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Effect of Flour-Oil Composite as Powdered Fat Source in Low-Fat Cake Mixes

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Abstract

The use of flour-oil composites as a source of fat in dry cake mixes was investigated. Wheat flour and canola oil were jet-cooked under excess steam to form composites. The composites were drum dried and milled to form a free flowing powder with 33 to 56% oil. The dried composites were used to replace fat, and part of flour in low-fat cake mix formulations. Specific gravity of cake batters was measured. The cakes were analyzed for crumb grain, color, texture, and water activity. The effects of storage were determined by evaluating cakes stored for 1, 4, and 7 days at ambient temperature. Cakes made with the composites were softer and had more spring as measured by the texture analyzer. Similar differences in texture were observed with cakes stored for a week. The cakes made with composites retained their softness and moisture better than control cakes made with equivalent flour and oil. The composites have great potential for delivery of fat in a dried form in bake mixes. High oil composites in dry form offer new avenues for its applications in food industry. This study provides the development of complete bake mixes by delivering fat in a dry form.

Keywords: Flour-oil composite; Cake mixes; Delivery agent; Low-fat; Fat powder

Introduction

Cake is a complex fat and water emulsion system containing flour, sugar, fat, eggs, and baking powder [1]. Fat interferes with gluten development by inhibiting contact between water and flour proteins [2]. Fat contributes to tenderness, air retention, flavor and a smooth, moist mouth feel in cakes [3].

Most of the cake mixes currently available require the addition of oil prior to baking, that is not included in the package. Single-stage cake mix is premix containing all the ingredients used for the preparation of cake. Cakes could be easily prepared from such premix by adding a required quantity of water. The advantage of using such a mix is convenience as it eliminates the need of additional ingredients in small quantities, measuring errors, and additional creaming step.

As the consumers become aware of the need to reduce fat in their diet, the demand for healthy, flavorful, low-fat food increases. Attempts have been made to use various fat replacers to reduce the fat in the baked goods. Various ingredients like mono and di glycerides, xanthan gum, polydextrose, maltodextrins, corn dextrins, pectin, apple pomace, fruit purees, fluffy cellulose, nutrim, high fructose corn syrup have been used as fat replacers in cakes [4-15].

Flour-oil composites (FOC) consist of a stable suspension of microscopic lipid droplets in a starch dispersion or gel, having the outward appearance of the cooked starch product but incorporating valuable properties of the included oil phase [16,17]. The lipid droplets do not coalesce or cream to the top on standing. These composites can be dried and milled to a powder of desired particle size [18]. Past research has been focused on the use of FOC as fat replacers and fat substitutes in various food products like beef patties, dairy products, and baked goods [19-22] rather than as fat delivery agents. Our objective was to deliver oil in powdered form to low-fat cake mix, eliminating the need of extra ingredient required prior to baking and providing a trans-free option.

Materials and Methods

Flour-oil composites

Flour and canola oil composites with four fat levels were prepared for use in the cakes. All-purpose flour (Honeyville Food Products, Honeyville, UT) was mixed with water to a solids content of 20%. The slurry was stirred in a Waring blender (model 37BL84, Dynamics Corporation of America, New Hartford, CT) and pumped through a laboratory model steam jet cooker consisting of a progressive cavity pump (Robins and Myers Inc., Springfield, OH) and manual stainless steel hydroheater (Hydrothermal, Waukesha, WI). The jet cooker was operated under excess steam conditions. Outlet pressure was maintained at 275.8 kPA (140°C) and steam line pressure was 448.2 kPa (155°C). Pumping rate was 1 L/min. To the resulting dispersion, canola oil (purchased from local market) was added at 50, 75, 100 and 125 parts to 100 parts of flour and passed again through the jet cooker under the conditions described above. The composite was dried on a double drum drier (Model 20, Drum Drier and Flaker Co, South Bend, IN) heated with steam at 208.6 kPa (135°C). The composites containing 50, 75, 100 and 125 parts of canola per 100 parts of flour content are being referred in the study as composite 50, composite 75, composite 100 and composite 125, respectively.

