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Rheological, textural and sensorial properties of low-sucrose muffins reformulated with sucralose/polydextrose

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ABSTRACT

A study was made of the structure, texture, appearance, colour and consumer sensory analysis of low-sucrose muffins in which the sucrose had been totally or partially replaced (25%, 50%, 75%) by a sucralose:polydextrose mixture (1:1012). The structural characteristics of the muffin batters and of the baked muffins were studied through rheometry, microscopy, image analysis and texture analysis. The replacement of sucrose decreased the viscosity, viscoelasticiy and specific gravity of the raw muffin batter. The evolution of the batter's viscoelastic properties during heating reveals a decrease in the thermosetting temperature with sucrose replacement. These changes in the batter were associated with a muffin with less height, hardness, springiness, cohesiveness, chewiness and resilience and fewer air cells than the control. For 50% sucrose replacement, the appearance, colour, texture, flavour and sweetness and general acceptability were similar to those of the control. Significantly less acceptable muffins were obtained with 100% sucrose replacement.

1. Introduction

The growing consumer interest in health and its relationship with diet has led to a considerable rise in the demand for low sucrose and low fat products.

Muffins are sweet, high-calorie baked products which are highly appreciated by consumers due to their good taste and soft texture. Muffin batter is a complex fat-in-water emulsion composed of an egg–sucrose–water–fat mixture as the continuous phase and bubbles as the discontinuous phase in which flour particles are dispersed. Muffins are characterised by a typical porous structure and high volume which confer a spongy texture. To obtain such a final structure, a stable batter lodging many tiny air bubbles is required.

Sucrose performs multiple functions in this kind of baked product. Besides contributing to the sweet taste, sucrose provides a considerable part of the bulk in batters or doughs, helps baked goods stay moist, and limits the swelling of starch, which helps to create a finer texture. Under nonacidic conditions, it also contributes to the browning of the crust. One important role it plays is to delay starch gelatinisation and protein denaturation temperatures during cake baking so that the air bubbles can be properly expanded by the carbon dioxide and water vapour before the batter sets (Rosenthal, 1995). As a result, the cake structure is highly aerated and voluminous (Baeva, Terzieva, & Panchev, 2003). Furthermore, sucrose promotes fat-crystal aggregates, thus enhancing air entrapment and the stabilization of air bubbles during baking (Beesley, 1995).

Due to the complex structural functionality of sucrose in baked products, obtaining good quality low-sucrose products is a difficult task. Sucrose replacement in baked products needs to consider both the sweetness and the bulking effect of sucrose.

Sucralose (SC) (1,6-dichloro-1,6-dideoxy-β-D-dructofuranosyl-4-chloro-deoxy-α-D-galactopyranoside) is a zero-calorie sweetener, which is 600 times sweeter than sucrose. SC is heat-stable, retaining its sweetness, and could therefore be considered a suitable sweetener for bakery products (Barndt & Jackson, 1990) (Knight, 1994). Although SC provides the sweetness and crystallisation properties of sucrose, it has the disadvantage that it cannot mimic the structural contribution of sucrose to baked products. As a result, SC has to be combined with other substances which provide this functionality. Lin and Lee (2005) studied the effect of replacement of sucrose by a mixture of sucralose and a type of indigestible dextrin in chiffon cakes obtaining good results in physical and sensory properties in samples with less than 50% replacement.

Polydextrose (PD) is a bulking agent which mimics the structural functions of sucrose, other than sweetness and crystallisation

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(Torres & Thomas, 1981). PD has a very low calorie content (1 kcal/g). Since PD has been shown not to increase serum glucose values or create insulin demand in diabetics, it would appear to be a suitable component for special foods for diabetics (Torres & Thomas, 1981) (Roberfroid & Slavin, 2000).

PD has often been combined with high intensity sweeteners. Attia, Shehata and Askar (1993) studied the effect of replacing sucrose with fructose, acesulfame-K or aspartame, with or without the addition of PD, on the physical properties of cakes. The results indicated that adding PD caused an improvement in textural properties. PD has also been employed alone to replace sucrose in bakery products. Hicsasmaz, Yazgan, Bozoglu, and Kaunas (2003) studied the effect of PD substitution on a high-ratio cake system; a higher sugar replacement level resulted in a decrease in crack-like cells and an increase in small sphere-like cells, causing a significant decrease in cake height. Ronda, Gómez, Blanco, and Caballero (2005) studied the effect on sponge cake volume, colour and texture properties of total replacement of sucrose by seven bulking agents, including PD. The results showed that xylitol-PD was a good option to replace sugar. There is no previous scientific research on sucrose substitution by a mixture of SC and PD in muffins. This study evaluated the suitability of a mixture of SC and PD to replace different percentages of sucrose in muffins. The properties of the muffin batters (rheology and microstructure) and of the muffins (texture, colour and sensory acceptability) were measured and conclusions about the structural features associated with sucrose replacement were drawn.

