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Physical Properties of Cowpea Paste and Akara As Affected by Supplementation with Peanut Flour

Witoon Prinyawiwatkul, Kay H. McWatters,* Larry R. Beuchat, and R. Dixon Phillips

Center for Food Safety and Quality Enhancement, Department of Food Science and Technology,
University of Georgia, Griffin, Georgia 30223-1797

Changes in the physical properties of cowpea paste and akara as influenced by the addition of partially defatted nonfermented (PDPF) and fermented (FPDPF) peanut flour were investigated. PDPF and FPDPF decreased the water absorption capacity of cowpea meal and increased the specific gravity and lowered the volume of whipped pastes. The apparent viscosity of pastes was influenced by increasing levels of peanut flour, increasing with PDPF and decreasing with FPDPF. The external color L^* and b^* values of akara containing only cowpea meal were higher than those of akara containing peanut flour. Akara containing PDPF (50%) and FPDPF (12.5 and 25.0%) required more force and energy to shear-compress than unsupplemented akara. Increased protein and decreased oil content were observed in akara containing peanut flour.

Keywords: *Cowpea flour; peanut flour; physical properties; akara*

INTRODUCTION

Cowpeas (*Vigna unguiculata* L.) are an important grain legume in East and West Africa (Dovlo et al., 1976; McWatters, 1983; Hung et al., 1990) and are consumed almost daily as steamed (moin-moin) and fried (akara) foods (Phillips et al., 1988). Akara is made from whipped cowpea paste flavored with salt, fresh onion, and fresh hot or bell pepper (Dovlo et al., 1976; McWatters et al., 1990, 1991, 1992). The batter is dropped by spoonful portions into hot oil and forms spongy balls during frying. Traditional methods employed in the preparation of cowpea paste are time-consuming and labor-intensive (Nnanna et al., 1990).

Recent efforts have resulted in development of technologies for producing ready-to-use cowpea meal and flour specifically for use in akara and moin-moin (Ngoddy et al., 1986; McWatters et al., 1988; McWatters, 1990). Williams (1980) recommended that cowpea meal with an intermediate particle size between flour and grits would be more appropriate than cowpea flour for making akara. To prepare cowpea meal, soaking and dehulling may not be necessary, provided that cowpea cultivars with a light-colored seed coat and little pigmentation in the hilum are employed. Meal prepared from Dixiecream cowpeas, for example, can be used to make akara with sensory qualities equally acceptable to that made by traditional procedures (McWatters and Brantley, 1982; McWatters and Flora, 1980).

In many countries, peanuts are considered as an oilseed crop grown primarily for oil production. Oil extraction results in a protein-rich peanut press cake as a byproduct, which is usually not used for human food but rather for animal feed. Peanut press cake, however, can be used for human food in the form of peanut flour if it is processed from edible-grade peanuts under sanitary conditions. Peanut flour, like soybean flour, contains a relatively high protein content; it has a bland flavor and light tan color which facilitate its incorporation into a wide range of food products (Prinyawiwatkul, 1992). Modification of peanut proteins to improve their functionality in food systems has been studied extensively in our laboratory. We have observed that fungal fermentation (*Rhizopus microsporus* var. *oligosporus*) enhanced certain functional properties of partially defatted peanut flour (Prinyawiwatkul et al., 1993b) and greatly affected the sensory characteristics of a product in which it was incorporated (Prinyawiwatkul et al., 1993a).

Table 1. Cumulative Percentage of Particles Larger than Sieve Mesh Sizes for Cowpea Meal[a]

sieve			
mesh no.	opening (mm)	percentage[b]	cumulative percentage
400	0.037	5.65 (0.96)	96.47
200	0.074	8.56 (1.05)	90.82
140	0.105	5.47 (0.43)	82.26
100	0.149	4.20 (0.14)	76.79
80	0.177	8.18 (0.22)	72.59
60	0.250	4.85 (0.05)	64.41
50	0.297	19.47 (0.06)	59.56
40	0.420	20.82 (0.08)	40.09
30	0.595	19.27 (0.35)	19.27

[a] Loss of meal particles to the sieve and as dust accounted for the difference between the cumulative percentage at mesh size 400 and 100%. [b] Numbers in parentheses refer to standard deviations of three replicates.

Changes in physical properties of cowpea paste would affect the overall quality of akara. The objective of the investigation reported here was to determine the effects of peanut flour supplementation on selected physical properties of cowpea paste and akara (fried cowpea paste) prepared from premilled cowpea meal.

