Effect of Sodium Lauryl Sulphate on the Texture of Sponge Cake

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Sponge cake was prepared by adding sodium lauryl sulphate (SLS), an anionic surfactant, to egg albumen during the mixing stage at levels of 0, 0.05, 0.1 and 0.2% on flour weight basis. The rheology of the cake batter was studied and texture of sponge cake crumb was measured on an Instron universal testing machine. Increasing levels of SLS lowered the specific gravity, surface tension, consistency coefficient and air bubble diameter. The cake volume increased with increasing levels of SLS. Texture profile analysis of cake crumb revealed that increasing SLS levels lowered crumb firmness and cohesiveness. Storage of cake crumb for up to 10 days at room temperature revealed that crumb containing SLS remained softer and that SLS may be involved in preventing starch retrogradation.

Key Words: sponge cake, sodium lauryl sulphate, texture profile analysis, consistency, firmness, cohesiveness

INTRODUCTION

Sponge cakes are high ratio, low fat, foamed type of cakes that rely on incorporated air for volume and texture. The egg white is whipped to form a foam and then other ingredients like flour, sugar, yolk are gently folded in. The egg protein matrix with its air incorporation forms the structure of the cake as it bakes. The quality attributes of sponge cake include a good volume with a uniform crumb structure and the ability to retain the crumb softness during storage. It has been reported that emulsifiers increase air incorporation, decrease specific gravity, produce a finer fat dispersion and as a result increase the final cake volume (Handelman et al., 1961; Wootton et al., 1967; Guy and Vettel, 1978). A number of different emulsifiers like mono and diglycerides, sucrose esters, polyglycerol esters, propylene glycolester and sodium steroyl lactylate have been used in cakes (Seibel et al., 1980; Vollmer, 1985; Pierce and Walker, 1987). Effect of dioctyl sodium sulphosuccinate on cake crumb softness has been investigated by Lechmann and Bechtel (1969). It was reported that this anionic surfactant when added at 50–70 ppm reduced the emulsifier content of shortening by up to 2% without reducing cake quality.

Sodium lauryl sulphate (SLS, an anionic surfactant) is used as a whipping aid in egg whites, marsh mallows and angel food cake mixes (Igoe and Hui, 1996). Code of Federal Regulations (172.822, USA) allows the use of SLS at concentrations of 100–125 ppm in egg white and it was approved for use to facilitate product formation with egg white (Artz, 1989). SLS is a known protein denaturant and solubilising agent and is used to improve the foaming properties of commercial egg white (Kakalis and Regenstein, 1986). It reduces the surface tension and also binds to the egg white proteins. SLS when dissolved in water will ionize into sodium cation and lauryl sulphate anion as surface-active molecule. Hydrophobic and electrostatic interactions are responsible for the interaction between albumen and SLS. Literature review revealed that studies on the effect of SLS on sponge cake quality had not been carried out. Since SLS shows strong interaction with egg white proteins the objectives of the present investigation were to study the effect of SLS on sponge cake batter and crumb texture and its potential use as an antistaling agent in sponge cake.

MATERIALS AND METHODS

Samples

Preparation of Cake Batter

Wheat flour was obtained from wheat variety PBW-343 having extraction rate of 74%, protein 9.6% and ash 0.41%. Fresh eggs were broken in the laboratory, the albumen and yolk were separated, blended and then used as required. Egg albumen (100 g) and sodium lauryl sulphate (AR grade, CDH, New Delhi) at varying levels

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(0, 0.05, 0.1 and 0.2% flour weight basis) were whipped for 1 min at speed 3 with a wire whisk in a laboratory mixer (Hobart N 50, Ontario, Canada). Sugar (100 g) was then added and mixing was done for 1 min at speed 2. Egg yolk (70 g) was then added and again mixing done for 1 min at speed 2. Wheat flour (100 g) and baking powder (2.2 g, Wakefield, Pune, India) sifted together beforehand were then added and mixed for 45 s, scraped down and again mixed for 45 s at speed 1.