Cake mix

Low-fat cake mix formulation based on AACC 10-90 method [23] was determined using several trials at different fat levels. A 75%

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reduction of fat based on cake flour used in the formulation was used in the study. The same amount of the composite was used in all the mixes containing composite. The added oil content varied from 8-14 parts per 100 g cake flour in the cake mix. For cake mixes with no composites, an equivalent amount of all-purpose flour and oil were added. The calculated fat content in the fat sources and in the cake mixes prepared is presented in Table 2. The formulation for the cake mixes using different fat sources is presented in Table 1. The ingredients were weighed into a jar and then mixed well.

Cake baking

The dry cake mix was mixed at speed 2 (Kitchen-Aid mixer) using a whisk for 1 min to ensure uniform blending of the ingredients. Part of water (60%) was added at low speed (2) in 30 seconds. The mixture was scrapped and mixed for 4 minutes at speed 6. The batter was scrapped from the bowl and 20% of the water in the formulation was added at low speed (2) in 30 seconds. The mixture was scrapped and mixed for 2 minutes at speed 6. The batter was scrapped from the bowl and the remaining water was added at low speed (2) in 30 seconds. The mixture was scrapped and mixed for 3 minutes at speed 6.

The specific batter of the cake batter was measured and part of the batter saved for viscosity measurement. Two cake pans (22 cm) were greased with baking spray. Cake batter (450g) was poured in each of the two pans. The cakes were baked at 175°C for 12 min in a convection oven.

The cakes were cooled in pans on wire racks for 20 min and then out of the pan on the racks for 30 min. The cooled cakes were stored in plastic containers till further analysis.

Specific gravity of batter

Cake batter was poured in a 4 ounce cup, tapped twice to remove any air pockets, and then leveled off with a spatula. Weight of the batter was measured and similarly weight of 4 ounce of water was measured. Specific gravity was determined by dividing the weight of the batter by the weight of an equivalent weight of water and reported as g/cc.

Cake analysis

Volume of the cakes was determined using the AACC cake measuring template. Cakes were sliced in half and the interior face of the cake was placed against the template. Volume index was calculated by adding cake's height at the center and at two points halfway between center and outer edge. The cakes were then cut into quarters. One quarter of each cake was used for measurements at Day 0, Day1, Day 4 and Day 7. The quarters were stored in plastic zippered bags at ambient temperature (20 ± 2°C).

Cake texture

Cake texture analysis was performed on a TAXT2i texture analyzer (Stable Micro Systems Ltd., Surrey, UK) with a 5 kg load cell. During the deformation test, 10 mm acrylic cylindrical probe (TA 10) compressed the cake slices while the force-time curve was recorded. The cake slices were tested under vertical compression at a constant speed of 1 mm/s, using 5 g trigger force, held for 60 and returned to start cycle at a speed of 10 mm/s. Firmness was defined as the force required for compressing the product by 25%, which is the peak force on the force–time curve. Springiness is derived from the ratio of the force required to hold the samples in compression to 75% of their original height for 60 s, to the peak force on the force–time curve. The presented values are mean of 3 values for each cake quarter.

Moisture and water activity

The moisture content of the inner crumbs of the cake was measured using the HG53 Halogen Moisture Analyzer (Mettler Toledo) set at 130°C for 20 min. An average of two measurements is reported for each cake sample. Water activity was determined using a Decagon Aqua Lab water activity meter series 3 (Pullman, WA). Water activity was performed on freshly baked cakes. Prior to testing, the meter was allowed to warm up for 30 min. Each sample was measured by covering the bottom of the cup with the interior crumbs scrapped off from the middle of the quarter of the cake. The results reported are average of at least two readings.

Crumb colsor

Crumb color of cakes was determined using a Hunter Color Lab Colorimeter model Lab Scan XE (Reston, VA). The instrument was calibrated using the black tile, and standardized using a white tile. The L* and the b* values of the interior crumb were measured using the cross section of the cake. The L* (lightness) value indicates how black or white the cake is, where 0= black and 100 = white. The b* is a measure of the hue where +b designates a yellow hue and –b a blue hue. The crumb grain of the cake was evaluated by taking scans of the inner part of the horizontally cut cake.