MATERIALS AND METHODS

Preparation of Cowpea Meal and Peanut Flour. Texas Cream 12 cowpeas (*V. unguiculata*) obtained from Texas Foundation Seed Service, Texas Agricultural Experiment Station, Vernon, TX, were used to prepare cowpea meal. Cowpea seeds were ground in a Champion hammer mill (Model 6X14, Eden Prairie, MN) equipped with a 1.6-mm-opening screen and stored at −18 °C until used. The particle size distribution of cowpea meal determined according to ASAE standard (ASAE, 1983) is given in Table 1. Approximately 40% of the cowpea meal had a smaller particle size than the

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* Author to whom correspondence should be addressed [telephone (404) 412-4737; e-mail FOODGRF-@GAES.GRIFFIN.PEACHNET.EDU].

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no. 50 mesh sieve. Proximate composition of cowpea meal was 12.4% moisture, 1.1% fat (dry basis), and 25.4% protein (dry basis).

Peanuts (Florunner, medium, 1991 crop) obtained from McCleskey Mills, Smithville, GA, were used to prepare partially defatted, nonfermented peanut flour (PDPF) and partially defatted, fermented peanut flour (FPDPF) using the procedure described in a previous study (Prinyawiwatkul et al., 1993b). Proximate compositions of PDPF and FPDPF were, respectively, 7.4 and 7.0% moisture, 28.6 and 26.4% fat (dry basis), and 38.4 and 37.0% protein (dry basis).

Preparation of Cowpea Paste and Akara. Cowpea meal supplemented with peanut flour, PDPF or FPDPF, at 0 (control), 12.5, 25.0, 37.5, and 50.0% (dry basis) was mixed in a gallon jar on a Ball mill (Norton Chemical Process Products, Akron, OH) for 10 min. The preparation of paste and akara was done according to procedures described by McWatters et al. (1990, 1991). Paste was prepared by adding predetermined amounts of water to 200-g portions of cowpea meal, with or without peanut flour, to adjust the moisture content to 58%. Preliminary work had shown that a water content below 58% or above 60% produced pastes (control) with poor flow characteristics which were not appropriate for akara-making. Unseasoned (not containing salt, pepper, and onion) whipped pastes were used for physical evaluations. Immediately after 2 min of deep-frying, akara balls were drained on absorbent paper and cooled to room temperature. Half of the balls from each treatment were then subjected to textural quality and colorimetric evaluations. The other half were packaged in heavy-duty freezer bags, sealed, and stored at −18 °C for subsequent analyses.

Water Absorption of Cowpea Meal and Peanut Flour Blends. Cowpea meal and peanut flour blends (2.0 g, S) were thoroughly combined with 20 mL of distilled water in 50-mL centrifugal tubes. After 1 h of intermittent stirring at 25 °C, the slurry was centrifuged at 18900g for 30 min at 25 °C. The wet pellet (WS) was weighed and freeze-dried for 12 h, and the weight of dry sample (DS) was determined. The proportion of water absorbed was expressed as (1) apparent water absorption [$WA_a = (WS - S)/S$] and (2) true water absorption [$WA_t = (WS - DS)/DS$]. Four replicates were performed for each treatment.

Specific Gravity and Foaming Capacity. The specific gravity of whipped pastes was determined in quadruplicate according to the method of Campbell et al. (1979). The foaming capacity of pastes, expressed as total paste volume (milliliters), was measured in quadruplicate with a pharmaceutical cylinder.

Apparent Viscosity. The flow behavior of whipped pastes was determined at 25 °C using a Brookfield digital viscometer (Model HATD, Brookfield Engineering Laboratories, Inc., Stoughton, MA), equipped with a no. 27 spindle. The sample chamber was filled with approximately 15 mL of paste using a syringe. Apparent viscosity at any specific shear rate was calculated from two equations ($\tau = \tau_0 + k\dot{\gamma}^n$ and $\eta_a = \tau/\dot{\gamma}$), where τ is the shear stress (Pa), τ_0 is the yield stress (Pa), k is the flow consistency index (Pa·s^n), $\dot{\gamma}$ is the shear rate (s^{-1}), n is the flow behavior index (dimensionless), and η_a is the apparent viscosity (Pa·s).

Color Evaluation. Colorimetric measurements of whipped pastes and akara balls (external and internal) were determined as previously described (McWatters et al., 1988). Measurements were recorded using a Gardner XL-800 tristimulus colorimeter (Pacific Scientific, Bethesda, MD) equipped with an XL-845 circumferential sensor. The instrument was calibrated with a yellow standard tile ($L^* = 83.52$, $a^* = -2.26$, $b^* = 28.45$). Surface color differences were minimized by reporting an average of eight readings per paste sample and akara ball from each treatment and replication. Psychometric color terms involving hue angle [$\tan^{-1}(b^*/a^*)$], chroma [$(a^{*2} + b^{*2})^{1/2}$], and total color difference [$[(L^* - L^*_0)^2 + (a^* - a^*_0)^2 + (b^* - b^*_0)^2]^{1/2}$], where L^*_0, a^*_0, and b^*_0 represent the respective readings of control samples, were computed.

