Addition of Sucrose Fatty Acid Ester Emulsifiers to Sponge Cakes[1]

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ABSTRACT

Sponge cakes are high-ratio, low-fat cakes that rely on incorporated air for volume and texture. Sucrose esters, recently approved for food use, have been shown to affect batter specific gravity, cake volume, crumb firmness, and texture of sponge cakes. Sucrose esters with hydrophil-lipophil balance values of 6, 11, and 15, and a commercial plastic α-mono/diglyceride emulsifier were tested at 1, 2.5, and 4% flour weight basis. When added in powder form to the dry ingredients, the sucrose esters increased volume and tenderness and produced a more desirable texture. When the same sucrose esters were hydrated before addition, resulting cake volumes averaged 20 to 160 cm^3 greater than when the sucrose ester was added in powder form.

Sponge cakes, often referred to as foam cakes, rely mainly on air cells for mixing or leavening agents for volume and texture. Like angel cakes, they depend on the air being whipped into the batter as a major leavening agent (Borders 1968). Sponge cakes are a relatively low-fat, high-ratio cake in that they contain more sugar by weight than flour and contain only those fats found in the eggs (Sultan 1981). Large-scale bakeries using a continuous mix process often use approximately 16% eggs on a dry basis in their formulation (Bennion and Banford 1973). Many manufacturers of sponge cakes use an "all in" method of mixing (Bennion and Banford 1973). Regardless of mixing technique, the main goal is to produce a stable foam that will not break down during baking.

Eggs are important in batters for their role in foam formation, and, because of their limited shelf life, many methods have been employed for their preservation. Spray drying is the most popular method (Stadleman and Cotterill 1977), but spray-dried eggs do not whip or retain air as well as fresh eggs (Bennion and Banford 1973).

The addition of emulsifiers to sponge cakes has been shown to result in a stiffer cake batter with smaller air cell size and increased cake volume (Bennion and Banford 1973). Emulsifiers that might have use in sponge cakes are the sucrose fatty acid esters. Sucrose fatty acid esters consist of a sucrose molecule esterified with various fatty acids, and because of the variability in these fatty acids a range in hydrophil-lipophil balance (HLB) of the resulting esters can be obtained (Walker 1984). Sucrose esters of HLB 5–15 have been approved for food use and currently are produced in Japan. The fatty acids most commonly used in these esters are stearic and palmitic acids (Ebeler and Walker 1984).

Ebeler and Walker (1984) found sucrose esters improved volume and tenderness of white layer cakes. It has also been shown that these esters have possible antimicrobial effects in that they inhibit the growth of some molds, which may aid shelf life (Marshall 1985).

The objective of this study was to evaluate the effects of sucrose esters on sponge cakes. Characteristics of cakes containing sucrose esters were compared to reference cakes containing α-mono/diglyceride and to control cakes with no added emulsifiers. Sucrose esters were incorporated into batters either as dry powders or as prehydrates. Esters of three HLBs at several concentrations were the variables used for the test.

MATERIALS AND METHODS

Sucrose esters tested were F-160, F-110, and F-50 (Dai-Ichi Kogyo Seiyaku Co., Ltd., Kyoto, Japan). The sucrose esters have the following approximate HLBs: F-160, 15; F-110, 11; and F-50, 6 (Walker 1984). The reference emulsifier was a commercial α-mono/diglyceride emulsifier in a plastic form with approximately 52% active α-monoglyceride content. The control contained no

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added emulsifiers. Emulsifiers were tested at concentrations of 1, 2.5, or 4% of the flour weight (14% moisture basis). A bleached cake flour (Softasilk, General Mills, Minneapolis, MN) of 13% moisture and 9.6% protein was used.

Sponge cakes were baked according to the formula given in Table I. The formula was modified from a commercial sponge cake formulation received from Henningson Foods (Omaha, NE).

