Physicochemical and Sensory Properties of Chicken Nuggets Extended with Fermented Cowpea and Peanut Flours

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Physicochemical and sensory properties of chicken nuggets extended with flours processed from fermented cowpeas (FCF) and fermented partially defatted peanuts (FPDPF) were investigated. Addition of FCF or FPDPF decreased moisture loss and fat gain. Reductions in protein content of nuggets were 20.2% and 15.8% when, respectively, 20% FCF and 20% FPDPF were added. Regardless of level of FPDPF, nuggets required relatively lower force and energy to shear compared to control nuggets and nuggets extended with FCF. Nuggets extended with FCF and/or FPDPF had higher *a** and lower *L**, *b**, and hue angle values compared to the control. Color of nuggets containing a mixture of 2.5% FCF and 2.5% FPDPF was similar to the control. Addition of 20% FCF or FPDPF caused flavor of nuggets to be unacceptable. The flavor, texture, and overall liking of nuggets containing 5% flour (2.5% FCF and 2.5% FPDPF) were as acceptable as the control nugget. Results from this study indicate that FCF and FPDPF have potential as extenders in meat systems.

Keywords: *Physicochemical properties; sensory properties; cowpea flour; peanut flour; chicken nuggets; extended meat; fermentation; Rhizopus microsporus var. oligosporus*

INTRODUCTION

Cowpeas (*Vigna unguiculata*) and peanuts (*Arachis hypogaea*) are legumes of major dietary and economic importance (McWatters et al., 1995). Mass production of flour from mature, dry cowpeas involves a simpler technology than that used for oilseed flour production (McWatters, 1990). Because of the low fat content of cowpeas (ca. 1−3%) (Prinyawiwatkul et al., 1996b), the defatting step necessary for production of peanut flour (Prinyawiwatkul et al., 1993a) is not necessary. Like soybean flour, cowpea and partially defatted peanut flours contain high levels of protein (18−35% and 37−38%, respectively), thus representing sources of nutrients and a potential functional ingredient in a wide range of food products (Prinyawiwatkul et al., 1993b, 1994, 1996d).

Modification of cowpea and peanut proteins to further improve their functional and nutritional qualities in food systems has been studied extensively in our laboratory. A simple solid-substrate fermentation using a tempeh mold, *Rhizopus microsporus* var. *oligosporus*, and a milling process for production of flour from peanuts was successfully developed (Prinyawiwatkul et al., 1993a) and modified for cowpeas (Prinyawiwatkul et al., 1996b). We found that fermentation enhanced certain functional properties of partially defatted peanut flour (Prinyawiwatkul et al., 1993a) and greatly affected physicochemical and sensory characteristics of products in which it was incorporated (Prinyawiwatkul et al., 1993b, 1994, 1995). Enhancement of nutritional quality of cowpea flour, including the absence of raffinose and stachyose, increased B-vitamin content, and decreased trypsin inhibitor activity using solid-substrate fermentation has also been demonstrated (Prinyawiwatkul et al., 1996a,c).

Interest in extension of meat products with legume and oilseed derivatives is based primarily on the potential of reducing product cost (McWatters, 1990) while maintaining nutritional and sensory qualities of end products that consumers expect. At present, soybean proteins are the predominant additives for use as fillers, binders, and extenders in meat systems (Ray et al., 1981; Miles et al., 1984). In contrast, nonmeat protein additives derived from cowpeas and peanuts are less common. Partial replacement of meat with cowpea and peanut proteins has been reported (McWatters, 1977; Torgersen and Toledo, 1977; Joseph et al., 1978; Cross and Nichols, 1979; McWatters and Heaton, 1979; Perkins and Toledo, 1982; Beuchat et al., 1992). To date, the use of fermented cowpea or peanut flours as meat extenders has not been reported. As noted by McWatters (1986), successful performance of legume flours as food ingredients depends greatly on the functional properties they impart to the end products. Loss of emulsion properties of fermented cowpea flour as a result of heat treatment during flour preparation (Prinyawiwatkul et al., 1997a) precludes its uses in emulsion-type extended meat products. However, the fat and water binding and heat-induced gelation properties of cowpea and peanut flours (Prinyawiwatkul et al., 1993a, 1997a,b) appear beneficial in other meat applications.

The objective of this study was to investigate physicochemical and sensory properties of chicken nuggets extended with flours processed from fermented cowpeas and fermented partially defatted peanuts.

MATERIALS AND METHODS

Flour Preparation. Mature, dry cowpeas (cv. White Acre) and peanuts (cv. Florunner) were obtained from Southern Frozen Foods, Montezuma, GA, and McClesky Mills, Smithville, GA, respectively. Flours processed from fermented cowpeas (FCF) and fermented partially defatted peanuts (FPDPF) were prepared using the procedures described in previous reports (Prinyawiwatkul et al., 1993a, 1996b). The commercial dried powder starter culture of *R. microsporus* var.

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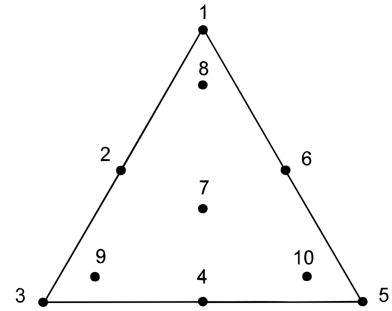
Table 1. Composition of Extended Chicken Nugget Formulations in a Three-Component Constrained Simplex Lattice Mixture Design Evaluated for Physicochemical and Sensory Properties[a]

	ingredient (%)		
formulation number[b]	chicken (*X*1)	FCF (*X*2)	FPDPF (*X*3)
1	100.0	*c*	*c*
2	90.0	10.0	*c*
3	80.0	20.0	*c*
4	80.0	10.0	10.0
5	80.0	*c*	20.0
6	90.0	*c*	10.0
7	87.0	6.5	6.5
8	95.0	2.5	2.5
9	82.5	15.0	2.5
10	82.5	2.5	15.0

[a] FCF = flour processed from fermented cowpeas; FPDPF = flour processed from fermented partially defatted peanuts. The chicken−FCF−FPDPF component (100% in the mixture design) was 84% of the actual formulations. All formulations contained 1% salt, 0.6% garlic powder, 0.4% black pepper, and 14% added water for a total of 100%. [b] Formulation numbers correspond to the numbers shown in Figure 1. [c] 0% of the mixture.

