Physical Properties of Muffins Containing Peanut Flour and Peanut Butter

M.J. Hinds[1]

ABSTRACT

Recent studies have reported that frequent peanut consumption may have positive effects on blood lipid profiles. This role of peanuts as a potential functional food is due mainly to its lipid composition. Consumers are demanding convenient and health-improving meal items, and sales of muffins have increased. Thus, muffins may serve as an excellent carrier to deliver the health benefits of peanuts. Previous studies on peanut utilization in muffins focused on increasing protein content by using defatted peanut materials. However, the potential functionality of peanut lipid suggests the need to investigate its inclusion in muffins. In this study, response surface methodology (RSM) was used to evaluate the effects of replacing wheat flour by partially defatted (12% fat, d.b.) peanut flour (PF, at 0, 40, 80%), and the addition of peanut butter (PB, at 0, 21.5, 35.4%, wt of dry ingredients) on physical properties of muffins. Experimental muffins containing 0% PF + 0% PB, and commercial banana-walnut muffins were used as controls. Replacement of wheat flour by PF or addition of PB significantly ($P < 0.05$) increased tenderness of the muffins. Peanut butter was the major factor decreasing muffin volume when formulations contained > 20% PB. As PF% was increased, the outer surface of muffins became more browner, whereas increased PB gave rise to a more intense hue. Internal crumb color became darker and more intense brown as both PF and PB were increased. RSM predicted that formulations ranging from 0% PF + 32% PB through 30% PF + 15% PB to 61% PF + 0% PB would have optimum texture and volume. Findings indicate the potential for production of good quality muffins containing up to 32% wt of peanut materials per weight of total ingredients, and ≤ 18% peanut lipid in the baked products.

Key Words: Baked goods, food consumption, lipids.

Traditionally, peanuts have been nutritionally important because of their high lipid and protein contents and reasonable amounts of carbohydrates, vitamins, and minerals. Peanut oil has been noted also for its excellent frying properties (Pattee *et al.*, 1985). However, in recent years, the role of peanuts as a potential functional food has become more apparent (Pzczola, 2000). Several studies (Fraser *et al.*, 1992; Hu *et al.*, 1998; Brown *et al.*, 1999; Kris-Etherton *et al.*, 1999a; Albert *et al.*, 2002) reported a positive correlation between frequent peanut consumption and marked reduction in cardiovascular disease (CVD) risk. For example, diets containing 34-36% total fat provided by peanut oil, peanuts, or peanut butter lowered total cholesterol by 10% and LDL cholesterol by 14%, and decreased CVD risk by 16-21% compared with a low-fat (Step II) diet which lowered CVD risk by 12% (Kris-Etherton *et al.*, 1999a). Also, consumption of peanuts 5 times per wk may decrease the incidence of CVD by 25-50% (Fraser *et al.*, 1992). These health benefits of peanut consumption may be derived from components such as oleic acid (Kris-Etherton *et al.*, 1999a), resveratrol (Sanders *et al.*, 2000), vitamin E (Cabrini *et al.*, 2001), folic acid, and others (Cobb and Johnson, 1973; Kris-Etherton *et al.*, 1999b).

In spite of the positive nutritional and health benefits derived from peanut consumption, intake of peanuts declined steadily in the U.S. from the mid-1980s to the late 1990s (Dreher *et al.*, 1996). For example, in southeast U.S., 85% of consumers spend less than $2/wk on peanuts and peanut products (Hinds and Jolly, 1997), 35% never eat roasted peanuts, and 56% eat roasted peanuts less than once per week (Jolly *et al.*, 2001). Approximately 50% of U.S.-harvested peanuts are used to manufacture peanut butter. However, the decline in peanut butter consumption (Jolly *et al.*, 2005) gives rise to surplus peanut butter on the market. On the other hand, U.S. consumption of bread is on the rise, and muffins are one of the top bakery items (Conan, 1997; Hetager, 2000). In January 2001, annual supermarket sales of muffins were 6% higher than that of the previous 52-wk period (Beach, 2001). Thus, muffins may serve as an excellent carrier to deliver additional health benefits.

Previous studies (Ahmed and Araujo, 1978; Kuo, 1980; Ory and Conkerton, 1983; Holt *et al.*, 1992) in which peanut materials were used to prepare muffins focused on increasing protein content of the products. Thirty percent or less peanut flour (1.3% fat) or ≤ 10% peanut grits (0.6% fat) did not adversely affect texture of muffins (Kuo, 1980). However, muffins in which wheat flour was replaced by either 100% defatted peanut flour (DPF), or a 2:1 ratio of DPF to freeze dried peanut butter, were more grainy, denser, and more gummy than 100% wheat muffins (Ory and Conkerton, 1983). Holt *et al.* (1992) validated the predicted performance of muffins containing 33.3% peanut flour (6.8% fat) replacing wheat flour in a standard formulation. They observed no significant differences in external or internal color attributes, volume, symmetry, and textural properties between the peanut flour muffins and the 100% wheat control. Also, there were no significant differences in mean sensory descriptive ratings for appearance, flavor, and mouth-feel attributes between the experimental peanut flour muffins and the wheat control.