Cake batters were mixed with a Kitchen Aid mixer model K-45 with a wire whip attachment. All ingredients were at room temperature. The mixing procedure was an "all in" method, in which all ingredients were mixed at once rather than the traditional method of whipping the eggs before adding flour. First, all dry ingredients (except eggs) were sifted. All ingredients except water were blended for 1 min on the stir (lowest) speed, then mixed at speed 4 for 1 min as the first water was added slowly. The sides of the bowl were scraped, and the batter mixed for 2 min at speed 8, which was decreased to speed 6 for 2 min as the second water was slowly added. The batter was mixed a final 2 min on speed 8. Batter samples (150 g) were measured into 9 × 16 × 5.5 cm loaf pans (the formula in Table I makes five) and baked in a preheated 375° F (190.5° C) oven for 25 min. After baking, the cakes were cooled 10 min, removed from the pans, cooled another 20 min, dusted with flour, and stored in an airtight container (plastic bag).

Dry esters were blended with other dry ingredients before mixing, as was the reference emulsifier. Prehydrates were made by mixing dry esters with water (deducted from the first water addition) at an ester-to-water ratio of 1:4. These prehydrates were then added to the batter with the first water.

Both sets (prehydrate and dry ester) were baked in triplicate, in three consecutive weeks. On any given day, 14 batters were made: three sucrose esters (either prehydrated or dry) at three concentrations, the reference at three concentrations, and two controls. The controls were the first and last samples in each series. All other samples were in a different random order each day. Immediately following the last mixing stage, batter temperatures were taken and recorded. Batter specific gravity was then measured with a small cup of known volume.

Batter viscosity was measured by a simple method developed by Ebeler et al (1986). A funnel with a top inside diameter of 10 cm and a bottom inside diameter of 1.6 cm (60°) was used. The funnel was filled with batter, and struck off at both ends, after which the batter was allowed to flow for 15 sec. The amount of batter that flowed from the funnel was weighed and reported as grams of batter flow per second. Thus, higher values indicate lower viscosities.

After baking, cake volumes were measured by a rapeseed displacement method. Cakes were weighed and placed in a pan with a volume of 1,700 cm^3. After 1,700 cm^3 of rapeseed was poured over the cake placed in this large pan, those seeds displaced by the cake were measured as the volume of the cake. Control cake volumes for each day were then subtracted from each test cake to determine the difference in volume attributable to the emulsifiers.

All cakes were scored visually (+ or −) on a scale of excellent, good, fair, and poor. They were judged for overall crumb color, loaf shape, and crumb texture (cell size, evenness, and density).

Shelf life was tested by determining crumb firmness and fragility over 14 days. The method used an Instron universal testing machine and was similar to that developed by Breyer and Walker (1983). A circular indentor with a diameter of 28 mm was used with the following machine settings: crosshead speed of 1 cm/min, chart speed of 20 cm/min, and a full-scale force of 1 kg. Two slopes (Fig. 1) were measured: the first represents compression (firmness), and the second measures the tearing of the crumb (fragility).

Crumb pH and crumb moisture were measured using AACC methods 02-52 and 44-40, respectively (AACC 1983). Percent starch gelatinization in the baked cake was estimated by a microscopic count of the percentage of the starch granules that still exhibited birefringence under polarized light.

Statistical analyses were done using multiple variable second order regression. The statistical program was run on a personal computer and graphs were prepared using values predicted by the program.

TABLE I
Sponge Cake Formula

Ingredient	% on Flour Weight Basis
Cake flour	100.00
Sucrose	92.50
Dextrose	38.75
Nonfat dry milk	10.00
Salt	2.50
Baking powder (Calumet)	5.00
Dried whole egg	15.00
Water (first addition)	57.78
Water (second addition)	42.50

RESULTS AND DISCUSSION

Batter Specific Gravity and Viscosity

Batter specific gravity is a measurement of total air-holding capacity but gives little information about bubble size or dispersion. As the amount of reference emulsifier increased, the batter specific gravity also increased, signifying a decrease in the amount of air entrapped in the batter. A slight decrease in specific gravity is obtained by adding dry esters. However, prehydration of the more polar, high-HLB esters, F-110 and F-160, resulted in significant decreases in specific gravity (16% and 20%, at 2.5% concentration, and 26% and 36% at 4% concentration, respectively) with a correlation coefficient of 0.94 (Fig. 2).