Methods

Baking

The cake batter (300 g) was transferred into baking trays measuring 18×18 cm and 4 cm high and baking was done at 200°C for 16 min in a laboratory oven (National Manufacturing Company, Lincoln NE, USA). Baking tests were carried out in triplicate. The cake was cooled for 1 h and then cut from the centre to measure volume index, symmetry index and uniformity index using the cake measuring template as described in the American Association of Cereal Chemists method 10–91 (AACC, 1995). Specific gravity of batter was determined by dividing the weight of a constant volume of batter by the weight of a constant volume of water.

Batter Rheology

Rheological properties were determined in triplicate using Brookfield Viscometer (Brookfield Engineering Labs Inc. model DV-II, MA, USA). A 500-mL beaker with a diameter of 8.5 cm was filled with the cake batter to a height of 8.5 cm and brought to 25°C in the TC-500 water bath (Brookfield Engineering Labs Inc.) Measurements were taken after the spindle (no. 18) was immersed for 2 min so as to allow thermal equilibrium in the sample. Log–log plots of shear stress versus shear rate were plotted to determine the consistency index (k) and flow behaviour index (n), using the power law equation (Gujral et al., 2001; Gujral et al., 2002a):

$$t = k(dv/dy)^n$$

where, t is the shear stress (N/m^2), k is the consistency index ($N\,s/m^2$) and dv/dy is the shear rate (s^{-1}).

Microphotography

A drop of batter was placed between two cover slips on a microscope glass slide and a third coverslip was placed on the batter sample. This was done to maintain a constant specimen thickness. The bubbles were observed at a magnification of 5x using a laboratory microscope (Focus MPM-2AA, India). Photographs were taken on Kodak black and white film with a SLR camera (Cosina C1s/C1, Japan). The microphotographs were used to determine average diameter of the bubbles by dividing by the magnification factor. The egg white after whipping was also observed under the microscope and photographs were taken.

Back Extrusion Force

Cake batter was filled to a height of 64 mm into a back extrusion cell having a inner radius of 22 mm and height of 100 mm. A cylindrical plunger having a radius of 16.7 mm was forced into the batter to a depth of 95 mm at a crosshead speed of 100 mm/min. The peak force was reported as back extrusion force (N).

Surface Tension of Batter

Surface tension was measured as described by Yadav (2000). A ring made of stainless steel wire was immersed in the horizontal position into the cake batter to a depth of 5 mm. It was then pulled out of the batter in the upward direction at a crosshead speed of 50 mm/min. The ring was attached to a stainless steel wire arm fitted to an Instron universal testing machine (Model 4464, Instron, Buckinghamshire, England). The following equation was used:

$$\gamma = F/4\pi R$$

where γ is the surface tension (N/mm), F is the peak force (N) on the ring when it breaks free from the batter surface and R is radius (mm) of the ring.

Texture Profile Analysis of Cake Crumb

Cake crumb samples in the form of cubes measuring 2.54 cm sides were cut from the centre of the cake. This was placed on the platform of an Instron universal testing machine and compressed to 50% of its initial height twice in two cycles with a flat circular plunger having a diameter of 80 mm and travelling at 100 mm/min. The force versus displacement data were plotted to obtain the texture profile curve from which the textural parameters like cohesiveness and firmness were determined as described earlier by Gujral et al. (2002b). Cake crumb samples sealed in polyethylene pouches were stored in a PET jar for texture profile analysis after 0, 48, 96, 144, 192 and 240 h (i.e. 10 days of storage at 25°C) to study the effects of staling on cake texture. The crumb firming data for control and sample containing varying concentrations of SLS was subjected to regression to obtain linear regression equation of the form $y = mx + c$ where m (slope) represents the rate of firming during storage. Higher values of m indicate a steeper curve representing a greater increase in the crumb firmness during storage whereas a lower m value indicates the inverse.

Syneresis in Starch Gel

Wheat starch (5 g) was cooked in 100 mL of 0 and 0.1% SLS solution for 20 min at 100°C to gelatinize the starch. The gelatinized solution (gel on cooling, 20 g) was filled in pre-weighed centrifuge tubes and kept in a refrigerator at 5°C for 24, 48, 72, 96 and 120 h. The tubes were centrifuged at 3200 rpm for 10 min to determine the percentage of syneresis (Gujral et al., 2001).

