Strategies to reduce sugar and fat in muffins: reduction by stealth, addition of fibers and aromas

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“Combining Technologies to achieve significant **binary Reductions in sodium, Fat and sugar** content in everyday foods whilst optimising their nutritional Quality”

**Targeted product groups:**

Ready-to-eat meals, Cheeses, Meat products, **Bakery products**

**Partners:**

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"Bakery” objectives

Muffins – Reformulation strategies:
1. Reduction by **stealth** (mere gradual reduction)
2. Replacement by **Inulin** and water-in-oil **emulsions**
3. Taste and texture enhancing **odorants**

**Perception & oral behaviour**
- Discrimination and liking
- Dynamic sensory perception during food consumption
- In-mouth aroma release & **fat coalescence**
1 Reduction by stealth: mere reduction of fat & sugar

![Graph showing weight percentage of various ingredients in reference and 40% fat reduced versions.](image)
1. **Reduction effects on structure**

- Fat reduction: 00+
- Sugar reduction: +++

- Sugar & - fat
- Sugar
- Fat
1 Discrimination tests: single reduction

- Discrimination test (triangle) on 112 consumers: reduced vs regular muffins
- 40% fat reduction or 15% sugar reduction < JND relative to full fat/sugar muffin

<table>
<thead>
<tr>
<th>Reduction %</th>
<th>% of correct answers</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>-20% oil</td>
<td>32.1%</td>
<td>0.640</td>
</tr>
<tr>
<td>-40% oil</td>
<td>37.8%</td>
<td>0.201</td>
</tr>
<tr>
<td>-60% oil</td>
<td>47.3%</td>
<td>0.001</td>
</tr>
<tr>
<td>-5% sugar</td>
<td>36.6%</td>
<td>0.261</td>
</tr>
<tr>
<td>-15% sugar</td>
<td>41.1%</td>
<td>0.052</td>
</tr>
<tr>
<td>-25% sugar</td>
<td>45.5%</td>
<td>0.005</td>
</tr>
</tbody>
</table>

Significance level p=0.05
1 Discrimination tests: Binary reduction

- Binary reduction of 10% sugar and 40% fat in muffins: consumers (n=76) do not perceive differences relative to full fat/sugar muffin

![Graph showing discrimination tests results](image-url)
### 2 Compensation: fat & sugar replacement

<table>
<thead>
<tr>
<th>No sugar reduction</th>
<th>No fat reduction</th>
<th>-40% fat</th>
<th>-58% fat (70/30 w-o emulsion)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No sugar reduction</td>
<td>Reference</td>
<td>mono reduced fat</td>
<td>binary reduced + fat compensation</td>
</tr>
<tr>
<td>-15% sugar</td>
<td>mono reduced sugar</td>
<td>binary reduced</td>
<td>binary reduced + sugar compensation</td>
</tr>
<tr>
<td>-30% sugar + short chain inulin</td>
<td>binary reduced</td>
<td>binary reduced + sugar compensation</td>
<td></td>
</tr>
</tbody>
</table>

- 6 muffins: 1 reference; 2 not discriminably amounts of reduced fat/sugar (green); 1 just discriminable reductions(yellow); 2 clearly discriminable (orange)
- Compensation strategies for most-reduced muffins
- Structural changes (fat distribution during mastication)?
- Perceptual changes?
Compensation: fat & sugar replacement: structure effects

- Fat droplet distribution changes in the bolus during mastication:

  - 4 panellists (M = 47.6 year)
  - 6 muffins in 3-fold.
  - Bolus expectorated after 8 s or 25 s
  - Focus on fat droplet area as $f(\text{size})$
Coalescence of fat droplets on the surface of food bolus defines fat perception.

Coalescence monitoring by CLSM: fluorescent dyes with high fat affinity (and starch affinity).

Dynamics of fat droplet coalescence during mastication provides insight into fat functionality in relation to the muffin matrix.
2 Total fat droplet areas...

- Depend on muffin fat%  \[ F(5,127) = 35.9; \ p < 0.001 \]
- Do not depend on chewing duration
- Differ between subjects \[ F(3,127) = 2.78; \ p < 0.05 \]
Volume contribution of coalesced fat on bolus interface per droplet size:

- **General**: short-term coalescence, long-term emulsification
- **Reference muffin**: droplets >0.01 mm² dominant after 8s, gone after 25s
- **-15% sugar muffin**: surprising increase in fat coalescence (both 8s & 25s)
- **-40% fat muffin**: less large coalesced droplets after 8s
- **-15% sugar/-40% fat**: droplets > 0.01 mm² slightly enhanced after 8s
- **Inulin-for-sugar**: decreased fat coalescence!
3 Compensation: odours enhancing taste/fat perception

Odour selection criteria:
- Proven effectivity (lit.)
- Natural in muffins
- Qualitatively congruent

Odours selected:
- Maltol/furaneol for sweetness
- Steam-distilled Butter/cream extract