As previously stated, the lipid fraction of peanuts may confer additional health benefits to consumers. However, previous studies on peanut utilization in muffins used defatted (0.6-6.8% fat) peanut materials, and did not investigate the effect of peanut lipid on muffin properties. In this study, peanut materials (e.g., peanut oil) with higher lipid content than previously used for muffins, and those peanut materials that may be currently either under-utilized for human consumption (viz., defatted peanut flour) or in surplus (viz., peanut butter) in the

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[1] Asst. Prof., Nutritional Sciences Dept., Oklahoma State Univ., Stillwater, OK 74078 (email: hindsmj@okstate.edu).

U.S. were used. Replacement of wheat flour by peanut flour, a nongluten forming flour, can adversely affect texture and volume of baked goods (Damodaran, 1996). The specific objectives of this study were (a) to evaluate the effects of peanut flour (as wheat flour replacement) and peanut butter on physical properties of muffins, and (b) to predict maximum levels of peanut materials that might be appropriate for use in muffin formulations.

Materials and Methods

Experimental Design. A 3 × 3 factorial arrangement of peanut flour (PF: 0, 40, 80% replacing wheat flour) and peanut butter (PB: 0, 21.5, 35.4% wt of dry ingredients), with one process replication, was used. Two types of muffins were used as standards. Muffin treatments containing 0% PF and 0% PB (the wheat control muffins) were used to provide a standard against which the effects of peanut flour and peanut butter on the reformulated muffins could be compared. Otis Spunkmeyer® banana nut muffins (containing walnuts) were selected as a commercial standard to set limits to indicate consumer acceptability of the experimental peanut muffins. Walnut-containing muffins were selected because they are the main commercial nut-supplemented muffins, and thus consumers may expect peanut muffins to have similar properties to walnut muffins. Response surface methodology (RSM) was used to evaluate the effects of PF and PB on physical properties of the muffins. RSM is a collection of statistical and mathematical techniques that may be used in product development to model formulation and processing parameters based on data collected (Box and Draper, 1987). RSM was used in this study to facilitate prediction of relationships between variables for data points that were not actually used in the experimental design.

Materials. Peanut flour (12% fat, light roast, code #521271) was made from virginia peanuts and donated by Golden Peanut Co., Alpharetta, GA. Peter Pan™ (no added salt or sugar) peanut butter, Planters™ unsalted dry roasted peanuts, Loriva® peanut oil, pasteurized milk (2% fat), E-Z Foil™ (25 mm diam.) baking cups, light brown cane sugar, Gold Medal™ all purpose wheat flour, large eggs, Clabber Girl® double acting baking powder, Karo™ corn syrup, noniodized salt, and Otis Spunkmeyer® banana nut muffins were purchased from local supermarkets. The dry roasted peanuts were chopped in a Waring commercial blender and sifted through a U.S. standard (no. 8) sieve to prepare topping-size granules.

Muffin Preparation. A standard muffin formulation (McWilliams, 1997) was used in which fat was replaced by peanut oil, and topping-size peanut granules were added to all the formulations. PF and PB were included according to the experimental design. Dry and wet ingredients for each treatment were mixed using the muffin method (McWilliams, 1997), and the mixture was stirred manually for 20 strokes with a wooden spatula. Using a no. 20 cookie scoop, 34 to 44 g aliquots of batter were weighed into muffin pans lined with E-Z Foil™ baking cups. Muffins were baked at 190.5 C (375 F) for 15-20 min. The baked muffins were allowed to cool to ambient temperature (25-27 C) for 30 min on wire racks; then held in Glad Lock™ freezer-safe plastic bags at 25-27 C for 24 hr.

Color. Three muffins per treatment were selected randomly for color evaluation. Color was measured using a Minolta Chroma Meter Reflectance System (Model CR-2000, Minolta, Japan) set in the CIE L*C*h* mode using a C light source at 2» observer angle. Calibration was based on a standard tile with the following color space chromaticity coordinates: Y = 94.3, x = 0.3134, and y = 0.3207 (L* = 97.75, a* = -0.58, and b* = +2.31). Three measurements per muffin were taken of the outer (top) crust, and the mean was recorded as the color of its external surface. The muffin was then sliced in half horizontally and three measurements of the inner crumb were taken.

