Development of quick, in-mouth dissolving, milk protein-rich extruded baby foods

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Baby’s First Solid Food & Baby Led Weaning (BLW)

- Convenient, melts in the mouth in <30 s
- Low nutrient density, starch-based

NUTRITION FACTS

<table>
<thead>
<tr>
<th>Amount per serving</th>
<th>Calories 25</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Infants through 12 months % DV*</td>
</tr>
<tr>
<td>Total Fat</td>
<td>0g</td>
</tr>
<tr>
<td>Sodium</td>
<td>0mg</td>
</tr>
<tr>
<td>Total Carbohydrate</td>
<td>6g</td>
</tr>
<tr>
<td>Total Sugars</td>
<td>1g</td>
</tr>
<tr>
<td>Protein</td>
<td>0g</td>
</tr>
</tbody>
</table>

- Create in-mouth dissolving, milk protein-based puffs

Geriatric food!

Premiumizing milk protein to deliver better nutrition!!!
Milk Powder vs Concentrate Based Formulations Extrusion

- Lactose Hydrolyzed Skim Milk Powder (LHSM-P)

POWDER

Vacuum Evaporation

Lactose Hydrolyzed Skim Milk Powder (LHSM-P) or Lactose Hydrolyzed Skim Milk Concentrate (SM-P)

Dry Ingredients

Preconditioning

SC-CO$_2$

<100°C

Supercritical CO$_2$ Extrusion
### In-mouth dissolving Formulations: Process Parameters & Product Characteristics

<table>
<thead>
<tr>
<th>Formulation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>20SM-P/70MPC-80</strong></td>
</tr>
<tr>
<td><strong>30LHSM-P/60MPC-80</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Formulation</th>
<th>Expansion ratio</th>
<th>Porosity ($\varepsilon$)</th>
<th>Piece density (g/cm$^3$)</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td><strong>7.32 ± 0.90</strong></td>
<td>0.81 ± 0.01</td>
<td>0.15 ± 0.01</td>
<td>Product has small to medium cell sizes. Shows in-mouth dissolving within the desirable 30-40 second time frame.</td>
</tr>
<tr>
<td>8</td>
<td><strong>9.17 ± 0.41</strong></td>
<td>0.70 ± 0.02</td>
<td>0.17 ± 0.02</td>
<td>Product has small cell sizes and a powdery texture when bitten. Also shows in-mouth dissolving within the desirable 30-40 second time frame.</td>
</tr>
</tbody>
</table>

**Formulation**
- MPC-80: 60-70%
- LHSM-P or SM-P: 19.6-29.6%
- Sugar: 8%
- SHMP: 0.4%
- Lecithin: 2%

**Parameters**
- Feed rate: 35kg/h
- Liquid flow rate: 12.3-12.7kg/h
- SME: 56.0-60.0
- Injection pressure: 1200psi
- CO$_2$ flow rate: 0.8-1.4kg/h
- Product temp: 85°C

**SEM Images of two highest performing In-Mouth dissolving products**

Formulation 7  
Formulation 8
**In-Mouth Dissolving Properties:** Skim Milk Powder and Lactose Hydrolyzed Skim Milk Powder Products

<table>
<thead>
<tr>
<th>Formulation</th>
<th>20SM-P/70MPC</th>
<th>30LHSM-P/60MPC</th>
<th>Market</th>
<th>90MPC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time (sec)</td>
<td>Pre-Soak Bite</td>
<td>Bite 1 (Post 30 sec Soak)</td>
<td>Bite 2</td>
<td>Bite 3</td>
</tr>
<tr>
<td>Hardness (kg)</td>
<td>0</td>
<td>30</td>
<td>40</td>
<td>50</td>
</tr>
</tbody>
</table>

**Formulation:**
- 20SM-P/70MPC
- 30LHSM-P/60MPC
- Market
- 90MPC
Design of In-Mouth Dissolving and Skim Milk Powder-containing Baby Puffs

Hannah Jones
Department of Chemical and Biomolecular Engineering and Food Science, Cornell University

Introduction

Skim milk powder (SMP) is manufactured on an industrial scale to convert surplus liquid milk into a long-shelf life product. This project utilizes SMP in an innovative way by creating a novel, high protein puff product with comparable mouth dissolving properties to the current carbohydrate-based puffs on the market. Using SMP in addition to milk protein concentrate (MPC) is advantageous for two reasons: SMP contains more lactose than MPC, and its use in puffs would create a new market for SMP.