Textural Quality. The textural quality of akara balls was evaluated with the Instron universal testing machine (Model 1122, Instron Inc., Canton, MA) equipped with the Kramer shear-compression cell and a 500-kg load cell. The instrument was operated at a cross-head and chart speeds of 100 and 200 mm/min, respectively. The weight of each individual akara ball was recorded. Maximum force (N) and energy (10^{-3} J) per unit sample mass (g) required to shear-compress an akara ball were calculated from the force deformation curve. Six akara balls were measured individually for each treatment and replication.

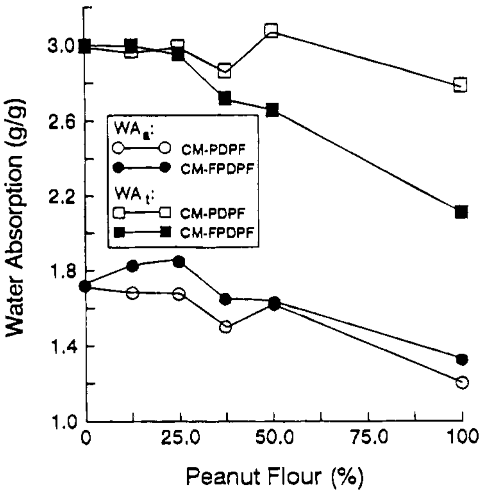

Figure 1. Effect of peanut flour supplementation of cowpea meal on the apparent (WA_a) and true (WA_t) water absorption capacity. CM, cowpea meal; PDPF, partially defatted nonfermented peanut flour; FPDPF, partially defatted fermented peanut flour.

Proximate Composition. Moisture content was determined using Procedure 14.004 as outlined by the AOAC (1984). Nitrogen content was determined using the Kjeldahl method (Triebold and Aurand, 1963). Protein conversion factors of 5.46 and 6.25, respectively, for peanut flours and cowpea meal (AOAC, 1984) were used to calculate the protein content of various akara formulations on the basis of percent cowpea meal and peanut flour in the respective formulations. Oil content of moisture-free samples was determined using a Goldfisch extractor (Model 3500, Laboratory Construction Co., Kansas City, MO). The amount of oil absorbed was calculated as the difference between oil content of the product before and after deep-frying. Three measurements for each treatment and replication were performed.

Statistical Analysis. Data were analyzed using analysis of variance (ANOVA), general linear model (GLM), and the least significant difference (lsd) test (SAS, 1985).

RESULTS AND DISCUSSION

Water Absorption. Water absorption is an index of the ability of protein to absorb and retain water which, in turn, influences the sensory quality of foods. The capacity of cowpea meal to absorb water when hydrated to form a foam when whipped and to produce paste with an appropriate viscosity is essential in akara preparation (Phillips and McWatters, 1991). Apparent and true water absorption capacities of cowpea meal (Figure 1) were, respectively, 1.71 and 2.99 g/g. Addition of up to 25% FPDPF slightly improved apparent water absorption capacities of CM−FPDPF. An increase in polar groups ($-NH_4^+$ and $-CO_2^-$) as a result of fungal proteolytic activity would increase the hydrophilicity of protein (Prinyawiwatkul et al., 1993b). Addition of up to 25% PDPF and/or FPDPF, however, did not affect the true water absorption capacities of CM−PDPF and/or CM−FPDPF. Apparent water absorption capacities of CM−FPDPF were slightly greater

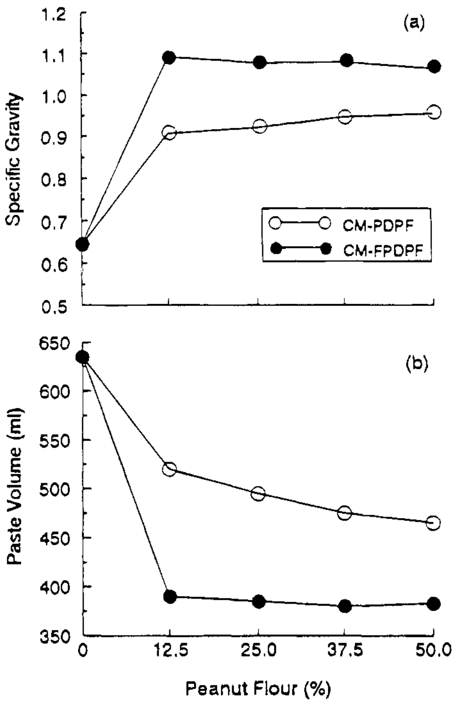

Figure 2. Effect of peanut flour supplementation on (a) specific gravity and (b) paste volume of whipped cowpea paste. See Figure 1 for key.