Texture. Texture was measured using a Food Technology Corp. TextureGage (Food Technology Corp., Rockville, MD) fitted with a Kramer cell and a 10-blade probe descending at a speed of 5 mm/sec. Three muffins per treatment were randomly selected for texture evaluation. Prior to texture determination, the E-Z Foil™ baking cup was gently peeled off each muffin, and the muffin was placed (top surface upwards) into the Kramer cell. Hardness of the muffin was interpreted as the maximum shear force (kg) required by the Kramer cell blades to cut through the muffins.

Volume. Height of three baked muffins per treatment was determined by a Marathon™ 150-mm Electronic Digital Caliper. Ease of depositing batter aliquots into the muffin cups varied with formulation, thus giving rise to a range (34-44 g) of batter weights. Therefore, to evaluate crumb density, actual volume of the baked muffins was not measured. Instead, the parameter, 'volume index' [height (mm) of baked muffin/wt (g) of batter] was derived to facilitate comparison of crumb volume among treatments.

Statistical Analysis. The SAS (1997) computer package was used to compute ANOVA, determine significant differences between means (Fisher's Protected LSD test), and to carry out response surface regression (RSREG procedure). RSREG is based on a second-order polynomial equation (Box and Draper, 1987), and it facilitates modeling by providing coefficients for the dependent variables. Thus, equations illustrating the effects of the PF and PB on the dependent (response) variables were derived (Table 1). The data points from these equations were exported to SigmaPlot (SPSS, 2000) to plot contours to predict values for the dependent variables from data points that were not actually used in the experimental design.

Results and Discussion

Effects of Peanut Flour and Peanut Butter. Tenderness of muffins increased as levels of peanut flour (PF) and peanut butter (PB) were increased (Tables 2 and 3). For example, the wheat control (0% PF and 0% PB) muffins had textures of 60.3 ± 1.59 kg shear force, whereas muffins containing 40% PF + 0% PB, or 0% PF + 21.5% PB had textures of 44.6 ± 0.71 and 50.2 ± 0.71 kg shear force, respectively.

Volume of muffins was not significantly affected by peanut flour content (Table 3), but muffin volume decreased significantly when formulations contained 35.4% PB (Table 4). For example, volume index of the wheat controls muffins was 1.05 ± 0.080, whereas muffins containing 0% PF + 35.4% PB had a volume index of 0.93 ± 0.030 compared with an index of 1.08 ± 0.075 for formulations containing 80% PF + 0% PB (Table 4).

Texture and volume of the experimental peanut muffins were expected to be different from those of the wheat control muffins for several reasons. Glutenin and gliadin, the unique proteins which impart cohesiveness and elasticity to the gluten complex in wheat dough, are absent from peanut flour. Therefore, as wheat flour was decreased, the structure of the muffins became more dependent on nongluten proteins and carbohydrates. The peanut flour and peanut butter contained 12 and 53% lipid and 18 and 6.25% sugar, respectively, compared with 0% fat and 1% sugar in wheat flour. Lipids and sugar both act

Table 1. Predictive regression models for the dependent variables as functions of peanut flour and peanut butter.

Dependent variable	Predictive model[a]	R^2 [b]
Texture	$61.3189 - 0.5461^* X_1 - 0.7201^* X_2 + 0.0033^* X_1^2 + 0.0056^* X_1 {}^\circ X_2 + 0.0021^* X_2^2$	0.95
Volume index[c]	$1.038109 + 0.000495^* X_1 + 0.007951^* X_2 - 0.000005^* X_1^2 - 0.000029^* X_1 {}^* X_2 - 0.000284^* X_2^2$	0.47
Outer surface color:		
Hue angle	$83.3914 - 0.3877^* X_1 - 0.1747^* X_2 + 0.0012^* X_1^2 + 0.0031^* X_1 {}^* X_2 + 0.0019^* X_2^2$	0.98
Chroma	$35.4544 - 0.0963^* X_1 - 0.1097^* X_2 - 0.0002^* X_1^2 + 0.0032^* X_1 {}^* X_2 + 0.0010^* X_2^2$	0.85
L Value	$65.6067 - 0.3711^* X_1 + 0.1118^* X_2 + 0.0008^* X_1^2 - 0.0006^* X_1 {}^* X_2 - 0.0057^* X_2^2$	0.78
Inner crumb color:		
Hue angle	$91.7046 - 0.4953^* X_1 - 0.2296^* X_2 + 0.0025^* X_1^2 + 0.0033^* X_1 {}^* X_2 - 0.0002^* X_2^2$	0.99
Chroma	$23.6354 + 0.3103^* X_1 + 0.1659^* X_2 - 0.0025^* X_1^2 - 0.0021^* X_1 {}^* X_2 + 0.00008^* X_2^2$	0.93
L Value	$70.4260 - 0.5468^* X_1 - 0.0541^* X_2 + 0.0026^* X_1^2 + 0.0020^* X_1 {}^* X_2 - 0.0028^* X_2^2$	0.99

[a] X_1 = % peanut flour replacing wheat flour, X_2 = peanut butter as wt (%) of dry ingredients. None of the models showed significant lack of fit.

