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Novel, clean-label sweetening ingredients in reduced sucrose cake and biscuits

Key external stakeholders:
Food manufacturers  
Bakeries  
Food ingredients companies

Practical implications for stakeholders:
High levels of sucrose in food have been linked with an increased risk of developing obesity and Type 2 diabetes. Therefore a reduced sugar intake is strongly recommended by health professionals. This has resulted in an increased consumer demand for reduced sucrose products, particularly bakery products. This project sought to formulate novel biscuit and cake formulations, with reduced sucrose contents by utilizing clean-label sucrose replacements. At all stages of the research, the dough and batter rheology, baking properties, structure, shelf-life and sensory characteristics of the re-designed products were monitored.

Main results:
The level of sucrose was reduced in a cake formulation, and replaced with natural alternatives (apple pomace, whey permeate, oligofructose, polydextrose). The resulting nutritional composition, staling kinetics, crumb structure and sensory acceptance of the re-formulated cake products were characterized. An acceptable sugar reduction of up to 27% was achieved.

The sucrose content of a control biscuit formulation was reduced using a combination of bulking agents (polydextrose, maltodextrin, plant fibres) with extracts (yeast, apple) and natural flavourings. The effect on dough rheology, spread ratio, density, microstructure and sensory/eating properties was studied. Overall, biscuits containing cereal fibres and a natural flavouring received the highest sensory scores for colour, appearance, sweetness, aftertaste and overall acceptability, and exhibited a similar staling profile to that of the control. A total sucrose reduction of up to 29% was achieved.

Opportunity / Benefit:
Outputs from this project include the formulation of novel ingredient blends and a suite of techniques for producing reduced sucrose cakes and biscuits, with a particular focus on the utilization of clean-label ingredients. Knowledge and expertise regarding ingredient interactions and the generation of new products has been acquired. For more information, please contact Eimear Gallagher (Eimear.Gallagher@teagasc.ie) or Kieran Kilcawley (Kieran.Kilcawley@teagasc.ie).

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1. Project background:
This project focused on the reduction of sucrose in bakery formulations, in particular cake and short dough biscuits. These products traditionally contain high levels of sucrose, and ongoing negative press, coupled with increasing consumer awareness regarding the increased risks associated with obesity and Type 2 diabetes has resulted in an increased demand for reduced sucrose products. However, sucrose has multiple important functions in cakes and biscuits. It provides sweetness and affects the structure, colour, spread ratio, lubrication, flavour and texture of the batters/doughs and final baked products. Therefore raises many technical challenges, which need to be addressed during the re-design process. The project aimed to formulate novel reduced-sucrose cake and biscuit formulations, with optimal texture and sensory attributes.

2. Questions addressed by the project:
- Which ingredients may be used to formulate reduced-sucrose baked products?
- What are the technological and sensory implications of formulating these new products?

3. The experimental studies:
- Reduced sucrose cake formulations were prepared, where the following clean-label ingredients were investigated as possible sucrose-replacing alternatives: Oligofructose (OLIGO), apple pomace (AP), whey permeate (WP) and polydextrose (POLY).
- Reduced sucrose biscuit formulations were prepared using the following ingredients, as sucrose replacers: yeast extract, maltodextrin, citrus fibres, apple extract, polydextrose, cereal fibre and flavourings.
- Advanced gas chromatography was used to analyze and identify aromatic volatiles.

The following trials took place:
1. Fundamental rheology and microstructure of reduced sucrose cake batter and biscuit dough:
   - Fundamental rheological studies on the reduced sucrose cake batters and biscuit doughs included a frequency sweep, amplitude sweep and temperature ramp test using a fundamental rheometer.
   - Light microscopy, confocal laser scanning microscopy (CLSM) and cryo scanning electron microscopy (SEM) techniques were used to assess the microstructures of the batters and doughs.

2. Optimisation of HS-SPME extraction parameters for the extraction of volatile compounds of baked confectionery products
   - Using response surface methodology, an optimum HS-SPME method was devised and validated.

3. Physical, textural and sensory characteristics of reduced sucrose cakes, incorporated with clean-label sucrose-replacing ingredients:
   - Cake analysis:
     - Physical characteristics: Specific volume, crust/crumb colour.
     - Textural properties (all analyses took place on days 1, 3 and 7 post-baking): Crumb texture and rate of staling, crumb moisture, crumb water activity.
     - Crumb imaging: 2-D C-Cell imaging, confocal laser scanning microscopy.
     - Sensory evaluation, composition: sugar (total sugars, monosaccharides, disaccharides); fibre (total, soluble and insoluble).
     - Statistical analysis: One-way ANOVA of results was performed using SPSS. A Tukey pairwise comparison of the means was conducted to identify where the sample difference occurred as required.

4. Characterising the sensory quality, volatile aroma profile and odour active compounds of sponge cakes formulated with clean label ingredients:
   - The HS-SPME-GC-MS was employed to profile the volatiles.
   - Ranked descriptive analysis (RDA) and hedonic (consumers= 30) sensory analysis was undertaken.
   - Gas Chromatography-Olfactory (GCO) was used to identify odour active compounds contributing to sensory perception for the control, AP and OLIGO products.
   - Statistical analysis of sensory and volatile profile was undertaken using SPSS and XLSTAT.