Crumb grain

The internal structure of the cake crumb was examined by taking images of the cake crumb. The cut surfaces were placed on a flatbed scanner and 300 dpi grayscale images were obtained.

Statistical analysis

All analysis was carried out in triplicates and means have been reported. Statistical analysis was conducted using the Statistical

Ingredients	FOC 200	FOC 300	FOC 400	FOC 500	APF 200	APF 300	APF 400	APF 500
Cake flour, g	250	250	250	250	250	250	250	250
Granulated Sugar, g	350	350	350	350	350	350	350	350
Nonfat dry milk powder, g	30	30	30	30	30	30	30	30
Egg white powder, g	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5
Salt, g	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5
Baking powder, g	15	15	15	15	15	15	15	15
Composite, g	62.5	62.5	62.5	62.5				
Comosite #	50	75	100	125				
All-purpose flour					41.7	35.7	31.25	27.8
Canola Oil, g					20.8	26.8	31.25	34.7
Water, ml	362.5	362.5	362.5	362.5	362.5	362.5	362.5	362.5

Table 1: Formulation of cake mixes.

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Analysis System (SAS Institute, Inc., Cary, NC). Analysis of variance (ANOVA) was used to establish the effect of fat delivery in form of flour-lipid composites at four levels of fat in low fat cakes. Proc GLM and Duncan multiple comparisons test were used to detect significant differences between treatments. Statistics are reported at a significance level of 0.05.

Results and Discussion

The composites prepared for the study were in form of free flowing powder, with a fat level range from 33 to 56% (Table 2). Canola oil used in the study was assumed to have 100% fat. The added fat content of the cakes mixes with composites, and cake mixes with oil ranged from 8-14% based on flour.

Specific gravity of cake batters

The specific gravity of batters estimates the air incorporated into a batter, a lower specific gravity is indicative of a batter with more air and viscosity. All batter had a specific gravity higher than 0.75 indicating a stable emulsion [24]. The specific gravity of the batters decreased with the increase in the added fat content in form of either dried powder or as oil. The specific gravity of batters with fat added as dried composites was lower than those with oil added (Figure 1). The batters with composites as the fat source compared to those with equivalent amount of oil had significantly lower specific gravity. The specific gravity of batter with 8% fat added as the composite was similar to that of 14% added fat as oil. A viscose batter helps keep air bubbles from rising out of the batter while a less viscous batter with higher specific gravity allows large bubbles to coalesce, rise to the surface and leave the batter [5,25]. The composites added to the viscosity of the batter.

Cake volume

The volume of cakes made from mixes with composites and oil at different levels are presented in Figure 2. As expected an increase in cake volume was observed with an increase in the added fat content. Cakes with fat added as composites had higher cake volumes at all fat levels than those of the equivalent oil. Volume of cake with 8% fat added as FOC 200 was similar to that of 13% added fat as oil (APF 400).

Crumb texture

The Crumb firmness of the cakes at four storage times is presented in Table 3. There was a significant gradual increase in the firmness of cakes with storage. The cakes with oil delivered in form of composites were significantly softer and stayed softer than those with added oil. The composites add to the softness of the cakes.

Oil Source	% Fat	Fat in mix, %[1]
FOC 200	33	8.3
FOC 300	43	10.7
FOC 400	50	12.5
FOC 500	56	13.9
APF 200	100	8.3
APF 300	100	10.7
APF 400	100	12.5
APF 500	100	13.9
[1] Based on flour		

Table 2: Fat level of composites cake mixes.