Chicken, X_1

(1.0, 0, 0)



FCF, X_2 (0.8, 0.2, 0)

FPDPF, X_3 (0.8, 0, 0.2)

Figure 1. Constrained region in the simplex coordinate system defined by the following restrictions: $0.8 \leq X1 \leq 1.0$, $0.0 \leq X2 \leq 0.2$, and $0.0 \leq X3 \leq 0.2$. Numbers (1−10) represent ten formulations and correspond to the numbers in Table 1.

oligosporus (tempeh mold) was purchased from Tempeh Lab, Inc., Summertown, TN. Fermentation times for cowpeas and peanuts were 21 and 22 h, respectively.

Chicken Nugget Preparation. Boneless, skinless chicken breasts obtained from Continental Grain Co., Pendergrass, GA, were trimmed of external fat and visible connective tissue and then coarsely ground in a Toledo chopper (model 5120-0-009, Toledo Scale Co., Toledo, OH) equipped with a 9.5-mm-opening disc. Flours prepared from fermented cowpeas and peanuts (FCF and FPDPF) and seasonings (garlic powder, salt, and black pepper) were weighed according to the formulations shown in Table 1, hydrated with tap water, and thoroughly mixed with ground chicken in a mixer (model N-50G, Hobart Mfg. Co., Troy, OH) equipped with a flat beater and operated at a low speed (#1) for 2 min. The chicken mixture was then transferred to a food cutter (model 84142, Hobart Mfg. Co., Troy, OH) and chopped for 30 s to obtain a uniform blend. Half of the mixture from each formulation was stored in Zip-loc freezer bags at 4 °C for further analyses. The other half was weighed to obtain individual nugget pieces (25 ± 1 g per piece), shaped into discs about 1.5-cm thick, and deep-fat fried in soybean oil at 193 °C for 2 min using a Wells automatic fryer (model F-48, Wells Mfg. Co., San Francisco, CA). Fried nuggets were drained on absorbent paper, cooled to room temperature, and used immediately for color, texture, and moisture analyses. Additional nuggets from each treatment were stored in Zip-loc freezer bags at 4 °C for subsequent fat and protein analyses conducted within 5 days. Freshly prepared nuggets were used for the consumer acceptance test.

Moisture, Crude Fat, and Protein Contents. Moisture content (%) was determined using Procedure 950.46a as outlined by AOAC (1995). Moisture loss (%) was calculated as the difference between moisture content of nuggets before and after frying. Crude fat content (%) of moisture-free samples was determined using a Goldfisch extractor (model 3500, Laboratory Construction Co., Kansas City, MO). Fat gain (%) was calculated as the difference between crude fat content of nuggets before and after frying. Nitrogen content was determined using the Kjeldahl method (Triebold and Aurand, 1963). Protein conversion factors of 6.25, 5.46, and 6.25, respectively, for chicken, peanut flour, and cowpea flour (AOAC, 1995) were used to calculate the protein content of various nugget formulations on the basis of percent chicken, cowpea, and peanut flours in respective formulations. Three replications were performed.

Textural Quality. The textural quality of fried chicken nuggets was evaluated in triplicate with the Instron universal testing machine (model 1122, Instron Inc., Canton, MA) equipped with the Warner-Bratzler (straight edge single blade) cell and a 500-kg load cell. The instrument was operated at a cross-head and chart speed of 50 mm/min. Maximum force (N) and energy (J) required to shear an individual nugget (whole piece) were calculated from the force deformation curve.

Color. Colorimetric measurements of fried nuggets (external and internal) were determined in triplicate using a Minolta Colorimeter (model CR-200, Minolta Camera Co., Ltd., Osaka, Japan). The instrument was calibrated with a yellow CR-A47Y standard tile: $L^* = 85.46$, $a^* = -0.13$, and $b^* = 54.58$. Psychometric color terms involving hue angle $[\tan^{-1}(b^*/a^*)]$, chroma $[(a^{*2} + b^{*2})^{1/2}]$, and total color difference, ΔE, $[(L^* - L^*_0)^2 + (a^* - a^*_0)^2 + (b^* - b^*_0)^2]^{1/2}$, where L^*_0, a^*_0, and b^*_0 represent the respective readings of control (all chicken) samples, were computed.

Consumer Acceptance Test. Untrained consumers were recruited from the Griffin, GA, area. Participants (n = 30, 18−65 years of age) were regular consumers of fried chicken products such as chicken fingers, patties, nuggets, or similar products. Consumers were asked to assess acceptability of the appearance, color, flavor, texture/mouthfeel, and overall acceptance (liking) of products using a 9-point hedonic scale (1 = dislike extremely, 5 = neither dislike nor like, and 9 = like extremely). Consumers were asked to evaluate two sets (replications) of samples with a 5-min break after the first set. A balanced incomplete block design (Plan 11.16, $t = 10$, $k = 4$, $r = 6$, $b = 15$, $\lambda = 2$, $E = 0.83$, type III) described by Cochran and Cox (1957) was used. This statistical design allowed each consumer to evaluate four samples out of ten. Each sample was evaluated 24 times (24 consumer responses), and each pair of samples was compared two times.

Statistical and Data Analyses. *Experimental Design.* A three-component constrained simplex lattice mixture design (Cornell, 1983) was used. The mixture components consisted of chicken ($X1$), flour from fermented cowpeas (FCF, $X2$), and flour from fermented partially defatted peanuts (FPDPF, $X3$) which made up 84% of the total formulation. All formulations contained 1% salt, 0.6% garlic powder, 0.4% black pepper, and 14% added water for a total of 100%. The component proportions were expressed as fractions of the mixture and the sum ($X1 + X2 + X3$) of the component proportions equaled 1.0. The practical range of proportions of component variables ($X1$, $X2$, and $X3$) was established (Figure 1 and Table 1) based on preliminary work. Ten mixtures were investigated.