5. Physicochemical effects of sucrose substitution with clean-label sweetening ingredients in
biscuits:

**Biscuit analysis:**
- Physical characteristics: Dimensions, spread ratio, density, external colour.
- Dough and biscuit texture: Dough TPA, biscuit hardness, moisture, water activity.
- Sensory evaluation, composition: sugar (total sugars, monosaccharides, disaccharides), fibre (total, soluble and insoluble).
- Statistical analysis: One-way ANOVA of results was performed using SPSS. A Tukey pairwise comparison of the means was conducted to identify where the sample difference occurred as required.

6. The impact of sucrose reduction on the acoustic (sound) properties, volatile profile and sensory attributes of a biscuit formulation:
The effects of incorporating polydextrose and citrus fibres as sucrose replacers (at a level of 40% replacement) in biscuits on the acoustic properties, volatile profile and sensory characteristics were assessed on days 1, 7 and 28 post-baking:

**Biscuit analysis:**
- External colour, moisture, water activity, texture/hardness/fracturability, acoustic properties/ acoustic emission, volatile flavour profiling, sensory acceptance testing.

4. Main results:

1. **Fundamental rheology and microstructure of reduced sucrose cake batter and biscuit dough:**
   - There was a significant increase in the storage and loss moduli of the reduced sucrose cake batters, compared with a control, indicating a change in flow properties of the batters. No significant differences were found in the rheological properties of the control biscuit formulation and the reformulated biscuit doughs.
   - It was found that the addition of the fibrous ingredients, rather than the reduction of the sucrose, had a greater effect on the microstructure of both the batters and the doughs, as evidenced by CLSM and cryo-SEM.

2. **Optimisation of HS-SPME extraction parameters for the extraction of volatile compounds of baked confectionery products:**
   - The optimized method consisted of; 5 min extraction time, 60 min extraction time, 60°C extraction temperature.

3. **Physical, textural and sensory characteristics of reduced sucrose cakes, incorporated with clean-label sugar-replacing ingredients:**
   - The use of POLY, WP, OLIGO as natural sucrose replacers produced cakes with similar physiochemical properties, crumb hardness, moisture and crumb water activity as the control cake.
   - Cakes containing AP had the lowest specific volume, highest crumb firmness and scored the lowest in overall acceptability by the sensory panelists.
   - Sensory panelists perceived no significant difference in sweetness between any of the reduced sucrose cakes in comparison to the control. The crumb cell structure was maintained for all cakes.
   - An acceptable sugar reduction of up to 28% was achieved.

4. **Characterising the sensory quality, volatile aroma profile and odour active compounds of sponge cakes formulated with clean label ingredients:**
   - Overall, the clean label sucrose sponge cakes were generally accepted by consumers, with the exception of AP.
   - RDA results showed that the clean label replacers were perceived as having a higher ‘nutty’ odour.
   - Volatile products of the Maillard reaction and caramelisation were key discriminators between the reduced sucrose products and the control.
   - GCO analysis identified 32 compounds contributing to the aroma of the sponge cakes.
   - Furfural ‘spicy bready’ had a significant contribution to all formulas, with the control having greatest levels of heptanal ‘fatty cake’. Both AP and OLIGO had the greatest contribution from methional ‘potato like’ and the AP product had the most contribution from both 2,3-dimethylpyrazine ‘bready caramel’ and 2-acetylpyrrole ‘cotton candy’.

5. **Physicochemical effects of sucrose substitution with clean-label sweetening ingredients in**
biscuits:
- No significant differences were found between the reduced sucrose biscuits and the control formulation, with regard to dough properties, volume, density and biscuit dimensions.
- All treatments received similar sensory scores as the control for flavour, aftertaste and sweetness.
- Sucrose content was reduced by up to 29%, and fibre content increased by 10-24% in the reformulated biscuits.

6. The impact of sucrose reduction on the acoustic (sound) properties, volatile profile and sensory attributes of a biscuit formulation:
- There were significant decreases in the acoustic properties (acoustic emission and linear distance) of the reformulated biscuits compared to the control, indicating an alteration to the crunchy/crispy properties of the products.
- The reduced sucrose products were accepted by panelists, however volatiles associated with lipid oxidation increased and Maillard browning reactions products decreased.

5. Opportunity/Benefit:
Following the use of new ingredient blends and the development of a range of reduced sucrose products during this project, advice, consultancy work and/or technical services can now be provided in this area through Teagasc’s fee-paying service. Commercial trials can be conducted in the test bakery and Prepared Consumer Food Centre at Ashtown and in the flavour chemistry facility at Moorepark.

6. Dissemination:
Peer-reviewed publications:


Scientific abstracts:


7. Compiled by: Dr. Eimear Gallagher, Ms. Emer Garvey and Dr. Kieran Kilcawley.