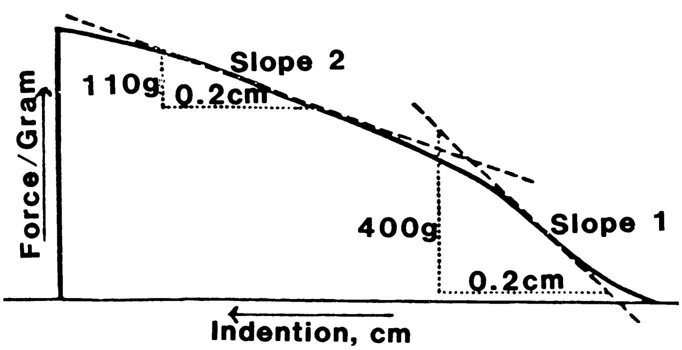

Fig. 1. Sample Instron curve. Slope = g force/cm indentation.

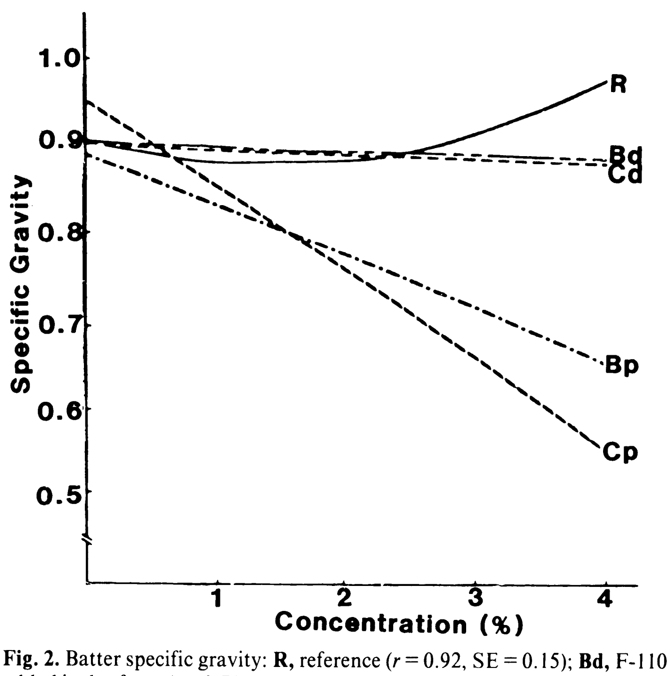

Fig. 2. Batter specific gravity: **R,** reference ($r = 0.92$, SE = 0.15); **Bd,** F-110 added in dry form ($r = 0.71$, SE = 0.10); **Bp,** F-110 added as prehydrate ($r = 0.94$, SE = 0.43); **Cd,** F-160 added in dry form ($r = 0.71$, SE = 0.10); **Cp,** F-160 added as prehydrate ($r = 0.94$, SE = 0.43).

In terms of batter viscosity, a lower batter flow rate indicates a more viscous batter with more air incorporation. As the concentration of reference emulsifier increased from 0 to 2.5%, so did the batter flow rate. At a concentration of 2.5%, the flow rate began to decrease (Fig. 3). Sucrose esters, added dry, resulted in very slight but not significant decreases in batter flow rates. Prehydration of the sucrose esters decreased batter flow rate (increased viscosity) especially at the higher HLBs. Prehydration of F-50 resulted in little change in its performance from the dry state, with only a slight decrease in flow rate (Fig. 3).

Correlation of batter viscosity to specific gravity is shown in Figure 4. As the specific gravity increases, flow rate increases, verifying that the prehydration of these sucrose esters does increase the amount of air that is incorporated into the batter.

Cake Volume

Volume is a measure of cake size reflecting, in part, the amount of air entrapped during mixing and CO_2 expansion throughout the crumb. These gases may be dispersed in small cells throughout a fine crumb or in larger cells throughout a more coarse crumb. Although high volumes do not always indicate a desirable cake, low volumes generally indicate a heavy, less desirable crumb. The low HLB ester (F-50) showed no correlation of concentration with volume. The resultant cakes were essentially the same as the control in volume. The reference cakes decreased in volume as concentration of reference emulsifier increased. When added dry, the higher HLB esters (F-110 and F-160) resulted in slightly larger volumes than the control. However, when the esters were prehydrated, the resultant increases in volume relative to concentration were much larger (Fig. 5). This was particularly true for the F-110.