Fitting of Model. Multiple regression analysis (Proc Reg) was used to fit a quadratic canonical polynomial model described by Scheffé (1958) as follows:

$$Y = (\beta 1X1) + (\beta 2X2) + (\beta 3X3) + (\beta 12X1X2) + (\beta 13X1X3) + (\beta 23X2X3)$$

where Y is a predicted physicochemical variable, $\beta 1$, $\beta 2$, $\beta 3$, $\beta 12$, $\beta 13$, and $\beta 23$ are corresponding parameter estimates for each linear and cross-product term, $X1$ = chicken, $X2$ = FCF, and $X3$ = FPDPF. Because of the restriction of the mixture

Table 2. Proximate Composition and Some Physical Properties of Flours Processed from Fermented Cowpeas (FCF) and Fermented Partially Defatted Peanuts (FPDPF)

properties	FCF[a]	FPDPF[b]
water (%)	6.2	7.3
fat (%)	2.0	26.3
protein (%)	28.5	36.9
total dietary fiber (%)	c	2.4
ash (%)	2.8	3.7
carbohydrate (%)[d]	60.5	23.4
pH	6.9	6.5
bulk density (g/cm^3)	0.9 ± 0.01	0.4 ± 0.01
color		
L^*	79.7	80.6
a^*	−1.2	3.7
b^*	20.2	20.6
hue angle	93.4	79.8
chroma	20.2	20.9

[a] Data obtained from Prinyawiwatkul et al. (1996b). [b] Data obtained from Prinyawiwatkul et al. (1993a). [c] Not measured. [d] Calculated by difference.

design ($X1 + X2 + X3 = 1.0$), it is not possible to estimate the intercept and all linear coefficients. Therefore, the regression model is not full rank. The intercept and parameters such as $X1X1$, $X2X2$, and $X3X3$ have been set to zero and thus were not included in the models. Adjusted R^2 was also redefined. Selection of variables was systematically performed based on prob > $|T|$ at a 0.1 level (Ho: $\beta i = 0$) and adjusted R^2 values to finalize and obtain reduced models for prediction of each physicochemical variable. Predictive models were used to generate contour plots.

Analysis of Variance (ANOVA). ANOVA was performed to determine differences in physicochemical and sensory properties among nugget samples. Tukey's studentized range test was performed for post-hoc multiple comparison (SAS, 1988).

RESULTS AND DISCUSSION

Flour Properties. Flour from fermented cowpeas (FCF) contained 2% crude fat, 28.5% protein, and 60.5% carbohydrate (Table 2). Flour from fermented partially defatted peanuts (FPDPF) contained much higher fat (26.3%) and protein (36.9%) contents and lower carbohydrate (23.4%) content than did FCF. FCF had higher bulk density (0.9) than FPDPF (0.4). The pH of FCF and FPDPF was slightly acidic. The color lightness (L^*), yellowness (b^*), and overall intensity (chroma) of FCF and FPDPF were similar. Unlike the color of FCF which was greenish yellow ($a^* = -1.2$, hue angle = 93.4), FPDPF was more brownish yellow ($a^* = 3.7$, hue angle = 79.8). Differences in composition, particularly fat and carbohydrate contents, and density or particle size distribution of FCF and FPDPF would be expected to affect physicochemical and sensory characteristics of chicken nuggets in which the flours would be incorporated.

Moisture, Fat, and Protein Contents. Moisture content of fried chicken nuggets ranged from 55.8% to 62.5% (Table 3). Control nuggets contained higher moisture content than nuggets extended with FCF and/or FPDPF. Reductions in moisture content of control nuggets were as high as 5.8% (from 62.5% to 56.7%) and 6.7% (from 62.5% to 55.8%) when 20% FCF and 20% FPDPF, respectively, were added in the formulations. At the same level of flour addition, nuggets extended with FCF had significantly ($p \leq 0.05$) higher moisture content than nuggets extended with FPDPF. For instance, the nuggets with 20% FCF (formulation #3) contained 56.7% moisture compared to 55.8% of the nuggets with 20% FPDPF (formulation #5). Regression analysis (Table 4) indicates that moisture content of nuggets after frying as influenced by proportions of chicken ($X1$), FCF ($X2$), and FPDPF ($X3$) can be well predicted (adjusted $R^2 = 0.9$). Increasing the amount of FCF and/or FPDPF in the formulations decreased moisture content of nuggets (Figure 2) compared to the control.

One important property of a nonmeat protein intended as a meat additive is the ability to bind water (Brown and Zayas, 1990; Reitmeier and Prusa, 1991). High loss of moisture (13.8%) from the control nuggets occurred during frying. Addition of either FCF or FPDPF to formulations decreased moisture loss, i.e., increased water retention (Table 3 and Figure 2). Higher moisture retention occurred in nuggets extended with FCF compared to nuggets containing the same level of FPDPF. Water absorption capacity of FCF and FPDPF was 2.58 and 0.66 mL/g, respectively (Prinyawiwatkul et al., 1993a, 1997a). The greater ability of FCF to absorb water from chicken meat and added water may have prevented excessive moisture loss during frying. Reduction in moisture loss in formulations supplemented with cowpea or peanut flour is favorable, since it increases the cooking yield. Increased water retention properties and, thus, increased cooking yield of beef patties extended with 5% peanut or cowpea flours have been reported (McWatters and Heaton, 1979).

The fat content of raw chicken nuggets was 1.0−9.2% (data not shown) as compared to commercial nuggets that are usually processed to contain 20% or more fat (Berry, 1994). The actual fat content (%) of all fried nuggets ranged from 6.3% to 16.3% and from 5.3% to 10.6% for fat gain (Table 3). At 10% and 20% flour addition, nuggets containing FPDPF had higher fat content than the control, while nuggets containing FCF had lower fat content. The amount of fat gain (%) by the control nuggets (10.6%) was, however, higher than that of extended nuggets, regardless of the type and amount of added flour. At 10% addition, the fat content in nuggets extended with FPDPF was higher than that in nuggets extended with FCF. The reverse, however, was observed for fat gain. This may have been due to differences in fat binding properties of flour proteins. As noted by Prinyawiwatkul et al. (1993a, 1997a), FCF is capable of absorbing more oil (0.87 mL/g) than is FPDPF (0.64 mL/g) under the same conditions. At 20% addition, fat content and fat gain in nuggets containing FPDPF were higher than observed for nuggets containing FCF. This was likely due to the fat content which is much higher in FPDPF (36.9%) than in FCF (2%) and, to a lesser extent, to the fat binding properties of flour proteins. In general, the fat content in nuggets decreased with increased FCF from 10% to 20% addition but increased with increased FPDPF (Table 3 and Figure 2). From the contour plot (Figure 2), the amount of fat gain, however, tended to decrease with increased FCF or FPDPF, except for nuggets containing 20% FPDPF.