than those of CM–PDPF. The reverse, however, occurred for true water absorption capacities, particularly in cowpea meal containing 37.5% or more peanut flour. Addition of defatted peanut flour to wheat flour (Khan et al., 1975) and sorghum meal (Ahmed and Ramanatham, 1988) was reported to improve water absorption capacity. Our results showed that addition of more than 37.5% PDPF and/or FPDPF to cowpea meal tended to decrease apparent water absorption capacities. The high fat content of peanut flour, which is nonpolar and has low affinity for water, may have lessened the ability of CM–PDPF and CM–FPDPF to bind water. The greater decrease in water absorption capacity of CM–FPDPF compared to that of CM–PDPF may be due to the degradation of starch during fermentation. The decrease in water absorption capacity of fermented sorghum meal (Ahmed and Ramanatham, 1988) was due to the degradation of starch, a component known to contribute to its water absorption capacity (Chandrasekhar and Desikachar, 1983).

Specific Gravity and Foaming Capacity. Specific gravity and foam volume are indices of texture lightness of food products. The desirable spongy texture of akara is due to whipping, which incorporates air into the paste. Uniform distribution of fine bubbles usually imparts body, smoothness, and lightness to foods (Cheftel et al., 1985). The specific gravity and paste volume of whipped pastes (Figure 2) were notably affected by supplementation of cowpea meal with peanut flour. The addition of either PDPF or FPDPF to cowpea meal decreased the volume and increased the specific gravity of whipped pastes. Reductions in the paste volume of CM–PDPF and CM–FPDPF mixtures compared to that of the control sample were as high as 26.7 and 40.0%, respectively. In all cases, CM–PDPF mixtures had lower specific gravities and greater paste volumes than those of CM–FPDPF. The process of preparing FPDPF involved a heat treatment which could have denatured the protein and consequently lowered its foaming capacity, i.e., lowered paste volume. The presence of fat can impair the foaming properties of proteins (Yasumatsu et al., 1972). The presence of lipids as well as hydrolyzed peanut triglycerides resulting from fungal lipase may have reduced the foaming capacity of whipped paste. Surface-active lipids may have interfered with the conformation of absorbed protein film by situating themselves at the air/water interface (Cheftel et al., 1985).

Cherry and McWatters (1981) reported that specific gravity and foam volume are indices of dispensing and frying characteristics of whipped paste in the preparation of akara. Whipped paste (control) exhibited good dispensing and frying characteristics; paste was well separated upon contact with the frying oil and formed uniformly shaped balls that floated and retained their structural integrity during frying. Traditional akara-making uses blackeye-type cultivars that are decorticated to remove the seed coat and blackeye (Dovlo et al., 1976). Observations of the machinability of paste made from the nondecorticated cream-type cultivar used in this study indicated that the presence of the seed coat did not adversely affect batter-handling properties. Thus, akara preparation could be simplified by the use of this type of cowpea. Whipped pastes containing PDPF were easily dispensed and floated upon contact with oil but failed to separate into individual balls. Whipped pastes containing FPDPF, particularly at a 12.5% supplementation level, had a very thick batter-like consistency, which caused difficulty in dispensing. The FPDPF pastes failed to separate into individual balls; the balls remained partially submerged during frying and were somewhat distorted in shape. Proper paste consistency is essential for ease of dispensing, shape formation and retention during frying, and acceptable product quality (McWatters and Brantley, 1982). The lower paste volume and greater specific gravity may explain why pastes containing FPDPF had poor dispensing and frying properties.

Apparent Viscosity. The flow characteristic parameters, n and k, of cowpea pastes (Table 2) were influenced by type and amount of peanut flour. The n value is an index of the departure from Newtonian flow; for $n = 1.0$, flow is Newtonian (Chhinnan et al., 1985). Addition of PDPF (25.0 and 37.5%) to cowpea meal decreased n, whereas addition of FPDPF increased n.