[b] R^2 = % variability explained by model.

[c] Volume index = ht (mm) of baked muffin/wt (g) of batter.

as tenderizing agents in baked products, and were responsible for promoting tenderness in the experimental peanut muffins as follows. The hydrophobic action of the lipid molecules in the peanut flour and peanut butter would have inhibited gluten development to some extent, whereas the hygroscopic action of the sugar molecules (in PF and PB) would have retarded gluten development. Sugar molecules also elevate coagulation temperature of the structural proteins during baking. This provides more time for cells to stretch and volume to increase before coagulation occurs to define the final volume of the baked product (McWilliams, 1997). Results indicate that the sugar:lipid ratio in all the formulations with PB and those with 40% PF + 21.5% PB were high enough to facilitate cell stretching, and thus gave rise to products with volumes similar to the wheat controls (Table 4). However, as PB was increased beyond 21.5%, muffin volume decreased indicating that the hydrophobic/tenderizing action of the lipid outweighed the influence of the sugar on the structural proteins (Tables 2 and 4).

Color of outer surface (Table 2) and inner crumb (Table 4) of all the experimental peanut muffins was browner and darker than the wheat control and was affected by both PF and PB (Table 3). As peanut flour levels were increased, muffins became darker and browner (Tables 2 and 4). A similar, but less dramatic, trend was observed when PB (%) was increased. For example, hue angles of the outer surface of the wheat control and formulations containing 80% PF + 0% PB, 80% PF + 35.4% PB, and 0% PF + 35.4% PB were 83.2 ± 2.75, 59.9 ± 0.47, 65.2 ± 2.00, and 79.7 ± 0.40, respectively (Table 1). The peanut flour

Table 2. Effect of formulation on texture, and outer surface color (means[a] ± s.d.) of muffins.

Formulation[b]			Outer surface color[c]		
PF	PB	Texture	Hue angle	Chroma	L value
------ % ------		kg (shear force)			
0	0[d]	60.3 ± 1.59 a	83.2 ± 2.75 a	34.9 ± 1.40 a	66.6 ± 2.23 a
40	0	44.6 ± 0.71 c	70.5 ± 0.69 c	32.0 ± 0.74 c	51.7 ± 1.14 d
80	0	39.6 ± 2.95 d	59.9 ± 0.47 e	26.6 ± 0.67 e	40.4 ± 0.47 f
0	21.5	50.2 ± 0.71 b	80.5 ± 0.45 b	34.1 ± 0.76 ab	64.3 ± 0.49 b
40	21.5	33.6 ± 1.85 ef	69.1 ± 0.00 c	31.9 ± 0.54 c	49.3 ± 0.49 d
80	21.5	31.9 ± 1.87 f	63.3 ± 0.26 d	30.0 ± 0.30 d	42.9 ± 0.39 f
0	35.4	36.1 ± 1.27 e	79.7 ± 0.40 b	32.8 ± 0.21 bc	62.5 ± 1.30 c
40	35.4	31.4 ± 0.93 f	70.4 ± 0.85 c	32.8 ± 0.76 bc	50.3 ± 0.54 e
80	35.4	32.5 ± 1.61 f	65.2 ± 2.00 d	33.6 ± 2.48 abc	33.8 ± 19.29 f

[a] Means for the same variable (column) followed by the same letter are not significantly different according to Fisher's Protected LSD test at P = 0.05.

[b] PF = % peanut flour replacing wheat flour, PB = peanut butter as wt (%) of dry ingredients.

[c] Hue angle (color descriptor): 0° = red, 90° = yellow; Chroma = intensity of hue; L value (lightness scale): 0 = black, 100 = white.

[d] Wheat control.

Table 3. ANOVA: Overall effect[a] of independent variables on dependent variables.

Independent variable	Dependent variable							
		Outer surface color			Inner crumb color			
	Texture	Hue	Chroma	L value	Hue	Chroma	L value	Vol.
	kg							
Peanut flour	**	**	**	**	**	**	**	ns
Peanut butter	**	ns	**	ns	**	**	**	**

[a]Significance level: ** $P < 0.01$; ns = not significant.

(h° = 72.6 ± 0.66, chroma = 25.3 ± 0.30, L value = 78.6 ± 0.20) and peanut butter (h° = 53.30.36, chroma = 28.5 ± 1.26, L value = 70.1 ± 0.15) were naturally tan to brown in color compared with the wheat flour (h° = 91.8 ± 0.66, chroma = 6.5 ± 0.14, L value = 86.9 ± 1.46), and would have influenced the color of the experimental peanut muffins. However, the fact that higher levels of PF gave rise to the darkest and most brown muffins, indicates that Maillard browning played a major role in the final color of the muffins because the sugar content of the peanut flour was 18% compared with 6.25% in the peanut butter.