The control nuggets contained 77.7% protein. Ranges of protein content in nuggets extended with only FCF or FPDPF were 57.5−63.4% or 61.9−68.1%, respectively (Table 3). The control nuggets had higher protein content than nuggets extended with FCF and FPDPF, regardless of the addition level. Reductions in protein content of nuggets were as high as 20.2% (from 77.7% to 57.5%) and 15.8% (from 77.7% to 61.9%) when FCF and FPDPF, respectively, were added at the 20% level. Without exception, at the same level of addition, protein

Table 3. Moisture, Fat, and Protein Contents of Chicken Nuggets Extended with Flours from Fermented Cowpeas and Peanuts[a]

formulation number	moisture (%) after frying	moisture (%) loss	fat (%)[b] after frying	fat (%)[b] gain	protein (%) after frying[b]
1	62.5 a (0.1)	13.8 a (0.1)	13.3 c (0.1)	10.6 a (0.2)	77.7 a (0.3)
2	60.6 c (0.1)	9.4 c (0.2)	10.9 f (0.1)	9.3 b (0.1)	63.4 d (1.0)
3	56.7 f (0.1)	7.4 e (0.2)	6.3 h (0.0)	5.3 e (0.0)	57.5 g (0.4)
4	56.3 g (0.0)	8.0 d (0.1)	11.0 f (0.2)	6.7 d (0.3)	59.3 fg (0.4)
5	55.8 h (0.2)	9.1 c (0.1)	16.3 a (0.3)	7.1 d (0.3)	61.9 de (0.2)
6	58.9 d (0.2)	11.6 b (0.4)	14.0 b (0.1)	7.0 d (0.1)	68.1 c (1.0)
7	60.5 c (0.1)	7.8 de (0.2)	11.8 e (0.1)	7.9 c (0.1)	62.8 d (0.7)
8	61.2 b (0.1)	11.8 b (0.2)	12.6 d (0.2)	8.9 b (0.2)	72.4 b (0.4)
9	59.0 d (0.1)	6.7 f (0.1)	7.1 g (0.1)	5.5 e (0.1)	60.0 ef (0.6)
10	58.4 e (0.1)	7.8 de (0.2)	13.4 c (0.1)	5.6 e (0.1)	63.6 d (1.1)

[a] Numbers in parentheses refer to standard deviation of three measurements. Mean values in the same column not followed by the same letter are significantly different ($p \leq 0.05$). Formulation numbers correspond to the numbers in Figure 1 and Table 1. [b] Dry weight basis.

Table 4. Full and Reduced Quadratic Canonical Polynomials for Each of Dependent Physicochemical Properties of Chicken Nuggets Containing Proportions of Chicken (*X*1), Cowpea Flour (FCF, *X*2), and Peanut Flour (FPDPF, *X*3)[a]

dependent variable	predictive model	R^2 adjusted
moisture		
after frying	$62.33X1 - 97.15X2 + 31.79X3 + 164.56X1X2 + 76.95X2X3$	0.90
loss	$13.88X1 + 132.62X2 - 12.11X3 - 189.32X1X2 - 98.01X2X3$	0.90
fat		
after frying	$13.39X1 - 88.58X2 + 112.58X3 + 81.1X1X2 - 106.56X1X3 - 62.43X2X3$	0.97
gain	$10.59X1 - 112.16X2 + 149.58X3 + 119.25X1X2 - 196.69X1X3$	0.88
protein	$78.02X1 + 303.80X2 + 124.11X3 - 409.68X1X2 - 157.31X1X3$	0.98
peak force	$104.86X1 + 31.85X2 + 911.48X3 - 1276.53X1X3 + 590.58X2X3$	0.82
energy[b]		
A	$834.28X1 + 1278.05X2 + 5348.75X3 - 7083.99X1X3 + 4013.03X2X3$	0.86
B	$1219.26X1 + 1422.66X2 - 786X3 + 5764.32X2X3$	0.82
external color		
L^*	$52.05X1 + 390.65X2 - 16.37X3 - 475.90X1X2$	0.90
a^*	$12.68X1 - 243.68X2 - 214.07X3 + 368.23X1X2 + 330.21X1X3$	0.95
b^*	$35.48X1 + 7.78X2 - 222.34X3 + 265.22X1X3$	0.90
hue angle	$70.42X1 + 415.55X2 + 133.37X3 - 521.35X1X2 - 189.73X1X3$	0.95
chroma	$38.25X1 + 30.85X2 - 262.15X3 + 343.56X1X3$	0.83
ΔE	$1.15X1 - 407.5X2 + 90.73X3 + 586.18X1X2$	0.93

[a] Based on 30 observations. R^2 adjusted $= 1 - [\{(n - i)(1 - R^2)\}/(n - p)]$, where $i = 0$ for a non-intercept regression model, $n =$ the number of observations used to fit the model, and $p =$ the number of parameters in the model (SAS, 1988). [b] See footnote *c* in Table 5.

contents of nuggets extended with FPDPF were higher than those of nuggets extended with FCF. This was due to the higher protein content of FPDPF compared to FCF.

The addition of either FCF or FPDPF to nugget formulations decreased protein content of the products (Figure 2). According to the U.S. 9CFR 319 (*Code of Federal Regulations*, title 9, part 319, as of January 1, 1996), protein additives in meat systems are limited to those containing a minimum protein content of 25% (*Code of Federal Regulations*, 1996). FCF (28.5% protein) and FPDPF (36.9% protein) meet this requirement. If protein additives are intended for use solely to increase the protein content of an extended meat product such as chicken nuggets as in this study, cowpea protein isolate may better serve as a protein supplement because of its high protein (91%) content (Letourneau, 1996). However, if the use of cowpea or peanut flours as meat extenders is to reduce cost, then application of further processed flour to obtain isolates would rule out this advantage.