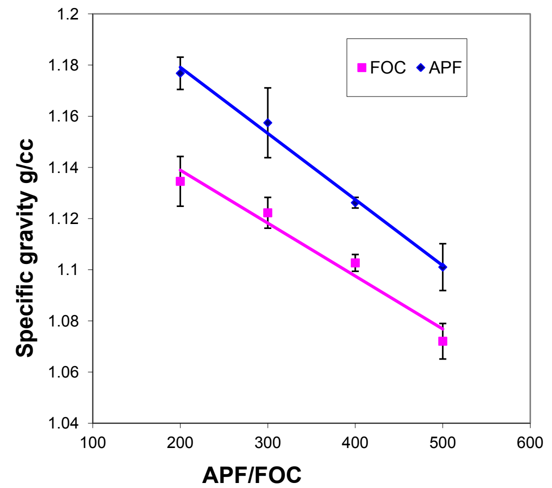

Figure 1: Effect of fat source FOC (Composite with no additional fat added to mix) and APF (Canola oil added separately to mix before mixing) on the specific gravity of the cake batters.

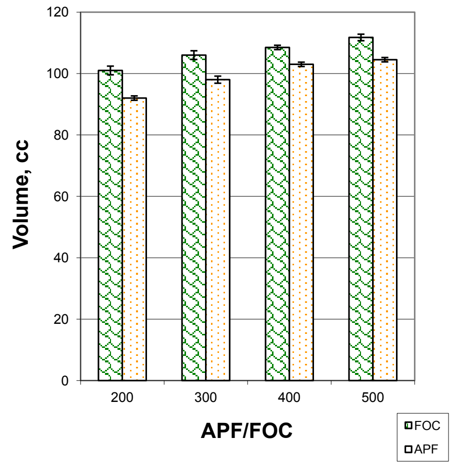

Figure 2: Effect of fat source FOC (Composite with no additional fat added to mix) and APF (Canola oil added separately to mix before mixing) on the volume of cakes after baking.

Crumb moisture and water activity

The moisture content and the water activity of the cake crumb were not significantly affected by the source of fat in the cake mix. The data is presented in Table 4. However as expected the water activity decreased with increase in the added fat content. Also a significant loss of moisture of the cake crumb occurred with storage.

Crumb color

The appearance of food is very important because the consumer's purchasing decisions are based on the expected appearance of certain foods. Often the sensory attribute deemed most important in foods is color [26]. The effect of composite, fat level and storage is presented in Table 5. The color of the cake crumb was not affected by the source of the fat in the cake mix. Color of the cake crumb was not significantly affected by storage up to one week.

Crumb grain

The cake crumb grain was influenced by the source of the fat. The crumb grain cakes with fat source as composites had a finer texture than those with equivalent oil added to them. Image of cake crumb with 14% added fat as composite and oil are shown in Figure 3. Uniform cell distribution was observed in the crumb of cakes made with mixes with added FOC. The crumb grain images confirm the earlier observations made with specific gravity of the batter and the volume of the cakes. Batters made with FOC in the mix had lower specific gravity resulting in higher volume of the cake. Crumb of the cake made with FOC had more air pockets needed for the higher volume.

	Days of Storage			
	0	1	4	7
Firmness, g				
APF 200	225.1[a]	355.1[a]	406.9[a]	434.6[b]
APF 300	174.1[e]	322.4[b]	378.5[c]	466.8[a]
APF 400	191.3[b]	280.7[d]	362.5[d]	424.2[d]
APF 500	179.9[d]	307.5[c]	398.7[b]	424.5[c]
FOC 200	189.8[c]	262.1[g]	351.5[e]	413.5[e]
FOC 300	165.4[g]	210.0[h]	296.7[h]	306.2[h]
FOC 400	171.1[f]	264.1[f]	325.5[g]	388.0[f]
FOC 500	151.3[h]	267.0[e]	335.2[f]	382.8[g]

[a] Means with same superscript are not significantly different (P<0.005) according to Duncan Means Test.

Table 3: Effect of fat source in cake mixes on the firmness of cakes during storage.

	Moisture, %	Water Activity
APF 200	33.35 ± 0.579	0.889 ± 0.0007
APF 300	33.38 ± 0.286	0.888 ± 0.0010
APF 400	33.69 ± 0.339	0.889 ± 0.0007
APF 500	33.43 ± 0.148	0.889 ± 0.0038
FOC 200	35.19 ± 0.45	0.887 ± 0.0021
FOC 300	33.66 ± 0.49	0.888 ± 0.0059
FOC 400	33.53 ± 0.388	0.890 ± 0.0006
FOC 500	33.42 ± 0.546	0.889 ± 0.0014

Table 4: Effect of fat source in cake mixes on moisture content and water activity of cakes.