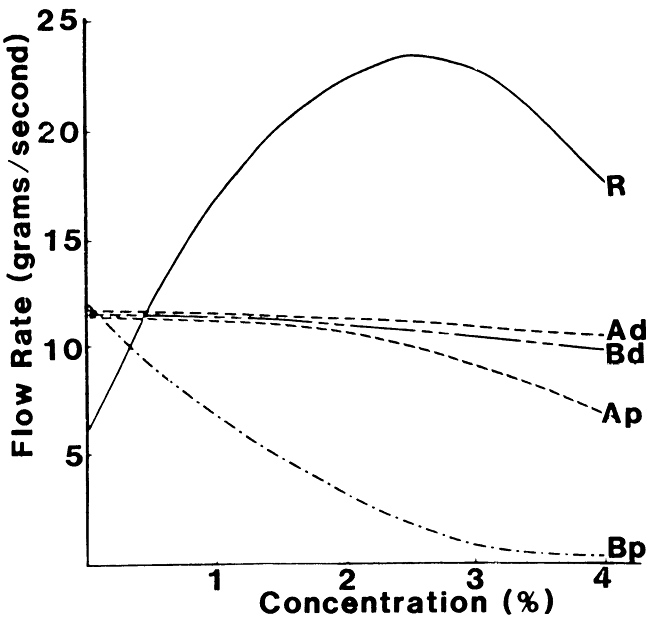

Fig. 3. Batter flow: **R,** reference ($r = 0.73$, SE = 6.88); **Ad,** F-50 added in dry form ($r = 0.90$, SE = 0.20); **Ap,** F-50 added as prehydrate ($r = 0.99$, SE = 0.16); **Bd,** F-110 added in dry form ($r = 0.99$, SE = 0.10); **Bp,** F-110 added as prehydrate ($r = 0.99$, SE = 0.77).

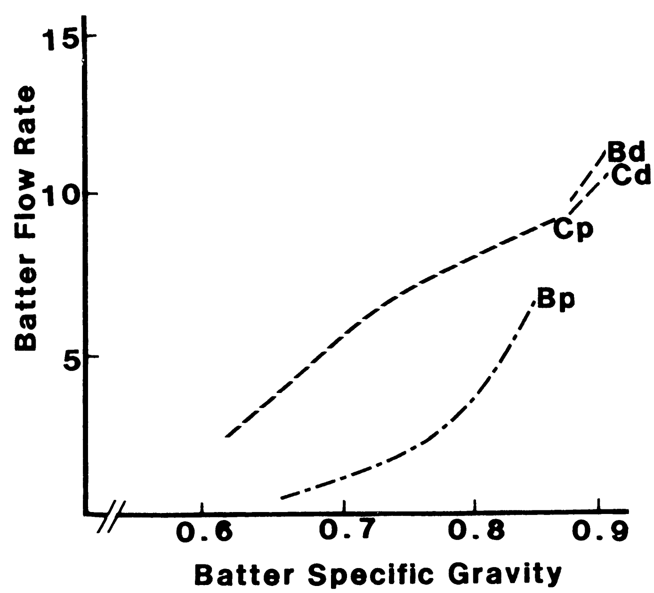

Fig. 4. Specific gravity vs. flow rate: **Bd,** F-110 added in dry form; **Bp,** F-110 added as prehydrate; **Cd,** F-160 added in dry form; **Cp,** F-160 added as prehydrate.

Visual Observations

A subjective, visual test was performed rating the cakes for crust color, cake shape, and crumb texture. There were no obvious differences between samples in crust color. All were a very similar light golden brown. With two exceptions, cakes were gently rounded with a slight split down the center. The two exceptions were esters F-110 and F-160 at a concentration of 4%, for which the cakes were less rounded, and the top was smooth with no cracks. As HLB and concentration increased, the texture showed smaller air cells, i.e., finer grain.

Shelf-Life Firmness

Shelf life was tested by measuring crumb firmness and fragility over a period of 14 days. There appeared to be a strong correlation between firmness and the emulsifier, especially the sucrose esters (Fig. 6). When added dry or prehydrated, the F-50 test cakes were very similar to the reference and for this reason are not shown on the graphs. At 4%, the reference cake was less tender than the cakes containing sucrose esters and remained so during the two-week study. F-110 added dry at all concentrations was similar to the reference. The F-160 performed better at the 4% concentration. It was the softest and retained better tenderness for the two-week period.