Materials and Methods

Extrudates with MPC/SMP ratios of 80%/20%, 70%/30%, and 60%/40% with 8% sugar, made using twin-screw, low-shear extrusion technology, and commercial conical puffs (market product) were compared. The 80%/20% puffs were previously extruded according to the specifications for MPC/SMP (Ace and Qua, 2013). During extrusion, CO2 flow rate, water flow rate, injection pressure, and temperature were manipulated to produce extrudates with in-mouth disintegration time comparable to the market product.

The methods used to measure physical properties are press density and expansion ratio (ER). The press density is defined as the number of the extruded puff which is specified by the extrusion parameters and affects the texture of the puff. The ER is determined by the extruder cross-sectional area to the area of the circular slice. The textural properties were quantified using hardness and crispness on a texture analyzer. The hardness is measured as the peak load required during compression of 30% strain, and the crispness is measured as the number of peaks during the same compression. For disintegration properties, a three-bite compression test was performed with a texture analyzer: the test consists of three relative “compressions” by measuring the difference in force before wetting, 10 seconds after wetting, and two compressions immediately after. The disintegration is characterized by the puff collapsing into a consomme that can be swallowed.

Table 1. Experimental Extrudate Formulations

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>10%/20%/30% NFC (g/100g)</th>
<th>NFC/MPC/SMP (%)</th>
<th>NFC/MPC/SMP (%)</th>
<th>NFC/MPC/SMP (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MPC</td>
<td>60</td>
<td>70</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>Sugar</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Lecithin</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>SMP</td>
<td>0.4</td>
<td>0.4</td>
<td>0.4</td>
<td></td>
</tr>
</tbody>
</table>

1. Physical/Textural Characteristics

Table 2. Comparing the physical characteristics of the SMP100, SMP200, and MPC formulations to a carb. based market sample

<table>
<thead>
<tr>
<th>Sample</th>
<th>Press Density (g/cm²)</th>
<th>Expansion Ratio (ER)</th>
<th>Diameter (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Market Product</td>
<td>0.12 ± 0.00</td>
<td>6.4 ± 0.00</td>
<td>14.4 ± 0.10</td>
</tr>
<tr>
<td>80%/20% MPC</td>
<td>0.10 ± 0.02</td>
<td>7.99 ± 0.60</td>
<td>15.6 ± 0.05</td>
</tr>
<tr>
<td>70%/30% MPC</td>
<td>0.13 ± 0.01</td>
<td>7.35 ± 0.13</td>
<td>15.5 ± 0.04</td>
</tr>
<tr>
<td>60%/40% MPC</td>
<td>0.13 ± 0.10</td>
<td>6.67 ± 0.60</td>
<td>16.5 ± 0.05</td>
</tr>
</tbody>
</table>

1.2. Dissolvability Test

Figure 1. Illustration of “Biodegradable Test in order to attain a swallowable mass

Figure 2. Bite test force vs. Time graph showing no-soak bite and three consecutive bites for an SMP100 sample

Figure 3. Bit test force vs. Time graph showing no-soak bite and three consecutive bites for each sample

Results

The physical, textural, and dissolvability property results indicate that the SMP samples have comparable or improved properties and can be used in addition to MPC. When comparing the ER and diameters, the SMP puffs had statistically significant smaller sizes which are more suitable for babies. Only SMP200 displayed a statistical significance for press density. Decreased hardness of the SMP containing sample is better for babies as less bite force is required to attain a swallowable mass. This is due to the addition of SMP causing less bitterness as can be seen as a sharp curve on their compression tests. The crispness test showed indistinguishable results between the market sample and 80%/20% MPC puffs and between the two SMP samples. Dissolvability based on three bite simulation is comparable to 80% MPC based product and superior to the market product.

Conclusion

The addition of SMP that can be further increased in future experiments has higher protein higher content than the market sample and more lactose than the 80%/20% MPC sample while still having melt in mouth characteristics like market sample. The future goal is to raise the percentage of SMP as much as possible while retaining comparable market product physical, textural and dissolvable properties.