Textural Quality. The texture of nuggets was influenced by the presence of FCF and FPDPF. The amounts of force and energy (A and B) required to shear the control samples were not significantly different from those for nuggets containing 10% FCF. Nuggets containing 20% FCF, however, required less force to shear than did the control. Nuggets containing 10% FPDPF flour required less force and energy (A and B) to shear than did the control and nuggets containing 10% FCF (Table 5). Ground beef patties extended with up to 15% defatted peanut flour or cowpea flour have been reported to be more tender, requiring less force to shear-compress than control patties (McWatters, 1977; McWatters and Heaton, 1979). Regardless of the level of flour addition, nuggets containing only FPDPF required relatively less force and energy to shear than control nuggets or nuggets extended with only FCF (Figure 3).

Warner-Bratzler shear force and energy values were used as indicators of resistance to shearing; a lower value indicates more tenderness (Tinney et al., 1995). Results shown in Table 5 and Figure 3 indicate that

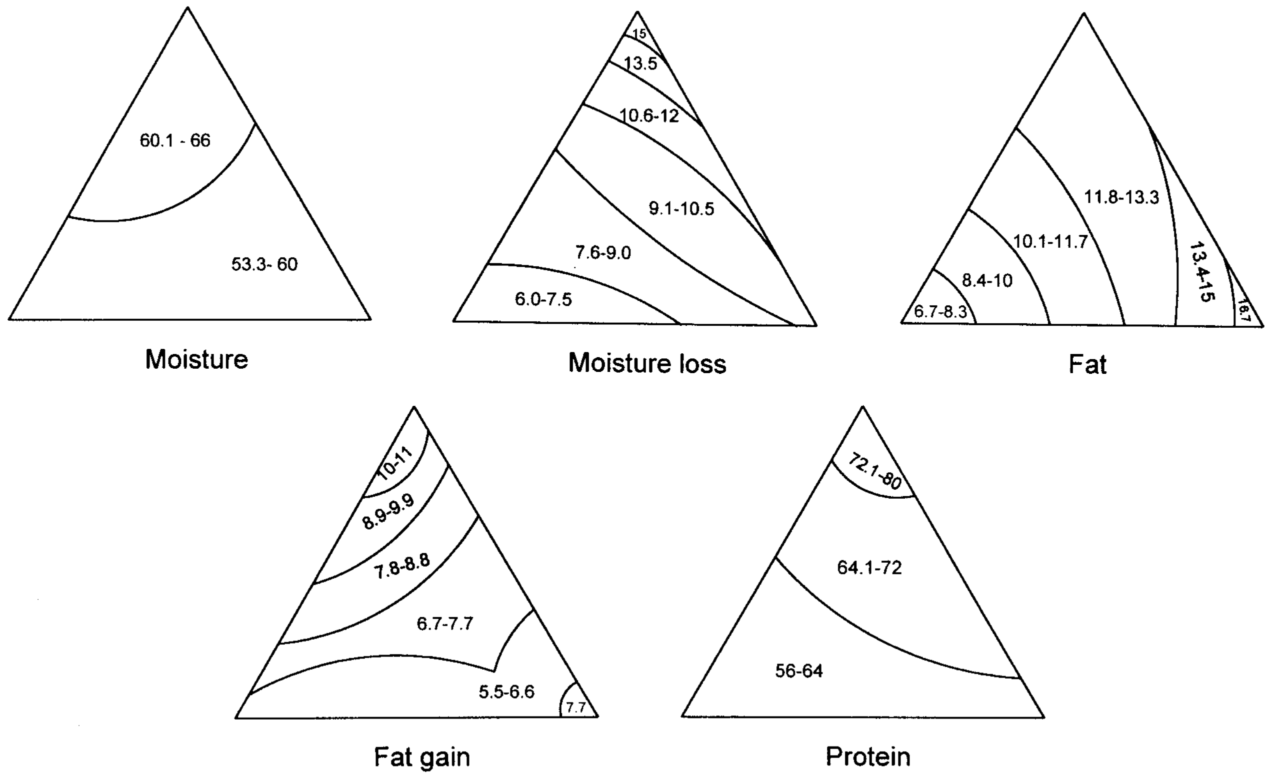


Figure 2. Contour plots for predicted moisture, fat, and protein contents of chicken nuggets extended with flours from fermented cowpeas and peanuts. See Figure 1 for coordinate points (*X*1, *X*2, *X*3) and formulation numbers.

Table 5. Texture Characteristics of Chicken Nuggets Extended with Flours from Fermented Cowpeas and Peanuts[a]

		energy ($\times 10^{-3}$ J)[c]	
formulation number[b]	peak force (N)	A	B
1	106.8 a (3.6)	842.4 ab (60.8)	1244.7 a (67.1)
2	93.0 ab (5.9)	848.8 ab (24.5)	1193.0 a (29.2)
3	88.1 bc (7.6)	923.2 a (17.3)	1258.1 a (52.0)
4	77.8 cd (0.7)	798.7 b (50.5)	1077.7 ab (73.2)
5	63.9 d (8.6)	618.5 c (5.8)	850.9 c (14.7)
6	69.0 d (2.4)	648.2 c (58.4)	974.4 bc (101.0)
7	89.1 bc (1.9)	792.4 b (45.0)	1161.4 a (59.2)
8	91.2 bc (6.5)	794.1 b (51.0)	1186.5 a (80.2)
9	96.7 ab (2.7)	901.6 ab (49.1)	1254.7 a (66.7)
10	66.1 d (3.9)	632.6 c (19.6)	921.6 bc (41.0)

[a] Numbers in parentheses refer to standard deviation of three measurements. Mean values in the same column not followed by the same letter are significantly different ($p \leq 0.05$). [b] Formulation numbers correspond to the numbers in Figure 1 and Table 1. [c] Energy was calculated based on (A) partial curve area (from the starting point to the second peak height) and (B) total curve area.

textural quality was greatly affected by FPDPF and, to a lesser extent, FCF added to nugget formulations. Changes in textural quality of extended nuggets could be influenced by the binding properties of myofibrillar proteins or by the ability of FCF and FPDPF to bind water, fat, and meat pieces during preparation and frying. The ability of protein additives to retain water and bind fat has been reported to govern texture, juiciness, and structural binding characteristics of extended meat products (Rocha-Garza and Zayas, 1995). Increased juiciness of extended meats is largely due to moisture retention rather than to fat binding properties (Anderson and Lind, 1975; Drake et al., 1975). Brown and Zayas (1990), however, noted that the degree of juiciness of beef patties perceived by consumers was due to increased retention of fat rather than water. In this study, the softer or more tender texture of nuggets containing 20% FPDPF, compared with nuggets containing 20% FCF, is attributed more to the amount of fat in the formulation and fat binding properties than to water binding properties of FPDPF proteins. Fat softens meat products and makes them more tender (Rakosky, 1970). Higher tenderness and juiciness associated with higher fat levels in extended beef patties have been reported (Berry and Leddy, 1984).