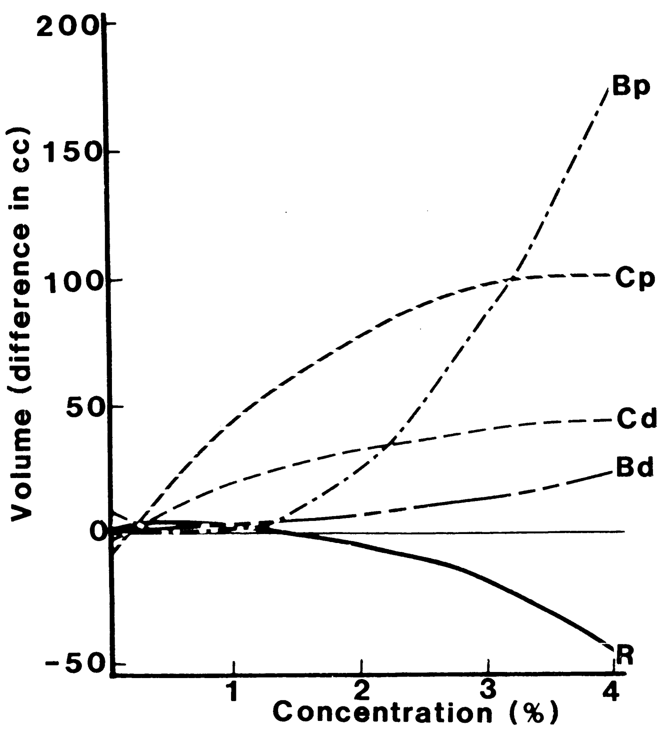

Fig. 5. Volume (difference from control): **R,** reference ($r = 0.92$, SE = 9.46); **Bd,** F-110 added in dry form ($r = 0.84$, SE = 6.32); **Bp,** F-110 added as prehydrate ($r = 0.97$, SE = 18.12); **Cd,** F-160 added in dry form ($r = 0.94$, SE = 7.03); **Cp,** F-160 added as prehydrate ($r = 0.96$, SE = 13.48).

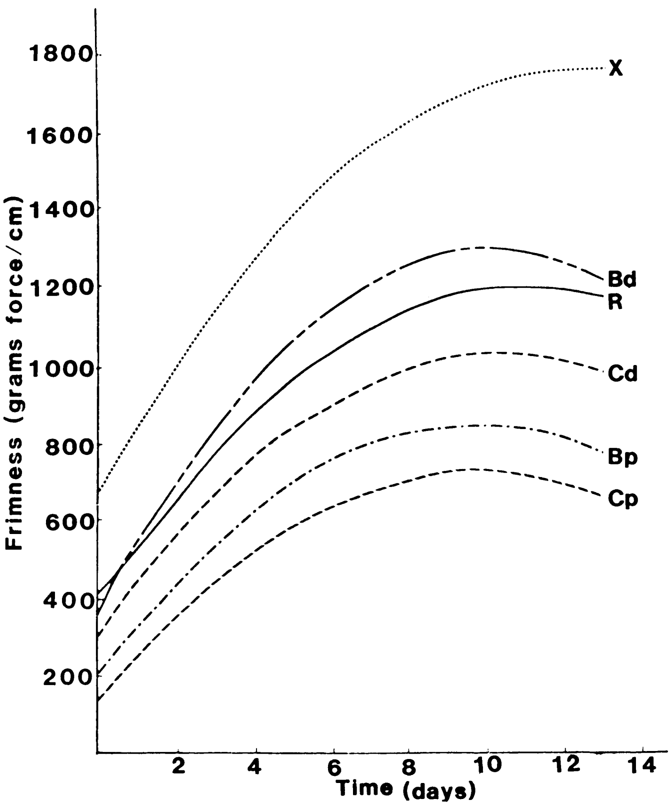

Fig. 6. Firmness (slope 1) 2.5% concentration: **X,** control ($r = 0.95$, SE = 155.70); **R,** reference ($r = 0.91$, SE = 167.90); **Bd,** F-110 added in dry form ($r = 0.93$, SE = 164.76); **Bp,** F-110 added as prehydrate ($r = 0.97$, SE = 126.81); **Cd,** F-160 added in dry form ($r = 0.97$, SE = 126.47); **Cp,** F-160 added as prehydrate ($r = 0.97$, SE = 127.57).