References


Acknowledgments

I would like to thank Dr. Seyd Nimi and Jessica Uhl for their support, time, and encouragement in pursuing this project.
Congratulations

Hannah Jones (Cornell University)
Other Formulations: Process Parameters & Product Properties

Formulation: Lactose Hydrolyzed Skim Milk Powder

Formulation: Skim Milk Powder

- LHSM-P or SM-P 48.8%
- MPC-80 48.8%
- SHMP 0.4%
- Lecithin 2%

Parameters:
- Feed rate 35kg/h
- Liquid flow rate 12.3-13kg/h
- SME 56.3
- Injection pressure 1200-1600psi
- CO₂ flow rate 1.0-1.5kg/h
- Product temp 85°C

Soluble Fiber Enrichment: Additional benefit

<table>
<thead>
<tr>
<th>CO₂ flow rate (kg/h)</th>
<th>% CO₂ Saturation Level in aqueous phase</th>
<th>GOS Concentration (DP3 mg/mL)</th>
<th>DP3 GOS concentration (% wt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-extruded Control</td>
<td>--</td>
<td>Present but undetectable</td>
<td>Present but undetectable</td>
</tr>
<tr>
<td>0.75</td>
<td>83</td>
<td>0.15 ± 0.04</td>
<td><strong>0.30</strong></td>
</tr>
<tr>
<td>1.5</td>
<td>167</td>
<td>0.22 ± 0.04</td>
<td><strong>0.44</strong></td>
</tr>
<tr>
<td>2.5</td>
<td>278</td>
<td>0.24 ± 0.05</td>
<td><strong>0.48</strong></td>
</tr>
</tbody>
</table>

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<tr>
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<td>--</td>
<td>Present but undetectable</td>
<td>Present but undetectable</td>
</tr>
<tr>
<td>0.75</td>
<td>63</td>
<td>0.12 ± 0.001</td>
<td><strong>0.24</strong></td>
</tr>
<tr>
<td>1.5</td>
<td>115</td>
<td>0.19 ± 0.02</td>
<td><strong>0.38</strong></td>
</tr>
<tr>
<td>Unable to hold 2.5</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
</tbody>
</table>
### Powder-based Formulations: Process Parameters & Product Properties

#### Savory Formulation

<table>
<thead>
<tr>
<th>Flavor:</th>
<th>Salt 3.4%</th>
<th>Nutritional Yeast 1.4%</th>
<th>Garlic Powder 1.4%</th>
<th>Citric Acid 0.3%</th>
<th>Paprika 0.3%</th>
</tr>
</thead>
</table>

#### Base Formulation

- **LHSMP**: 68%
- **Xpander**: 14-15%
- **Rice Flour**: 10-15%
- **Lecithin**: 2%

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Feed rate</th>
<th>Liquid flow rate</th>
<th>SME</th>
<th>Injection pressure</th>
<th>CO₂ flow rate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>35kg/h</td>
<td>7.5-8kg/h</td>
<td>60.5-63.8</td>
<td>1500-1900psi</td>
<td>0.3-0.65kg/h</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Formulation</th>
<th>Expansion ratio</th>
<th>Porosity (ε)</th>
<th>Piece density (g/cm³)</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>5.4 ± 0.2</td>
<td>0.73 ± 0.08</td>
<td>0.18 ± 0.04</td>
<td>The 80°C drying temperature most likely resulted in Maillard browning in the products, although color could also be due to flavorants. Desirable cheesy/garlic flavor while being a lactose free product. Has a desirable crunchy texture for snacking.</td>
</tr>
<tr>
<td>4</td>
<td>4.6 ± 0.4</td>
<td>0.71 ± 0.04</td>
<td>0.19 ± 0.02</td>
<td>Has a light nutty coffee flavor. Is slightly sweet without the addition of any sugar. Has a crunchy texture which is good for a snack product.</td>
</tr>
</tbody>
</table>

#### Sweet Formulation

| Flavor: | Coffee Powder Conc. 0.3% |

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To do:

Objective 3: Finalize best formulations (with SHMP or SLSA), produce puffed products and evaluate their physico-chemical and sensory properties.
Thank You
For your support