The tougher texture of nuggets containing 20% FCF, compared with nuggets containing 20% FPDPF, is associated with the available water in the nuggets and water binding properties of the FCF proteins. Binders or extenders may be used without added water or with added water only in amounts that would result in desirable product characteristics (Rakosky, 1989). Added water was reported to cause a softening effect on the texture of pork nuggets (Berry, 1994). In our study, the added water was held constant at 14% for all formulations. When there is a water restriction, performance of protein additives may be minimal because the need for water to manifest functionality may not be satisfied. When this happens, the resulting product will be somewhat dry and tough as was the case of nuggets with 20% FCF observed in this study. Nonprotein components such as carbohydrates (starches and polysaccharides) possess good hydration and meat-binding properties (Gnanasambandam and Zayas, 1994). High carbohydate content (60.5%) of FCF may have also contributed to textural changes of nuggets, as also

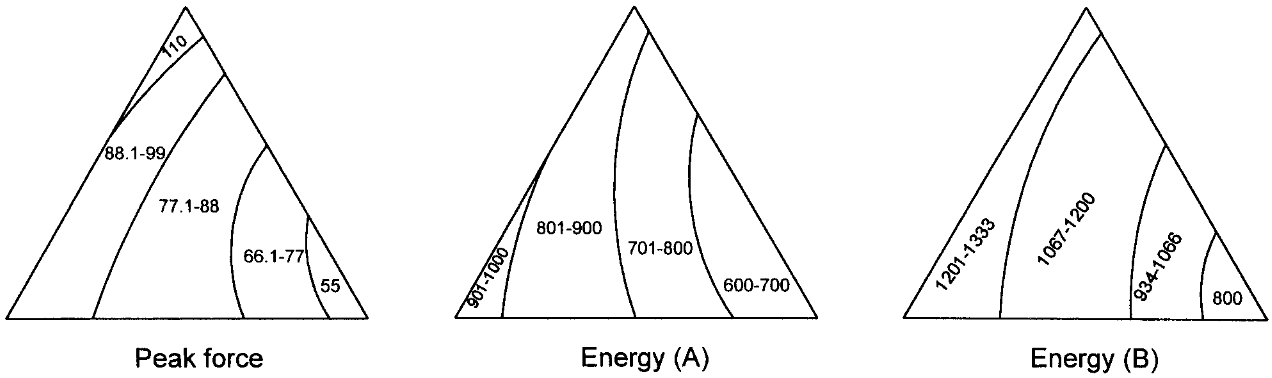


Figure 3. Contour plots for predicted peak force and energy needed to shear chicken nuggets extended with flours from fermented cowpeas and peanuts. See Figure 1 for coordinate points (*X*1, *X*2, *X*3) and formulation numbers. See footnote *c* in Table 5 for definitions of A and B.

Table 6. External Color of Fried Chicken Nuggets Extended with Flours from Fermented Cowpeas and Peanuts[a]

formulation	L^*	a^*	b^*	hue angle	chroma	ΔE
1	52.8 a	12.4 c	35.6 a	70.9 a	37.7 abc	0.0 f
	(0.2)	(0.8)	(0.4)	(1.1)	(0.6)	-
2	42.2 cde	20.5 a	31.9 cd	57.3 cde	37.9 abc	13.8 cd
	(0.5)	(0.2)	(0.7)	(0.7)	(0.5)	(0.2)
3	43.4 cd	20.4 a	30.3 de	56.1 cdef	36.5 bcd	13.5 cd
	(0.8)	(0.0)	(1.2)	(1.1)	(1.0)	(0.9)
4	40.2 ef	20.6 a	28.0 ef	53.6 fg	34.8 de	16.9 ab
	(0.7)	(0.2)	(1.1)	(0.8)	(0.9)	(0.6)
5	38.4 f	20.1 a	26.4 f	52.7 g	33.2 e	18.8 a
	(0.3)	(0.4)	(0.8)	(0.3)	(0.9)	(0.2)
6	43.9 c	19.9 a	33.2 abc	59.0 c	38.7 ab	12.0 d
	(1.1)	(0.1)	(0.9)	(0.7)	(0.8)	(1.0)
7	44.3 c	19.9 a	32.6 bcd	58.5 cd	38.2 ab	11.8 d
	(1.5)	(0.6)	(1.9)	(2.1)	(1.3)	(1.8)
8	47.0 b	17.7 b	35.0 ab	63.1 b	39.2 a	7.9 e
	(1.5)	(0.4)	(0.8)	(1.0)	(0.6)	(1.4)
9	42.9 cd	20.7 a	30.2 de	55.6 defg	36.6 bcd	14.0 cd
	(0.0)	(0.3)	(0.2)	(0.4)	(0.2)	(0.2)
10	41.1 de	20.7 a	28.9 ef	54.4 efg	35.6 cde	15.8 bc
	(1.3)	(0.5)	(0.8)	(1.0)	(0.7)	(1.2)

[a] Numbers in parentheses refer to standard deviation of three measurements. Mean values for external and/or internal color in the same column not followed by the same letter are significantly different ($p \leq 0.05$). Formulation numbers correspond to the numbers shown in Figure 1 and Table 1.

observed in beef patties and frankfurters extended with corn/wheat germ protein flours (Brown and Zayas, 1990; Gnanasambandam and Zayas, 1994; Rocha-Garza and Zayas, 1995).

Color. Data for external color of the control nuggets and extended nuggets are presented in Table 6 and Figure 4. For external color, the control nuggets were significantly lighter (higher L^*) than nuggets containing FCF and/or FPDPF. Nuggets containing 20% FPDPF had the lowest L^* value (38.4) compared to that of the control (52.8). All extended nuggets had higher a^* (redness) values than that of the control sample, regardless of the type and amount of added flour. Addition of FCF and FPDPF up to 20% to formulations decreased color yellowness (b^*), compared with the control. The lowest b^* value was observed for nuggets containing 20% FPDPF. The marked increase in ΔE (total color difference) of nuggets containing 20% FPDPF is attributed to low L^* and b^* values. Only slight differences in total color (ΔE) were observed as the amount of FCF in nugget formulations was increased from 10% to 20%. Color of nuggets containing 5% flour (formulation #8, 2.5% FCF and 2.5% FPDPF) was least different from the control as indicated by the lowest ΔE. Furthermore, its color was lighter (higher L^*), less red (lower a^*), and more yellow (higher b^* and hue angle) than all other extended nuggets.