RESULTS AND DISCUSSION

Specific Gravity

The egg albumen when whipped for 1 min resulted in white foam having a specific gravity of 0.474 (Table 1). With addition of SLS at levels of 0.05, 0.10 and 0.20% the specific gravity of egg white foam decreased to 0.461, 0.455 and 0.454. The volume of the egg white foam increased with the addition of SLS. This increase in foaming and decrease in specific gravity can be attributed to the formation of protein-surfactant complex. The interaction of anionic surfactant with proteins have been reviewed by Schwuger and Bartnik (1980) and the available data showed that both polar and hydrophobic interactions are involved. The polar interactions between the negatively charged hydrophilic group of the surfactant and positively charged centers along the protein chain are the basic requirement for the development of hydrophobic bonds between the hydrophobic surfactant residue and the protein involved. This may be visualized as a process in which polar interactions lead to a closer approach between surfactant and protein molecule and favoured the formation of hydrophobic bonds. The SLS–albumen complex thus formed is adsorbed at the air–aqueous interface, facilitating entrapment of air bubbles in the aqueous phase thus increasing foam volume. This process leads to the decrease in specific gravity. The concentration of SLS used in the present study was above its critical micellar concentration at 25°C (0.008 mol/dm^3). The specific gravity of the cake batter also decreased with increasing concentration of SLS (Table 1). The cake batter had a specific gravity of 0.724 and this decreased by 13.86% at 0.2% of SLS addition.

Table 1. Effect of SLS concentration on some physical properties of whipped egg white and batter.

	SLS concentration[1] (%, flour weight basis)			
Parameter	0	0.05	0.1	0.2
Consistency index (N s/m^2)	17.38^a	14.08^b	13.27^c	12.98^c
Flow behaviour index	0.423^a	0.465^b	0.474^b	0.511^c
Specific gravity of batter	0.724^a	0.699^b	0.650^c	0.624^d
Specific gravity of albumen foam	0.474^a	0.461^b	0.455^c	0.454^c
Surface tension of batter (N/mm)	0.183^a	0.126^b	0.105^c	0.096^c
Volume index (cm)	13.35^a	14.80^b	14.82^b	14.82^b
Uniformity index (cm)	0.6^a	0.4^b	0.38^b	0.36^b
Symmetry index (cm)	1.3^a	0.8^b	0.6^b	0.3^c

[1]Values within the same row followed by different superscripts are significantly different ($P > 0.05$).

Batter Surface Tension and Rheology

The cake batter had a surface tension of 0.183 N/mm and it decreased by 31.14, 42.62 and 47.59% with increasing levels of SLS (Table 1). Surfactants lead to protein solubilization and facilitate air incorporation into the aqueous phase of the batter by lowering the interfacial tension. Electrophoretic studies have indicated that SLS complexes with lysozyme and also reduces the surface tension of the egg white system (Stadelman and Cotterill, 1977).

The batter consistency index progressively decreased with increasing levels of SLS. The degree of fit (R^2) between shear stress versus shear rate was high (>0.94) indicating that the rheological behaviour is well described by the power law equation. The flow behaviour index was less than one unit in all cases due to the pseudoplastic nature of the batter. The back extrusion force of the cake batter was 2.39 N and it decreased to 2.01, 1.93 and 1.65 N at SLS levels of 0.05, 0.10 and 0.20% respectively.

Whipped egg albumen containing 0% SLS had larger uneven air bubbles whereas the egg albumen containing 0.2% SLS had more uniform and smaller air bubbles (Figure 1(a) and 1(b)). The cake batter containing 0% SLS showed larger air bubbles (average diameter 0.138 mm) and air bubbles in batter containing 0.2% SLS were smaller in diameter (0.105 mm) and more uniformly distributed (Figure 1(c) and (d)).

Cake Volume

The volume of cake significantly increased with increase in SLS concentration (Table 1). The control sample had a volume index of 13.35 cm and this increased by 10.86% with 0.05% SLS addition. The increase was 11.01 and 11.08% with 0.1 and 0.2% SLS addition. Conrad et al. (1993) reported that SLS reduced whipping time and increased cake volume.

