

Abstract

The research of this doctoral thesis has focused on the study of the structure, physical properties and sensory acceptability of cakes and biscuits, in which fat has been replaced by inulin and sugar has been replaced by oligofructose. The principal aim of this thesis was to develop reformulated bakery products with significantly less sugar and fat content and thus, with a healthier nutritional profile.

Batter structure was characterised using confocal laser scanning microscopy and light microscopy techniques. Cake batter was observed as a matrix constituted mainly by lipids and proteins from flour and egg. In this matrix starch granules, oil globules and air bubbles were dispersed. Oil showed a complex functionality in batters; increasing batter viscosity, forming an interface air-bubble and thus, increasing bubble stability in the batter and gas retention during baking. Moreover, the oil acted as a lubricant by coating and creating a continuous matrix; therefore it influenced the structure, texture, and palatability of the cake. In cakes, fat was replaced by inulin and extra aqueous component. Fat replaced batters showed a significant decrease in apparent viscosity, which led to a broad size distribution of occluded bubbles. During baking, the low stability of the gas phase gave place to a less gas retention and a lower cake expansion. Therefore, cakes showed a more compact crumb structure with less crumb cells and lower height and thus, harder cakes with less springiness were obtained. Cakes with 70% of fat replacement did not differ significantly from the control in the sensory attributes. In conclusion, high quality cakes with fat replacement up to 70% were obtained.

Sugar replacement by oligofructose affected the thermosetting mechanism of cake batters. Sugar plays an important role in delaying starch gelatinization and protein denaturation temperatures. When sugar content was reduced in cakes these processes came early and in successive steps, and thus the formation of the porous-solid structure was affected. Sugar-replaced batters showed a lower apparent viscosity and a higher number of air bubbles in comparison to control cake batter. During baking air bubbles slightly increased. Cakes with oligofructose were characterised by a crumb cell structure of few and little cells, and low height. These cakes showed low hardness and springiness values. Changes in the batter thermosetting mechanism gave place to cakes with more compact but softer crumbs. Cakes with sugar replacement up to 30% had similar consumer acceptability to control cakes. When sugar and fat were replaced simultaneously, batter apparent viscosity decreased significantly and a great bubble expansion was observed during heating. The resulting cakes had an open and uneven crumb cell structure. Sugar replacement had an important effect on cake texture giving place to cakes with low springiness. Cakes with simultaneous fat replacement of 50% and sugar replacement of 30% were scored by consumers slightly lower than the control cake. Nevertheless, these cakes were similar to cakes with simple replacement of 50% of fat and cakes with simple replacement of 30% of sugar. In general, consumer considered that

sponginess and sweetness needed to be improved in these cakes to achieve a higher acceptability.

In large-scale cake manufacturing all-in mixing method is used for batter preparation on one stage. To scale up our cake production at pilot scale the traditional multi-stage mixing procedure was replaced by an all-in mixing method without modifying cake's physical and structural properties.

To improve the appearance and crumb cell structure of cakes with reduced fat content (50% and 70% of fat replacement) the effects of emulsifier and lipase incorporation were studied. The addition of 0.03% of lipase and 0.5% of emulsifier improved the crumb cell structure. Each improver had different effects in cake structure; batters with lipase showed a lower degree of system structuring than control batters. Emulsifier incorporation decreased significantly batter relative density. However, during heating, batters with high levels of emulsifier (> 0.5%) showed a decreased in batter complex viscosity. This batter could not retain the air bubble and thus, the obtained cakes were characterised by a collapsed structure. Differential scanning calorimetry studies showed that the control formulation displayed the highest thermal parameters values and thereby the control cake showed the highest volume. Lipase and emulsifier incorporation decreased the thermal parameter values and the obtained cakes showed lower volumes. Nevertheless, the crumb cell structure was improved showing a more uniform appearance and a similar hardness to the control cake. During storage time fat-replaced cakes showed higher hardness; however, lipase incorporation slowed down this increase.

Dough and biscuit microstructure was studied using confocal laser scanning microscopy and cryo scanning electron microscopy. Micrographs showed a continuous matrix composed mainly by sugar and proteins; starch granules were observed dispersed in the matrix and fat was located surrounding the granules and breaking the structure continuity. When fat was replaced by inulin an increase in dough and biscuit hardness was observed due to a higher hydration of flour components. Biscuits with fat replacement up to 20% were similar to control biscuits in terms of structure and textural properties. However, consumers were able to differentiate between control biscuits and biscuits with 20% of fat replacement reporting that the former was slightly less hard and sweet than the latter.