Response Surface Regression. Response surface regression is an informative and economical technique in the development and improvement of food products because it facilitates a graphical surface relationship between the independent and dependent variables that predicts responses at all possible combinations of independent variables (Hu, 1999). In this study, the polynomial equations derived from the response surface regression (Table 1) facilitated plotting of contours to predict values for the dependent variables at levels for the independent variables that were not actually observed. For example, the equation for texture of the muffins was:

$$\text{Texture} = 61.3189 - 0.5461 * X_1 - 0.7201 * X_2 + 0.0033 * X_1^2 + 0.0056 * X_1X_2 + 0.0021 * X_2^2 \quad \text{[Eq. 1]}$$

where X_1 = peanut flour (%), and X_2 = peanut butter (%).

This equation predicts that the texture of muffins containing 20% peanut flour (replacing wheat flour) and 20% peanut butter would have a texture of approximately 40 kg in terms of shear force (Fig. 1). None of the equations showed significant lack of fit (Table 1).

Table 4. Effect of formulation on volume, and inner crumb color (means[a] ± s.d.) of muffins.

Formulation[b]			Inner crumb color[d]		
PF	PB	Volume index[c]	Hue angle	Chroma	L value
---- % ----					
0	0[e]	1.05 ± 0.080 abc	92.5 ± 1.64 a	23.1 ± 1.12 e	70.4 ± 1.87 a
40	0	1.00 ± 0.069 a-d	74.5 ± 0.25 d	33.1 ± 0.65 ab	52.8 ± 0.79 d
80	0	1.08 ± 0.075 ab	68.7 ± 0.50 f	31.7 ± 0.60 b	43.5 ± 0.45 f
0	21.5	1.11 ± 0.063 a	86.3 ± 0.40 b	27.3 ± 0.10 d	68.0 ± 1.07 b
40	21.5	1.08 ± 0.072 ab	74.1 ± 0.46 de	33.7 ± 0.45 a	52.2 ± 0.54 d
80	21.5	0.99 ± 0.055 bcd	68.7 ± 0.23 f	32.3 ± 0.71 b	44.3 ± 0.59 f
0	35.4	0.93 ± 0.030 d	82.9 ± 0.21 c	30.1 ± 0.54 c	65.0 ± 1.45 c
40	35.4	0.96 ± 0.088 cd	73.2 ± 0.10 e	34.0 ± 1.04 a	50.0 ± 1.63 e
80	35.4	0.90 ± 0.061 d	68.4 ± 0.46 f	32.8 ± 1.30 ab	43.9 ± 0.91 f

[a]Means for the same variable (column) followed by the same letter are not significantly different according to Fisher's Protected LSD test at $P = 0.05$.

[b]PF = % peanut flour replacing wheat flour, PB = peanut butter as wt (%) of dry ingredients.

[c]Volume index = ht (mm) of baked muffin/wt (g) of batter.

[d]Hue angle (color descriptor): 0° = red, 90° = yellow; Chroma = intensity of hue; L value (lightness scale): 0 = black, 100 = white.

[e]Wheat control.

As was previously discussed, replacement of wheat flour by peanut flour and addition of peanut butter influenced texture, volume, and color of the muffins. Thus, it was more practical to utilize a composite commercial muffin (vs. the wheat control) as a standard to identify optimal quality characteristics of the experimental muffins from the results of the response surface regression. Otis Spunkmeyer® commercial banana nut muffins were selected because they contain sugar and nonwheat starch (from banana puree) as well as walnut toppings and are an established and acceptable brand. Therefore, properties of the experimental peanut muffins that are similar to those of the commercial banana nut muffins would be acceptable to consumers. The mean and standard deviation values of the properties of the commercial banana nut muffins were used to set upper (means + s.d.) and lower (means - s.d.) limits for acceptable texture and color of the experimental peanut muffins. However, the wheat control muffins were used to set limits for volume because they provided the only appropriate comparison for cell structure (in the absence of microstructure examination) of the muffins.