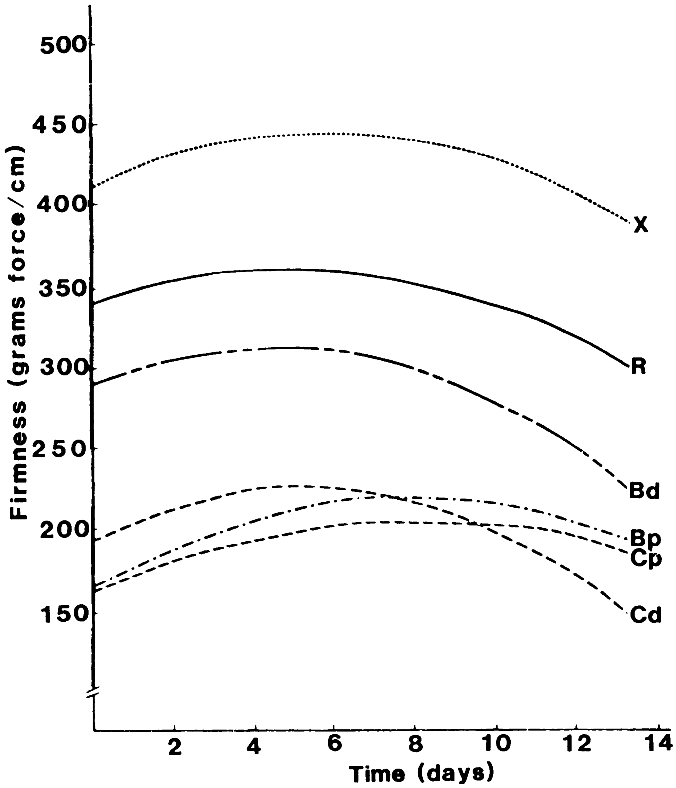

Fig. 7. Fragility (slope 2) 2.5% concentration: **X,** control ($r = 0.50$, SE = 48.98); **R,** reference ($r = 0.92$, SE = 9.46); **Bd,** F-110 added in dry form ($r = 0.84$, SE = 6.92); **Bp,** F-110 added as prehydrate ($r = 0.97$, SE = 18.12); **Cd,** F-160 added in dry form ($r = 0.96$, SE = 13.48); **Cp,** F-160 added as prehydrate ($r = 0.94$, SE = 7.03).

Prehydration of F-110 and F-160 at 2.5 and 4% concentrations greatly improved both initial tenderness and shelf life (Fig. 6). All samples exhibited a tenderness loss over time, but the prehydrated, high-HLB, high-concentration combinations remained relatively soft throughout the two weeks.

The second Instron measurement was the tearing of the crumb, or fragility (Fig. 7). For the reference and all sucrose esters added dry at all concentrations, the force needed to tear the cake increased for the first five to seven days of storage. After this time, the crumb became fragile, and the force needed to tear the cake dropped, reaching a point nearly equal to or below the initial force needed to tear the crumb. The F-110 and F-160 prehydrated cakes were much alike. The higher concentrations (2.5% and 4%) resulted in superior cakes, with day one being very soft (Fig. 7). Over time these did toughen slightly but still remained acceptable.

Data for moisture, pH, and gelatinization for all cakes is as follows: pH, 7.30 ± 0.05; moisture, 29.94 ± 0.79; percent gelatinization was 95.5 ± 3.89. No statistical correlations were found between HLB or concentration with moisture, pH, or gelatinization. Ebeler and Walker (1984) found differences in gelatinization of the starch in white layer cakes. It is believed the lack of gelatinization differences in the sponge cake test may be caused by the glucose in the batter, which lowers the gelatinization temperature (Bean et al 1978).

CONCLUSIONS

Based on the above tests, it appears that some, but not all sucrose esters can be useful in sponge cake production. The F-50 did not perform well dry or prehydrated. This may be because of its low HLB (higher hydrophobiticity). The higher HLB F-110 and F-160 appear to be the more useful. Prehydration improved ester action significantly. This improvement may result from allowing the sucrose esters to more completely hydrate, unlike those added dry, before they must compete with the sugar for water.

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