Hue angle values of all nuggets were lower than 90°. Angles of 0° and 90°, respectively, represent red and yellow hues, and nuggets with an angle between 0° and 90° are toward orange-red (Prinyawiwatkul et al., 1994). Addition of FCF and FPDPF to nugget formulations resulted in lower hue angles for the external surface color compared to the control. As the amount of FCF and FPDPF increased, a more intense orange-brown color was observed. Addition of up to 20% FPDPF caused the external color of nuggets to become dark brown (lowest L^*, b^*, and hue angle). Nuggets extended with FPDPF browned more during cooking than control nuggets and nuggets extended with FCF. Few changes in chroma (saturation) occurred, although some significant differences were observed in nuggets extended with FCF and FPDPF. The lowest chroma value (33.2) of nuggets containing 20% FPDPF was due primarily to the lowest b^* value.

Consumer Acceptance. Results from physical and chemical analyses indicate that it is possible to extend chicken nuggets with up to 20% FCF and/or FPDPF. Knowledge of consumer attitudes toward extended nuggets is needed, since it is pointless to develop a product which is unacceptable on the basis of sensory quality and, therefore, would not be consumed. Although results from consumer studies are highly subjective as compared to physicochemical measurements, sensory information is very useful for further product improvement and larger-scale production. Mean con-

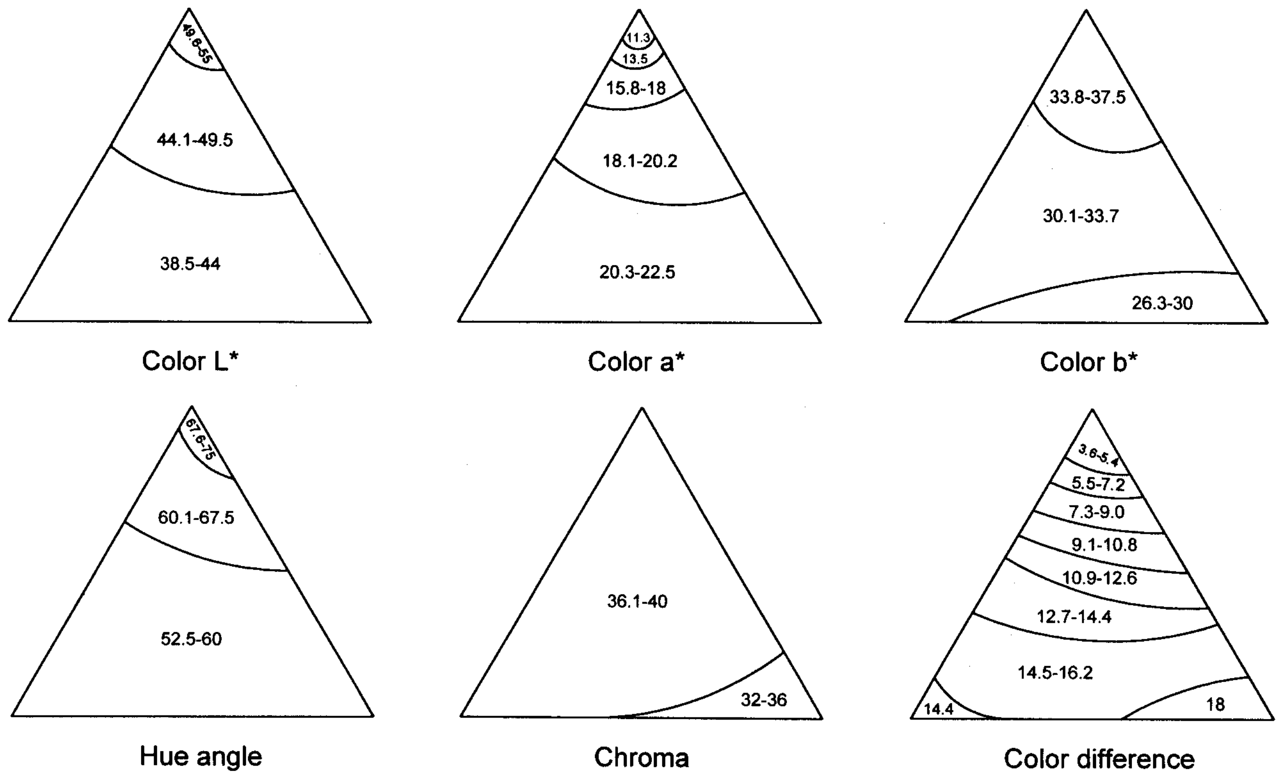


Figure 4. Contour plots for predicted external color L^*, a^*, b^*, hue angle, chroma, and total color difference (ΔE) of chicken nuggets extended with flours from fermented cowpeas and peanuts. See Figure 1 for coordinate points ($X1$, $X2$, $X3$) and formulation numbers.

Table 7. Mean Consumer Scores for Acceptability of Appearance, Color, Flavor, Texture/Mouthfeel, and Overall Acceptance (Liking) of Chicken Nuggets Extended with Flours from Fermented Cowpeas and Peanuts[a]

	acceptability score				
number[b]	appearance	color	flavor	texture	overall liking
1	7.2 a (1.4)	7.4 a (1.0)	6.8 a (1.3)	6.5 a (1.4)	6.8 a (1.3)
2	7.3 a (1.1)	7.5 a (1.1)	5.8 abc (1.9)	5.4 ab (2.1)	5.5 abcd (2.2)
3	5.2 b (1.9)	5.6 b (1.7)	4.0 d (1.8)	3.7 c (1.7)	4.1 d (1.9)
4	6.5 ab (1.5)	6.8 ab (1.5)	4.8 bcd (1.9)	5.1 abc (2.0)	4.7 bcd (2.2)
5	6.2 ab (1.9)	6.8 ab (1.5)	4.7 cd (1.6)	5.2 abc (2.2)	4.9 bcd (1.8)
6	7.0 a (1.0)	7.0 a (1.3)	5.5 abcd (1.6)	6.2 a (1.7)	5.8 abc (1.5)
7	6.8 a (1.5)	6.9 a (1.5)	5.0 bcd (2.0)	5.3 abc (2.0)	5.1 bcd (2.0)
8	6.8 a (1.3)	6.8 ab (1.6)	6.3 ab (1.7)	6.7 a (1.4)	6.3 ab (1.6)
9	6.0 ab (1.9)	6.6 ab (1.4)	4.7 cd (1.9)	4.4 bc (1.8)	4.3 cd (1.9)
10	6.9 a (1.7)	7.2 a (1.2)	5.3 abcd (1.7)	6.2 a (1.2)	5.7 abcd (1.6)