<table>
<thead>
<tr>
<th>sensory element (aroma, taste, microstructure)</th>
<th>sensory perception (sweetness, saltiness, fat)</th>
<th>compound or mechanism</th>
<th>% reduction sugar, salt, fat</th>
<th>food matrix (product, sweet/savour application)</th>
</tr>
</thead>
<tbody>
<tr>
<td>aroma</td>
<td>sweetness</td>
<td>ethylbutyrate (esters; fruity aroma)</td>
<td>&lt;15%</td>
<td>desserts, sweet products</td>
</tr>
<tr>
<td>aroma</td>
<td>sweetness</td>
<td>ethylhexanoate</td>
<td>15-20%</td>
<td>apple juice (apple-arom products)</td>
</tr>
<tr>
<td>aroma</td>
<td>sweetness</td>
<td>maltol</td>
<td></td>
<td>sugar containing heated (maillard, pyrolysis)</td>
</tr>
<tr>
<td>aroma</td>
<td>sweetness</td>
<td>various 3(2H)-furanones (strawberry, caramel etc)</td>
<td></td>
<td>sugar containing heated (maillard, pyrolysis); fru (depending on version)</td>
</tr>
<tr>
<td>aroma</td>
<td>sweetness</td>
<td>vanillin (phenolic aldehyde)</td>
<td></td>
<td>Beverages, desserts, chocolate, confectionery, bakery</td>
</tr>
<tr>
<td>aroma</td>
<td>sweetness</td>
<td>2,3-butadione (diacetyl) and homologues</td>
<td></td>
<td>soups, meat broth</td>
</tr>
<tr>
<td>aroma</td>
<td>saltiness</td>
<td>sotolon, abhexone</td>
<td>10-30%</td>
<td>Meat broths, simple salt</td>
</tr>
<tr>
<td>aroma</td>
<td>saltiness</td>
<td>Various volatile extracts of bacon, ham, sardines, cheeses.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>aroma</td>
<td>fat</td>
<td>methyl ketones, lactones, volatile fatty acids</td>
<td></td>
<td>butter, cream</td>
</tr>
<tr>
<td>aroma</td>
<td>fat</td>
<td>volatile fat-oxidation products</td>
<td></td>
<td>meat products,</td>
</tr>
<tr>
<td>aroma</td>
<td>fat</td>
<td>methyl, ethyl, propyl, butyl esters</td>
<td></td>
<td></td>
</tr>
<tr>
<td>aroma</td>
<td>fat</td>
<td>fatty acids and acetate, propionate, butyrate of fatty acid alcohols</td>
<td></td>
<td></td>
</tr>
<tr>
<td>aroma</td>
<td>fat</td>
<td>Di ketones (buta-dione, penta-dione)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
3 Sensory evaluations
temporal dynamics of sensations (TDS)

- + / - compensating *aromas* (just noticeable)
- 9 sensory attributes
- 12 panelists (11 female, age 49.9, SD = 6.6)
- triplicate measurements (3 bites, ¼ muffin each)
3 TDS: reference muffins (full fat/full sugar)

Dominant attributes (expert panel, n=12):

- 1 = dry
- 2 = egg cake
- 3 = sweet taste
- Second half = sticky
**3 TDS: -40% fat**

**Changes:**

- Egg cake flavor reduced
- Less sticky, in favour of late sweetness
3 Differential TDS: Ref vs -40% fat

Again:
- Overall ANOVA effect on egg-cake / sticky response durations by Muffin $p < 0.001$
3 Reparing defects by aroma? Reference vs -40% fat + aroma

Changes:
- Eggcake defect not repaired by aroma
- Stickyness defect reduced (Aroma x Fat interaction, p < 0.05)
3 Sugar reduction effects (ref. vs -15% sugar)

Changes:
- Remarkably: no effects on sweetness
- Sugar reduction makes less egg cake-like and less sticky ($p < 0.05$)
- Egg cake flavor = Maillard product?
3 replacing sugar by aroma (low sugar vs. low sugar+aroma)

Aroma compensation of sugar reduction:

- Stickiness repaired in low sugar muffin
- “Aromatic sticky” later than “sugar sticky”
- early sweetness enhanced
- egg cake further reduced (hence a defect)
Conclusions

- **40% fat** and **10% sugar**: Consumers: no perceptual/preference defects
- **40% fat** and **15% sugar**: perceptual defects, partly repaired by aromas (expert panel)
- **Fat** reduction: little textural effect / large tribological effects during mastication: muffin tribology less important than rheology?
- **Sugar** reduction influences texture (hardness, cohesiveness, water activity, cell area), but improves fat functionality during mastication
- **Inulin** did not compensate sugar, but suppresses fat functionality during mastication

Outlook

Reports on cross-modal interactions i.r.t. binary reductions in:

- Muffins, dried fermented sausages, ready-made-meals & cheeses