2. Materials and methods

2.1. Batter and muffin preparation

Five muffin formulations were prepared by replacing part of the sucrose with polydextrose and sucralose (both from Tate & Lyle, McIntosh, Alabama) (1012:1). The samples were identified as control, 25%PD-SC, 50%PD-SC, 75%PD-SC and 100%PD-SC (Table 1). The muffin ingredients were wheat flour (Belenguer S.A., Spain. Information provided by the supplier: ≤15% moisture, 10% proteins), pasteurised liquid egg yolk and pasteurised liquid egg white (Ovocity, Spain), refined sunflower oil (Coosur S.A., Spain), whole milk (Puleva, Spain), sucrose (Azucarera Ebro, Spain), sodium bicarbonate (Martínez, Cheste, Spain), citric acid (Martínez, Cheste, Spain) and natural lemon peel.

The batter was prepared in a mixer (Kenwood Major Classic, UK), in which the egg whites were whisked for 2 min at top speed. The sucrose, PD and SC (depending on the formulation) were added and mixed in for 30 s more at top speed. The egg yolk, half the milk and the citric acid were then added and the mixer was set to speed 3 for 1 min. The flour, sodium bicarbonate and natural lemon peel were added and the mixture was beaten for a further 1 min at speed 3. Lastly, the mixer speed was increased to 4, the rest of the milk was added and the oil was gradually dripped in. The mixture was beaten for 3 min at speed 4 until it was smooth.

Table 1
Formulations of control muffins and muffins prepared with increasing quantities of polydextrose and sucralose mixture (PD-SC) as sucrose replacer.

Ingredients (g/100 g flour)	Control	25% PD-SC	50% PD-SC	75% PD-SC	100% PD-SC
Flour	100	100	100	100	100
Egg yolk	26.92	26.92	26.92	26.92	26.92
Egg white	53.85	53.85	53.85	53.85	53.85
Milk	50	50	50	50	50
Sucrose	100	75.00	50.00	25.00	0.00
Polydextrose	0.00	24.97	49.95	74.93	99.90
Sucralose	0.000	0.025	0.049	0.074	0.098
Oil	46.15	46.15	46.15	46.15	46.15
Sodium bicarbonate	3.96	3.96	3.96	3.96	3.96
Citric acid	3.04	3.04	3.04	3.04	3.04
Natural lemon peel	0.69	0.69	0.69	0.69	0.69

The batter was poured into a dosing machine (Edhard Corp., Hackettstown, USA). With the aid of a weighing scale, the quantity of batter dispensed was adjusted to exactly 45 g in each 60 mm diameter × 36 mm high paper mould. 12 moulds were arranged in three rows of four on a baking tray and baked for 17 min at 175 °C in an electric oven (Fagor Elegance 2H-114B, Guipúzcua, Spain) that had been preheated to this temperature for 10 min. The oven, the tray and the tray position in the oven were identical in each case.

The muffins were left to cool at room temperature for 1 h on a rack in order to avoid moisture condensing on their undersurface. The twelve muffins baked on the same baking tray were packed in sets of six in two polypropylene bags (O_2 permeability at $23\ ^\circ C = 1650\ cm^3/m^2$.day; water vapour permeability at 38 °C and 90% humidity = 9 g/m^2.day; thickness = 65 μm) and stored at 20 °C for one day.

2.2. Properties of the batter

The specific gravity of the dough (SG) was measured as the ratio of the weight of a standard container filled with batter to that of the same container filled with water. Two replicates from different batches of each formula were measured.

Dough bubbles were observed with a microscope (Nikon Eclipse 90i) using clear field mode. The micrographs were taken with a Nikon Digital Sight DS-5Mc cooled colour digital camera, using 40x magnification. Each formulation was prepared twice, on different days, and 4 replicates of each formula were photographed.

The rheological properties of the muffin batters were studied using an AR G2 controlled-stress rheometer (TA Instruments, Crawley, UK). The batters were all kept at 25 °C for 60 min after batter preparation before the rheological test. The samples were allowed to rest in the measurement cell for a 25 min equilibration time. A 40-mm diameter plate–plate sensor geometry with a serrated surface and a 1-mm gap was employed. A continuous ramp at 25 °C was applied and the apparent viscosity was measured as a function of shear rate over the 0.01–100 s^{-1} range for 5 min. Two replicates of each flow curve were run with samples prepared on different days. All the curves were adjusted to the Ostwald model: $\eta = K\dot{Y}^{n\ 1}$

Where η is the apparent viscosity, K is the consistency index, gamma dot is the shear rate and n is the flow index.

To simulate the effect of heating in the batter structure, temperature sweeps were performed from 25 °C to 95 °C at a heating rate of 1.0 °C/min and a strain amplitude of 0.0005. The strain applied was selected to guarantee the existence of a linear viscoelastic response according to previous stress sweeps carried out at 25 °C and 95 °C. Vaseline oil was applied to the exposed surfaces of all the samples. Two replicates from different batches of each formula were measured.

2.3. Properties of the muffins

The muffins were weighed before (W3) and after baking and cooling (W4) and the weight loss was calculated. Each formulation was prepared twice, on different days, and seven muffins from each batch (fourteen determinations) were measured.

The muffin height was measured with a calliper from the highest point of the muffin to the bottom of the paper mould after