Texture Analyser during a ‘measure force in compression’ test. Hardness and brittleness of the specific cookies, as calculated during the Texture Analyser tests, are presented in Figs 2(a) and 2(b) respectively. The results of these tests showed that cookies prepared

<table>
<thead>
<tr>
<th></th>
<th>Sucrose</th>
<th>Lactitol</th>
<th>Sorbitol</th>
<th>Maltitol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture content (a_w)</td>
<td>11.6a 0.08a</td>
<td>22.4b 0.17a</td>
<td>24.1a 0.19a</td>
<td>23.7b 0.17a</td>
</tr>
<tr>
<td>Raftiline</td>
<td>14.3b 0.11b</td>
<td>23.0a 0.18a</td>
<td>20.5a 0.22ab</td>
<td>21.7b 0.19a</td>
</tr>
<tr>
<td>C*deLight</td>
<td>17.7bc 0.16c</td>
<td>18.0a 0.16a</td>
<td>24.4a 0.23b</td>
<td>19.0c 0.16c</td>
</tr>
<tr>
<td>Simplesse</td>
<td>21.9c 0.21d</td>
<td>20.0ab 0.19a</td>
<td>22.5a 0.22ab</td>
<td>22.5a 0.22ab</td>
</tr>
<tr>
<td>Polydextrose</td>
<td>19.0c 0.16c</td>
<td>21.2b 0.18a</td>
<td>24.4a 0.23b</td>
<td>23.2ab 0.17a</td>
</tr>
</tbody>
</table>

Mean Values with the same letter within the same column are not significantly different at \(p < 0.05\).
Fat and sugar replacement in cookies

With polydextrose were significantly harder than the control and other fat-reduced samples, irrespective of the sweetener used. The use of C*deLight, Simplesse and Raftiline led to the production of cookies with similar hardness. The type of sweetener also had a pronounced effect on hardness. Lactitol and sorbitol cookies were significantly softer than sucrose and maltitol ones. Moreover, cookies prepared with lactitol or sorbitol demonstrated lower hardness than the control. Brittleness results were similar to hardness ones. Specifically, cookies prepared with Raftiline, Simplesse or C*deLight did not show significant differences in brittleness values. Samples containing polydextrose were extremely brittle. Sucrose or maltitol combined with all fat mimetics led to significantly higher brittleness than that measured in cookies prepared with lactitol or sorbitol. Consequently, cookies prepared with maltitol showed greater hardness and brittleness than the control sample. On the other hand, cookies prepared with lactitol or sorbitol showed similar or even lower hardness and brittleness compared with the control cookies.

The results of sensory analysis showed that hardness and brittleness estimated by the panel were in good agreement with measurements derived from the Texture Analyser. On the other hand, all low-fat, sugar-free cookies had significantly lower flavour and general acceptance scores than the control cookies, as indicated in Table 2. Samples prepared with maltitol had significantly higher flavour and general acceptance scores than cookies containing lactitol and sorbitol. Nevertheless, lactitol and sorbitol cookies were judged as acceptable by the panelists, and their flavour score could be markedly improved by the addition of an intensive sweetener such as acesulphame-K.17

According to the results presented so far, in order to prepare sugar-free cookies with up to 50% fat reduction and acceptable hardness and brittleness, maltitol was not used at all, and a 1:1 (w/w) blend of lactitol and sorbitol was added to the formulation. For the same reason, polydextrose was not used as a fat replacer in the 50% fat reduction formulations, since it had the most adverse effect on texture.