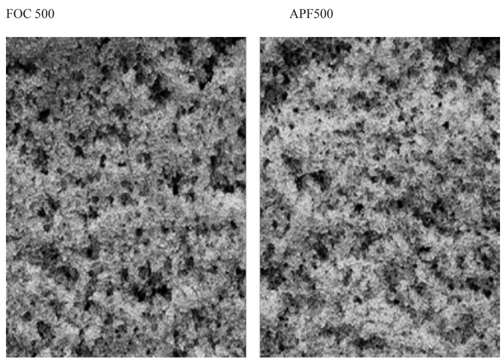

Figure 3: Effect of fat source FOC (Composite with no additional fat added to mix) and APF (Canola oil added separately to mix before mixing) on the crumb grain of cakes.

	Day 0	Day 4	Day 8
	L*		
APF 200	88.44 ± 0.417	89.00 ± 0.390	89.31 ± 0.325
APF 300	88.86 ± 0.867	87.79 ± 2.377	86.67 ± 2.148
APF 400	88.02 ± 0.325	88.97 ± 0.302	89.11 ± 0.057
APF 500	89.14 ± 0.410	88.93 ± 0.323	89.62 ± 0.148
FOC 200	89.04 ± 0.483	87.69 ± 1.110	88.13 ± 2.020
FOC 300	89.24 ± 1.145	87.41 ± 1.609	87.61 ± 2.075
FOC 400	89.00 ± 0.884	89.18 ± 1.642	88.33 ± 1.432
FOC 500	88.38 ± 0.758	87.70 ± 1.715	87.53 ± 1.572
	a*		
APF 200	-1.12 ± 0.198	-1.19 ± 0.039	-1.19 ± 0.021
APF 300	-1.15 ± 0.240	-1.19 ± 0.227	-1.13 ± 0.255
APF 400	-1.08 ± 0.021	-1.12 ± 0.056	-1.14 ± 0.007
APF 500	-1.20 ± 0.007	-1.10 ± 0.033	-1.08 ± 0.057
FOC 200	-1.20 ± 0.096	-1.19 ± 0.057	-1.21 ± 0.142
FOC 300	-1.09 ± 0.246	-1.08 ± 0.174	-1.13 ± 0.200
FOC 400	-1.17 ± 0.099	-1.20 ± 0.105	-1.12 ± 0.029
FOC 500	-1.03 ± 0.176	-1.13 ± 0.074	-1.13 ± 0.072
	b*		
APF 200	16.62 ± 1.054	16.35 ± 0.218	16.06 ± 0.212
APF 300	15.08 ± 0.720	14.21 ± 1.089	14.13 ± 1.604
APF 400	16.30 ± 0.643	16.43 ± 0.321	16.41 ± 0.028
APF 500	16.34 ± 0.007	16.53 ± 0.325	16.47 ± 0.085
FOC 200	15.50 ± 0.296	14.39 ± 0.847	14.36 ± 1.183
FOC 300	14.50 ± 0.407	13.52 ± 1.320	13.28 ± 1.402
FOC 400	15.03 ± 0.330	14.61 ± 1.179	14.33 ± 1.369
FOC 500	15.91 ± 0.394	14.88 ± 1.089	14.54 ± 1.076

L* is the degree of lightness with 0 being black and 100 being white; Positive values of a* denote the intensity of red color, Negative a* is intensity of green, Positive b* denotes yellow, and Negative b* is blue

Table 5: Effect of fat source in cake mixes and storage on the color of cakes.

Conclusions

High oil FOC having up to 56% oil can be prepared by jet cooking wheat flour and canola oil, and drum drying the cooked composite to form free flowing powder. Cakes made with FOC as the fat source in baking mix had higher volume and better texture than those made with added oil. This study indicates potential new applications for FOC that benefit the baking industry by generating new products offering greater convenience and consistently higher quality results.

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