Symmetry index is an indicator of surface contour while uniformity index is a measure of cake symmetry. Both the symmetry index and uniformity index of cake decreased with increasing levels of SLS, the decrease being more significant in the case of symmetry index. The control sample had a higher symmetry index, that meant the cake had more height in the centre and less at the sides and a convex shape. The lowering of symmetry index indicated that the cake had a flatter surface when SLS was present, because SLS delayed the setting time, and the sides and the centre rose more. Hegg and

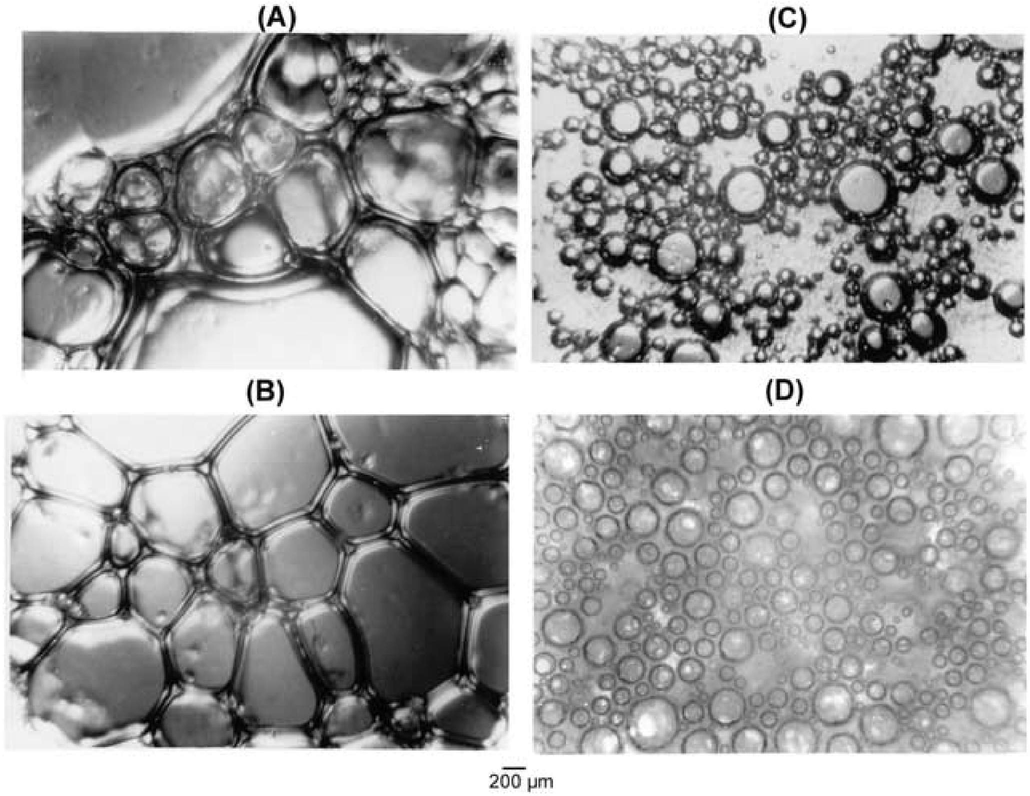

Figure 1. Effect of SLS on the microstructure of whipped egg white and batter: **A**. Air bubbles in whipped egg white containing 0% SLS; **B**. Air bubbles in whipped egg white containing 0.2% SLS; **C**. Air bubbles in cake batter containing 0% SLS. **D**. Air bubbles in cake batter containing 0.2% SLS.

Lofquist (1974) reported the protective effect of small amounts of anionic surfactant (SLS) on the thermal aggregation of crude ovalbumin. Higher uniformity index values revealed that the cake has an uneven surface. SLS addition resulted into a cake with lower uniformity index values and thus greater symmetry.