Properties of sugar-free cookies with 50% fat replacement
C*deLight, Simplesse and Raftiline were used as fat mimetics in these cookies. Sucrose was replaced by a blend of lactitol and sorbitol in equal quantities. A combination of these polyols was used because lactitol imparted a better flavour and sorbitol a softer, less brittle texture to the cookies. The results of physical property measurements, texture analysis and flavour evaluation are given in Table 3. Sugar-free cookies prepared with Raftiline or C*deLight showed a significantly lower diameter increase after baking compared with the control, while samples prepared with Simplesse had a diameter similar to that of the control cookie. Moisture content and water activity measurements showed that all samples had significantly higher values than the control. Furthermore, samples containing C*deLight showed a significantly lower moisture content than Simplesse samples, but there were no significant differences in water activity values. It should be noted that water activity values are still within the limits that ensure shelf-life stability of the product.

Hardness and brittleness data showed that all formulations had significantly higher values of both textural properties compared with the control cookie, while no significant difference in hardness or brittleness among fat mimetics was noted. According to the

### Table 2. Sensory evaluation (1–5) of cookies with various sweeteners and 35% of fat replaced by fat mimetics

<table>
<thead>
<tr>
<th>Sweetener</th>
<th>Flavour</th>
<th>General acceptance</th>
<th>Flavour</th>
<th>General acceptance</th>
<th>Flavour</th>
<th>General acceptance</th>
<th>Flavour</th>
<th>General acceptance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>4.25a</td>
<td>4.09a</td>
<td>3.37bc</td>
<td>3.21b</td>
<td>2.72c</td>
<td>3.47b</td>
<td>2.72c</td>
<td>3.47b</td>
</tr>
<tr>
<td>Raftiline</td>
<td>3.31bc</td>
<td>3.05a</td>
<td>3.09a</td>
<td>2.97a</td>
<td>2.50b</td>
<td>2.63ab</td>
<td>2.63a</td>
<td>3.50a</td>
</tr>
<tr>
<td>C*deLight</td>
<td>3.37bc</td>
<td>3.05a</td>
<td>3.09a</td>
<td>2.97a</td>
<td>2.50b</td>
<td>2.63ab</td>
<td>2.63a</td>
<td>3.50a</td>
</tr>
<tr>
<td>Simplesse</td>
<td>2.72c</td>
<td>3.05a</td>
<td>2.95a</td>
<td>2.83a</td>
<td>2.40b</td>
<td>2.64a</td>
<td>3.07b</td>
<td>3.43a</td>
</tr>
<tr>
<td>Polydextrose</td>
<td>3.47b</td>
<td>2.63ab</td>
<td>2.95a</td>
<td>2.83a</td>
<td>2.40b</td>
<td>2.64a</td>
<td>3.07b</td>
<td>3.43a</td>
</tr>
<tr>
<td>Maltitol</td>
<td>3.47b</td>
<td>2.63ab</td>
<td>2.95a</td>
<td>2.83a</td>
<td>2.40b</td>
<td>2.64a</td>
<td>3.07b</td>
<td>3.43a</td>
</tr>
</tbody>
</table>

Mean values with the same letter within the same column are not significantly different at \( p < 0.05 \).

### Table 3. Physical, textural and sensory properties of cookies with 50% less fat and without sugar (replaced by a 1:1 lactitol/sorbitol blend)

<table>
<thead>
<tr>
<th>Sweetener</th>
<th>Diameter increase (%)</th>
<th>Moisture content (g kg(^{-1}))</th>
<th>( a_w )</th>
<th>Hardness (N)</th>
<th>Brittleness (Ns(^{-1}))</th>
<th>Flavour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>23a</td>
<td>11.6a</td>
<td>0.08a</td>
<td>36.1a</td>
<td>24.8a</td>
<td>4.25a</td>
</tr>
<tr>
<td>C*deLight</td>
<td>12b</td>
<td>37.6b</td>
<td>0.20b</td>
<td>58.1b</td>
<td>41.2b</td>
<td>2.87b</td>
</tr>
<tr>
<td>Raftiline</td>
<td>13b</td>
<td>43.4bc</td>
<td>0.22b</td>
<td>60.0b</td>
<td>38.6b</td>
<td>2.79b</td>
</tr>
<tr>
<td>Simplesse</td>
<td>20a</td>
<td>45.9c</td>
<td>0.23b</td>
<td>59.4b</td>
<td>42.6b</td>
<td>2.29c</td>
</tr>
</tbody>
</table>