Texture. Tenderness of the muffins was increased to a greater extent by peanut flour than by peanut butter (Fig. 1). For example, muffins containing 10% peanut flour and 20% peanut butter would have a texture of 43 kg shear force, whereas muffins containing 20% peanut flour and 10% peanut butter would have a texture of 47 kg (Fig. 1). Texture of the commer-

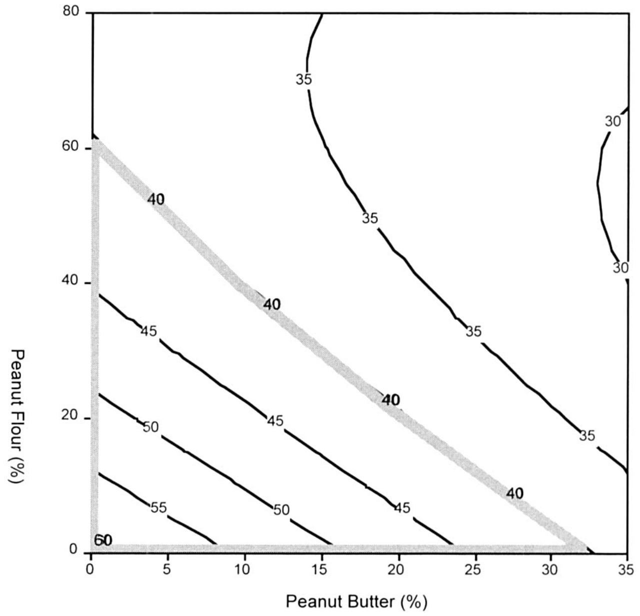

Fig. 1. Contour plot of texture (kg, shear force) of muffins as a function of peanut flour and peanut butter.

cial banana nut muffins was 50.7 ± 10.57 kg. Using the latter mean and standard deviation from the commercial muffin to set upper (61.3 kg) and lower (40.1 kg) limits for optimum texture of the experimental muffins indicated that all formulations within the gray-bordered area of Figure 1 fall within the region of interest. This indicates that muffin formulations ranging from 61% PF + 0% PB through 30% PF + 15% PB to 0% PF + 32% PB would have similar texture to commercial banana nut muffins. Previous studies, in which peanut flour was used to replace wheat flour in muffins, reported no significant difference in texture when 33.3% PF was used (Holt *et al.*, 1992) but a very dense, gummy texture when 100% PF was used (Ory and Conkerton, 1983). Results from the present study not only indicate that a higher percent of peanut flour (than previously reported) may be used in muffins, but also provide possible combinations of PF and PB that would give rise to appropriate muffin texture (Fig. 1).

Volume. Peanut butter was the major factor decreasing volume when formulations contained > 20% PB (Fig. 2). The volume index (1.05 ± 0.080) of the control formulation that contained 0% PF + 0% PB was used to set upper (1.13) and lower (0.97) limits for the region of interest. The gray-bordered area (Fig. 2) predicts that formulations ranging from 24% PF + 35% PB to 80% PF + 29% PB may have volumes similar to nonsupplemented wheat flour muffins. Holt *et al.* (1992) observed no significant difference in volume of muffins containing 33.3% PF compared with wheat flour controls. However, when 100% wheat flour was replaced by a 2:1 ratio of peanut flour:freeze dried peanut butter, muffins had low volume (Ory and Conkerton, 1983). Results from the present study predict that more than twice the percentage of PF as reported by Holt *et al.* (1992) may be used with no significant decrease in muffin volume if PB is included in the formulation.

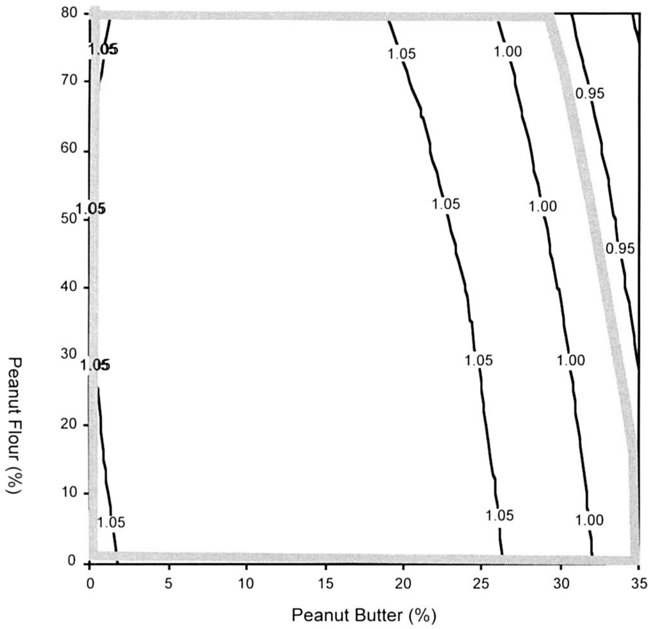

Fig. 2. Contour plot of volume index (ht of baked muffin/wt of batter) of muffins as a function of peanut flour and peanut butter.