Cake Crumb Texture

The control sample had a firmness of 1.98 N (Figure 2). The addition of SLS lowered the firmness of cake crumb. The cake crumb firmness decreased to 1.41 N with 0.05% SLS addition but no further significant decrease was observed beyond that SLS concentration. The firmness of cake crumb increased during storage likely due to the retrogradation of starch in the cake crumb (4.7 N after 240 h of storage). However, the cake crumb containing SLS remained soft even after 240 h of storage. SLS could have some anti-staling properties and may be responsible in preventing retrogradation of starch. To confirm this, syneresis in starch gel was studied. Starch gel containing 0% SLS showed a syneresis of 1.88, 2.69, 4.99, 5.54 and 6.20% after 24, 48, 72, 96 and 120 h of storage respectively. The starch gel containing 0.1% of SLS did not form a rigid gel even after 5 days of storage at 5°C and thus syneresis could not be determined, because SLS prevented the re-association of starch molecules

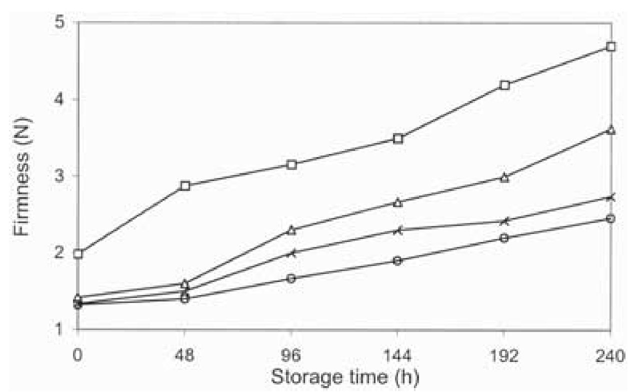

Figure 2. Effect of increasing concentration of SLS on the firmness of cake crumb during storage at 25°C. Percentage of SLS: 0 (□); 0.05 (△); 0.1 (×); 0.2 (○).

and thus prevented gel formation. SLS could play a similar role in cake crumb, since the values for *m* (slope) were 0.511, 0.446, 0.288 and 0.238 for cake crumb containing 0, 0.05, 0.1 and 0.2% SLS respectively. The slope decreased with increasing SLS concentration showing that SLS lowered the firming rate, which confirmed its anti-staling effect.

Cohesiveness is the dimensionless unit obtained by dividing the energy consumed during second compression by energy consumed during first compression. Lower values of cohesiveness indicate that less energy is required during second compression. Cohesiveness

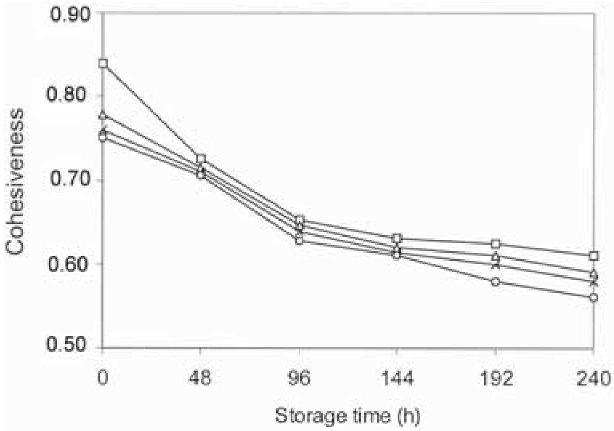

Figure 3. Effect of increasing concentration of SLS on the cohesiveness of cake crumb during storage at 25°C. Percentage of SLS: 0 (□); 0.05 (△); 0.1 (×); 0.2 (○).

during storage of cake crumb showed a decreased (Figure 3). The cohesiveness of control sample decreased by 27.29% after 240 h of storage whereas the decrease was only 24.16, 23.68 and 23.48% in the presence of 0.05, 0.10 and 0.20% SLS respectively.

Storage and SLS concentration had a significant effect on the cake crumb firmness and the crumb cohesiveness at 5% level of significance.

In conclusion, SLS can be used as an effective surfactant in sponge cakes to increase the cake volume and prevent retrogradation of starch. The addition of SLS leads to a softer crumb even after a few days of storage. It can be used with excellent results at concentrations of 0.05, 0.10 and 0.20% of flour weight basis, which was equal to only 0.013, 0.027 and 0.05% of the total cake batter.

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