Mean values with the same letter within the same column are not significantly different at \( p < 0.05 \).
sensory panel, 50% fat-reduced cookies were harder and more brittle than samples with 35% less fat, but these differences were not statistically significant. These results were in agreement with the Texture Analyser measurements. Increasing the amount of fat removed from 35 to 50% resulted in lower flavour and general acceptance scores. In particular, cookies prepared with Simplesse demonstrated a significantly lower flavour score than samples prepared with C*deLight and Raftiline. On the other hand, there were no significant differences in general acceptance score among all 50% fat-reduced, sugar-free cookies; values varied from 2.51 to 2.81.

**Effect of amount of polyol on properties of cookies with 50% less fat**

In all previous experiments the weight of sweetener (sucrose or polyols) added to the formulation was constant and amounted to 390 g kg\(^{-1}\) flour. In order to examine the way in which the total quantity of polyol added to the formulation affects the properties of a sugar-free, low-fat cookie, three different amounts of lactitol, ie 310, 390 and 470 g kg\(^{-1}\) flour, were compared. Fat was replaced at the 50% level by C*deLight or Raftiline.

Increasing lactitol amounts added to the formulation resulted in an increase in diameter expansion of 11% for 310 g kg\(^{-1}\), 14% for 390 g kg\(^{-1}\) and 17% for 470 g kg\(^{-1}\) flour, were compared. Fat was replaced at the 50% level by C*deLight or Raftiline.

Increasing lactitol amounts added to the formulation resulted in an increase in diameter expansion of 11% for 310 g kg\(^{-1}\), 14% for 390 g kg\(^{-1}\) and 17% for 470 g kg\(^{-1}\). Using various sugars (ie sucrose, dextrose, liquid glucose, HFCS, etc), Manohar and Rao\(^{21}\) also observed that increasing the amount of sugar resulted in an increase in biscuit diameter after baking. All sugars used had the same effect. There were no significant differences in diameter increase between fat mimetics. Increasing the amount of lactitol added also affected moisture content and water activity of the cookies, as it caused a significant increase in both physical characteristics. These results are presented in Fig 3.

The effect of polyol content on the textural properties of cookies is shown in Fig 4. As can be seen, a decrease in the total amount of lactitol added leads to cookies with reduced hardness and, at a lactitol content of 310 g kg\(^{-1}\), hardness is comparable to the control cookie hardness (36.1 N). On the contrary, in full-fat cookies, Manohar and Rao\(^{21}\) found that an increase in sucrose content resulted in a decrease in hardness. Brittleness was also affected by the reduction in lactitol content; however, cookies prepared with 310 g lactitol kg\(^{-1}\) flour were significantly more brittle than the control cookies.

According to the sensory panel, the polyol content did not affect the flavour score significantly, but there was a significant decrease in general acceptance score as the lactitol amount increased, ie 3.38, 3.06 and 2.73 for 310, 390 and 470 g kg\(^{-1}\) respectively. This is attributed to increasing hardness and brittleness of the cookies. Consequently, a reduction in alternative sweetener content can be used in order to prepare sugar-free, fat-reduced cookies with acceptable textural properties. The sweetness of the cookies can be easily adjusted by incorporation of an intense sweetener in the formulation.

**Effect of concentration of fat mimetic preparation on cookie properties**

In order to improve further the properties of cookies with 50% fat replacement, the effect of the concentration of fat mimetic gel was studied. C*deLight was used as fat mimic in this experimental series, because...
it resulted in cookies with good physical and textural properties. Another advantage of fat-reduced cookies containing C*deLight was the better flavour and general acceptance scores they had compared with samples prepared with Raftiline in previous experiments. Flavour and general acceptance scores for cookies containing C*deLight were 2.87 and 2.81 respectively, while for cookies containing Raftiline they were 2.79 and 2.66. Four different gel concentrations (100, 150, 200 and 300 g kg\(^{-1}\)) were used. Sucrose was replaced in these formulations by lactitol, sorbitol or a 7:3 (w/w) lactitol/sorbitol blend.