Color of Upper Surface. As peanut flour (%) was increased, the muffins became more brown (decrease in hue angle from ~80 to < 65; Fig. 3) and darker (L value decreased from ~65 to ~40; Fig. 4) in color. Chroma values (Fig. 5) indicate that color of the muffins became less intense with increased peanut flour, but became more intense when PB was ≤ 15% and PF was ≥ 40%. Holt *et al.* (1992) reported no significant difference in external color between muffins containing 66.6% wheat flour:33.3% PF and those containing 100% wheat flour. Although our peanut-containing muffins were more brown than the wheat control (Table 3), they were fairly similar in color to the commercial banana walnut muffins

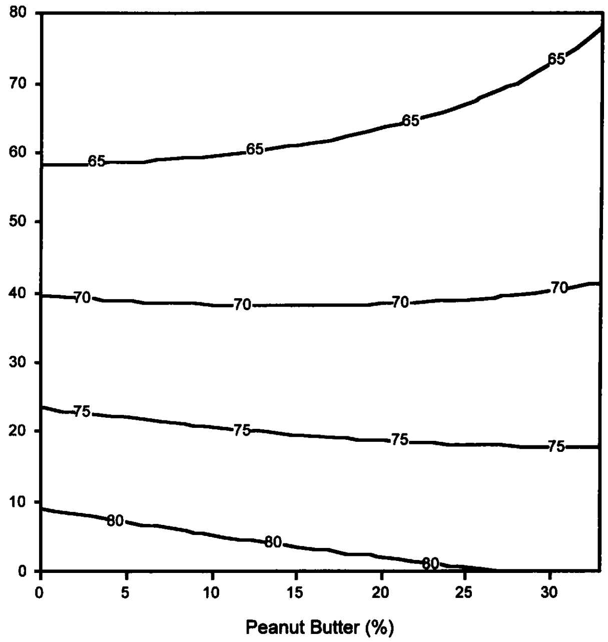

Fig. 3. Contour plot of hue angle (0° = red, 90° = yellow) of outer surface of muffins as a function of peanut flour and peanut butter.

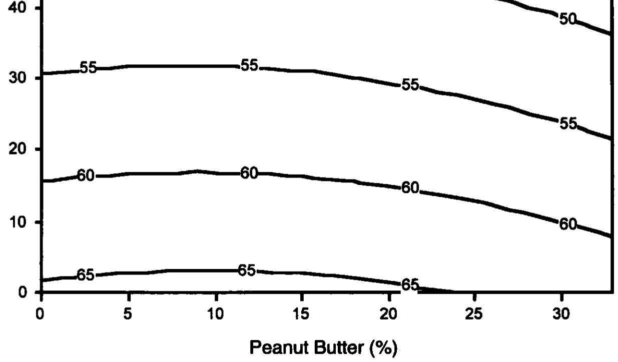

Fig. 4. Contour plot of L value (0 = black, 100 = white) of outer surface of muffins as a function of peanut flour and peanut butter.

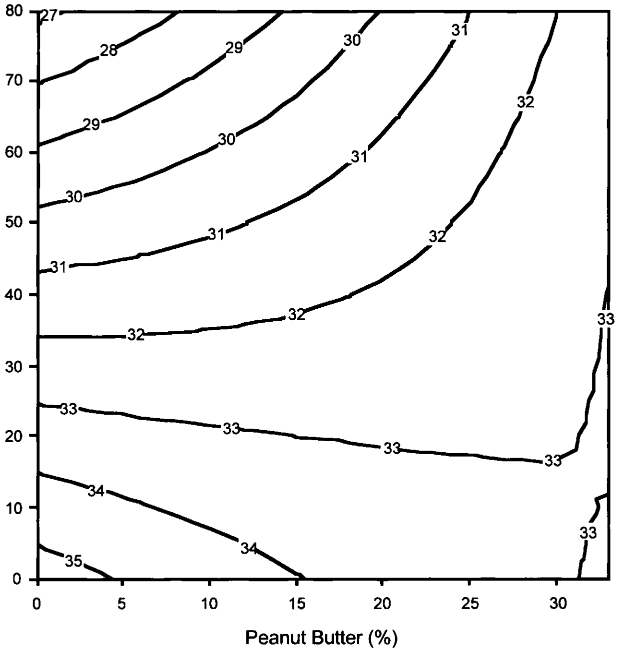

Fig. 5. Contour plot of chroma (intensity of hue) of outer surface of muffins as a function of peanut flour and peanut butter.