[a] Numbers in parentheses refer to standard deviation of 24 consumer responses. A 9-point hedonic scale was used (1 = dislike extremely, 5 = neither like nor dislike, and 9 = like extremely). Mean values in the same column not followed by the same letter are significantly different ($p \leq 0.05$). [b] Formulation numbers correspond to the numbers shown in Figure 1 and Table 1.

sumer acceptability scores for nuggets are presented in Table 7. Appearance acceptability scores for extended nuggets, excluding nuggets containing 20% FCF, ranged from 6.0 (like slightly on the 9-point hedonic scale) to 7.3 (like moderately). The lowest appearance acceptability score (5.2) observed for nuggets containing 20% FCF may have been due to the particle size of FCF. As noted by Cardello et al. (1983), both color and particle size of protein ingredients affect visual and textural appearance of extended beef patties. Although FCF particles were uniformly dispersed and suitably small to allow good binding of water, fat, and chicken pieces during nugget preparation, particles were large enough to be discernible at the surface and in the interior of nuggets. Visual observation indicated that extended nuggets had a smooth outer surface and less shrinkage compared to the 100% chicken nugget. The smooth surface was not a characteristic expected by consumers. Shrinkage and an unsmooth surface of control nuggets after frying did not adversely affect the appearance acceptability as indicated by a mean score of 7.2 (like moderately).

Color acceptability scores for the control nuggets and extended nuggets (excluding nuggets with 20% FCF) were 7.4 and 6.6−7.5, respectively (Table 7). As pointed out by Blouin et al. (1981), color is probably the first characteristic of a food to be observed by consumers. In many cases, the quality of a food is judged according to its color based on consumers' expectations. The flour additives ranged in color from light yellow to light brown. These colors may or may not be undesirable depending on their influence when added to formulations. Consumers described the color of nuggets extended with 10% FCF as golden brown, which is a typical and desirable color for fried chicken products. Like the appearance acceptability, color acceptability of nuggets containing 20% FCF received the lowest score (5.6), yet was still considered acceptable on the 9-point hedonic scale.

Undesirable flavor associated with the characteristic raw-beany flavor of FCF and FPDPF is eliminated during flour preparation and fermentation (Prinyawiwatkul et al., 1993a, 1996b). The flavor of FPDPF has been described as soy sauce-like and meat-like compared to the mild, nut-like flavor of FCF (Prinyawiwatkul et al., 1993a, 1996b). Flavor acceptability of the control nuggets scored 6.8 and was influenced greatly by the addition of FCF and FPDPF (Table 7). Among extended products, nuggets from formulation #8 (2.5% FCF and 2.5% FPDPF) received the highest score for flavor (6.3); this product was characterized as having a sweet, chickeny flavor similar to that of the control nugget. A high incidence of sweet flavor in patties containing soy flour was attributed to carbohydrates in the flour (Berry et al., 1985). Although addition of 10% FCF or FPDPF to formulations decreased the flavor acceptability score, the flavor was still acceptable (score $\geq$5.5). Addition of 20% FCF or FPDPF caused flavor of the products to be unacceptable (score <5.0). Some consumers described the flavor of nuggets extended with 20% FPDPF as resembling spiced, seasoned, sour sausage; others noted that the product had a nut-like, hay-like, or peanut-shell flavor. The hay-like and sour flavors were undoubtedly objectionable to consumers. The nugget containing 20% FCF was described as mild, bland, or tasteless. Whenever additives, binders, and extenders are used, meat flavor is diluted. This is especially apparent when protein additives are bland in flavor.

Texture has been identified as the second most readily noticed sensory property of foods (Rakosky, 1989). There is an obvious limit to how much FCF and FPDPF can be added to nugget formulations. The water/fat availability and binding properties of FCF and FPDPF evidently influenced textural differences of nuggets that could be readily discerned by consumers. The texture of nuggets containing 5% flour (2.5% FCF and 2.5% FPDPF) was as acceptable as the control nuggets. Nuggets containing 10% FPDPF had a texture acceptability score (6.2) equal to that of nuggets containing a mixture of 15% FPDPF and 2.5% FCF. Consumers described the texture of nuggets extended with FPDPF as moist, juicy, and tender but lacking the typical chunkiness of chicken nugget products. Addition of 20% FCF to formulations caused the texture to be tough and dry, resulting in an unacceptable score of 3.7 (dislike slightly). The overall product acceptance (liking) scores of nuggets extended with more than 5% flour ranged from 4.1 to 5.8 compared to 6.8 for control nuggets. Among extended products, the nugget containing a mixture of 2.5% FCF and 2.5% FPDPF was most acceptable with an overall liking score of 6.3 (like slightly).

In summary, this study has demonstrated that flours from fermented cowpeas (FCF) and fermented partially defatted peanuts (FPDPF) can be incorporated, with regard to processing practices, at a level up to 20% in a chicken nugget formulation. Partial replacement of chicken meat with FCF or FPDPF, or in combination, affected physicochemical and sensory characteristics of nuggets, depending on the level of addition. The ability of FCF and FPDPF to bind water, fat, and meat pieces during preparation and frying is the key factor affecting moisture loss, fat gain, and texture of extended nuggets. Flavor and texture of extended nuggets as affected by amount of FCF and FPDPF added to formulations influenced the overall acceptance (liking) of the products. The flavor, texture, and overall liking of nuggets containing a mixture of 2.5% FCF and 2.5% FPDPF were as acceptable as the control nuggets. A large-scale consumer test is needed to confirm the results obtained in this study and to acquire more information concerning consumer attitudes toward this new product.

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