The effect of gel concentration on cookie properties is presented in Figs 5–7. The C*deLight gel concentration affected the diameter increase after baking, as can be seen from Fig 5. Decreasing the gel concentration resulted in a greater diameter expansion. Samples prepared with lactitol showed a greater diameter increase after baking compared with cookies containing sorbitol; therefore previous results were verified.

Moisture content and water activity of all sugar-free cookies prepared with varying gel concentrations were significantly higher than those of the control (Fig 6). Decreasing the C*deLight concentration to 100 g kg\(^{-1}\) resulted in a significant increase in moisture content and water activity values, which was expected, since a reduction in fat mimetic concentration is followed by an increase in water content in the gel. Cookies containing lactitol had lower moisture content and water activity values than cookies containing the blend of lactitol and sorbitol or sorbitol alone, though differences were not significant in most cases.

The results of the Texture Analyser measurements, presented in Fig 7, were very interesting. The 50% fat-reduced cookies prepared with a gel concentration of 300 g kg\(^{-1}\), combined with all three alternative sweetener preparations, demonstrated a hardness which was comparable to that of the control cookie. On the other hand, reducing the fat mimetic concentration to 100 g kg\(^{-1}\) led to cookies with noticeably high hardness. Brittleness results were similar to those for hardness. Samples containing C*deLight gel with a concentration of 300 g kg\(^{-1}\) showed low values of this textural characteristic which were comparable to the control cookie value. Decreasing the concentration of the gel resulted in an increase in brittleness. The type of alternative sweetener preparation did not significantly affect cookie textural properties.

The sensory analysis showed that an increase in the concentration of fat mimetic gel resulted in a decrease in hardness from 2.80 at a concentration of 100 g kg\(^{-1}\) to 1.82 at a concentration of 300 g kg\(^{-1}\), while it did not affect the flavour score of the cookies. Consequently, the general acceptance score was increased.
from 2.58 at a concentration of 100 g kg\(^{-1}\) to 2.98 at a concentration of 300 g kg\(^{-1}\).

According to these results, the use of a gel of C*deLight with a higher concentration, ie 300 g kg\(^{-1}\), would be beneficial for the textural properties, moisture content and water activity of cookies. Diameter expansion in this case can be maintained within acceptable limits if lactitol is incorporated in the formulation as sugar replacer.

**CONCLUSIONS**

Raftiline, Simplesse or C*deLight combined with lactitol or sorbitol in 35% fat-reduced, sugar-free cookies resulted in products with hardness and brittleness comparable to those of the control. Polydextrose as fat mimetic and maltitol as sugar substitute resulted in very hard and brittle products. The diameter increase after baking of all formulations, except samples prepared with Simplesse and polydextrose, was low. Further fat replacement to 50% was achieved using Raftiline, Simplesse or C*deLight combined with a blend of lactitol and sorbitol, but the final products were hard, brittle and did not expand properly after baking. Cookies prepared with Simplesse showed the greatest expansion, but their flavour was the least acceptable. On the contrary, cookies prepared with C*deLight were rated as the most acceptable by the sensory panel, followed by cookies prepared with Raftiline. The problems of greater hardness and brittleness were solved by either decreasing the amount of alternative sweetener (lactitol) from 390 to 310 g kg\(^{-1}\) flour or increasing the C*deLight gel concentration from 200 to 300 g kg\(^{-1}\). All fat-reduced, sugar-free cookies prepared in this study had higher values of moisture content and water activity than the control, but these values were below the upper limit that affects cookie shelf-life.

**REFERENCES**