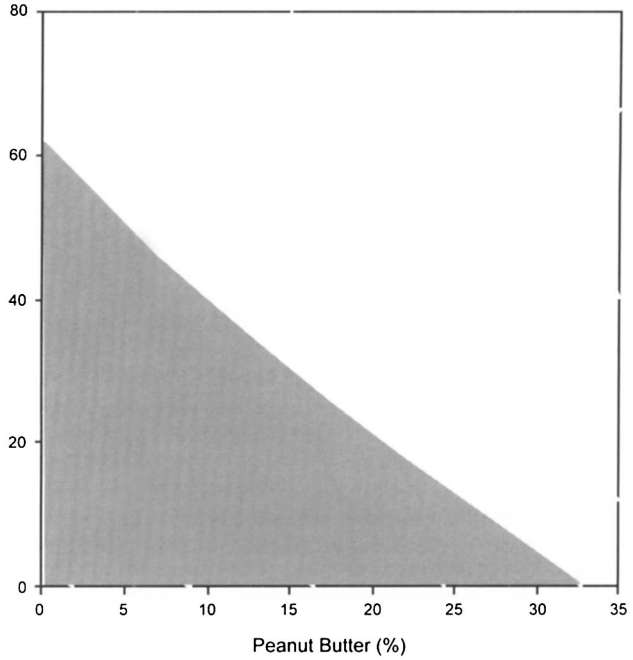

Fig. 6. Optimization area for texture and volume of muffins as a function of peanut flour and peanut butter.

(h° = 74.0 ± 9.35, chroma = 28.6 ± 2.10, L value = 48.7 ± 7.03), indicating that their external color may not be objectionable to consumers.

Color of Inner Crumb. The commercial banana walnut muffins (h° = 92.0 ± 0.55, chroma = 1.9 ± 0.36, L value = 65.4 ± 1.23) were paler yellow (i.e., similar hue but less intense chroma) than the wheat control, but more yellow (much less brown) than the peanut-containing muffins (Table 4). Holt *et al.* (1992) did not observe a significant difference in internal color between their control wheat and experimental peanut muffins.

Predictions for Optimization. External and internal color of the experimental muffins (Tables 1 and 3) fell within a narrower range than that of the commercial banana walnut muffins which were deep brown on the outside but pale yellow on the inside. In the U.S. market, there are a variety of types and colors of commercial muffins that are consumer acceptable. Acceptable colors range from pale yellow [e.g., Otis Spunkmeyer® cheese streudel muffins (upper surface: h° = 99.2 ± 0.59, L value = 70.2 ± 1.99, chroma = 21.1 ± 0.29; inner crumb: h° = 88.1 ± 0.90, L value = 71.0 ± 2.51, chroma = 27.3 ± 3.60)] to very dark brown [e.g., Otis Spunkmeyer® chocolate chocolate-chip muffins (upper surface: h° = 44.4 ± 0.90, L value = 27.4 ± 0.87, chroma = 15.7 ± 0.58; inner crumb: h° = 36.5 ± 1.26, L value = 28.0 ± 0.81, chroma = 10.3 ± 0.62)]. Outer surface and inner crumb colors of the experimental peanut muffins fell within these ranges. Thus, color was not used to set limits for further work.

The range for texture of commercial muffins is wide. Acceptable textures range from 37.2 ± 7.70 kg shear force (e.g., Otis Spunkmeyer® blueberry muffins) through 59.2 ± 2.88 kg (e.g., Otis Spunkmeyer® chocolate chocolate-chip muffins) to 145.1 ± 7.69 kg shear force (e.g., Otis Spunkmeyer® cheese streudel muffins). Texture of all the experimental peanut muffins fell within this range, but the banana nut muffins (50.7 ± 10.5 kg shear force) were selected as the standard for texture because consumers may expect peanut muffins to have similar texture to banana nut muffins.

When nonwheat flours are used in bakery items, texture, and volume are important quality characteristics to monitor (Damodaran, 1996). Thus, Figures 1 and 2 were superimposed to find a common region of interest (shaded area; Fig. 6) in which texture and volume of the experimental peanut muffins would not be significantly different from the controls. Findings indicate that as little as 0-6% PF may be used with 29-32% PB, whereas up to 61% PF may be used with 0% PB (Fig. 6). These findings need to be validated in an optimization study that includes sensory evaluation.

Potential Health Benefits and Peanut Utilization. In addition to varied levels of peanut flour and peanut butter, all the muffins in this study contained fixed quantities of peanut oil and peanut toppings. Thus, formulations at the borders of the region for optimum quality (0% PF + 32% PB to 61% PF + 0% PB; Fig. 6) would contain 30 to 32% peanut materials per weight of total ingredients. The baked muffins would also contain ≤ 18% peanut lipid and thus would provide potential for lowering the risk to cardiovascular disease (Kris-Etherton *et al.*, 1999a). In a previous study in which peanut flour replaced 100% wheat flour and gave rise to appropriate muffin texture, peanut material per weight total ingredients was 25.9% only (Ory and Conkerton, 1983), and all of it was from defatted peanut flour. Thus, findings from this study indicate potential for utilization of a greater percentage of peanuts in a muffin formulation than has been previously reported, and for production of a functional food product by incorporating peanut lipid. The response surface regression predicts that similar quality muffins may be obtained from several combinations of peanut flour and peanut butter. This would facilitate production of value-added products with consistent quality from underutilized peanut flour only, surplus peanut butter only, or any economically feasible combination of peanut flour and peanut butter that falls within the region for optimum quality on Figure 6.

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