Table 2. Effect of Peanut Flour Supplementation on Flow Behavior (n), Flow Consistency (k), and Yield Stress (τ_0) of Cowpea Paste[a]

	n (dimensionless)		k (Pa·s^n)		τ_0[b] (Pa)	
peanut flour (%)	CM–PDPF	CM–FPDPF	CM–PDPF	CM–FPDPF	CM–PDPF	CM–FPDPF
0	0.71 (0.05)	0.71 (0.05)	12.6 (1.87)	12.6 (1.87)	30.2 (0.28) e	30.2 (0.28) e
12.5	0.78 (0.10)	0.98 (0.08)	19.4 (3.39)	71.1 (5.63)	27.1 (0.14) e	88.7 (5.09) a
25.0	0.57 (0.05)	0.86 (0.02)	29.4 (5.86)	78.1 (4.97)	27.5 (3.54) e	71.0 (1.41) b
37.5	0.47 (0.15)	0.89 (0.01)	60.6 (9.63)	103.8 (1.47)	31.5 (12.0) de	60.0 (0.00) c
50.0	0.69 (0.02)	1.18 (0.16)	28.7 (2.60)	113.7 (18.63)	27.5 (3.53) e	42.1 (2.89) d

[a] Numbers in parentheses refer to standard deviations of two replications. See Figure 1 for key. [b] Mean values of τ_0 not followed by the same letter are significantly different ($\alpha = 0.05$).

Table 3. Effect of Peanut Flour Supplementation on Shear Stress (τ) and Apparent Viscosity (η_a) of Cowpea Paste[a]

sample[b]	peanut flour (%)	true shear rate (s^{-1})	τ (Pa)	η_a (Pa·s)
control	0	0.37 (0.01)	35.4 (1.69)	95.7 (1.71)
		1.85 (0.05)	46.0 (1.84)	25.6 (0.23)
		3.70 (0.11)	63.5 (2.84)	17.2 (0.25)
CM−PDPF	12.5	0.35 (0.18)	37.1 (3.70)	103.4 (4.95)
		1.79 (0.09)	57.3 (3.09)	32.0 (0.06)
		3.58 (0.18)	74.5 (3.16)	20.8 (0.20)
	25.0	0.40 (0.02)	46.5 (1.49)	114.3 (1.46)
		2.03 (0.09)	69.4 (3.96)	34.1 (0.42)
		4.07 (0.18)	90.8 (3.42)	22.3 (0.16)
	37.5	0.45 (0.07)	75.9 (0.15)	167.8 (27.92)
		2.29 (0.38)	118.6 (0.00)	52.5 (8.84)
		4.58 (0.77)	152.3 (10.91)	33.9 (8.09)
	50.0	0.37 (0.00)	41.4 (1.08)	110.9 (4.01)
		1.86 (0.02)	71.0 (0.39)	38.0 (0.59)
		3.74 (0.04)	103.1 (1.52)	27.6 (0.13)
CM−FPDPF	12.5	0.16 (0.00)	100.8 (2.10)	611.1 (28.85)
		0.33 (0.01)	112.6 (0.41)	341.4 (10.23)
		0.82 (0.02)	147.4 (1.93)	178.8 (2.36)
	25.0	0.17 (0.00)	87.9 (1.29)	510.5 (2.49)
		0.34 (0.00)	102.2 (0.22)	296.8 (2.27)
		0.86 (0.01)	139.4 (1.85)	161.9 (3.73)
	37.5	0.17 (0.00)	81.2 (0.69)	476.7 (2.29)
		0.34 (0.00)	99.9 (1.27)	293.1 (2.63)
		0.85 (0.00)	149.6 (1.57)	175.7 (1.18)
	50.0	0.16 (0.00)	54.7 (0.65)	350.0 (17.71)
		0.31 (0.01)	70.6 (0.95)	225.8 (11.78)
		0.78 (0.03)	126.5 (9.63)	161.9 (18.57)

[a] For control and CM−PDPF, shear rate, τ, and η_a were determined at 1.0, 5.0, and 10.0 rpm; for CM−FPDPF, at 0.5, 1.0, and 2.5 rpm. Numbers in parentheses refer to standard deviations. [b] See Figure 1 for key.

Since the observed n values of paste formulations deviated from 1.0, the pastes were non-Newtonian. In most cases, paste formulations exhibited shear thinning viscosity patterns as shown by the magnitude of the flow behavior index ($n < 1.0$). The flow consistency index (k) of pastes containing PDPF and/or FPDPF was higher than that of the control and generally increased with increased amounts of peanut flour. Without exception, k values of pastes containing FPDPF were higher than those of pastes containing PDPF, which indicated an increased resistance to flow.

Values for yield stress, defined as the minimum stress required before flow occurs, are presented in Table 2. The addition of PDPF to cowpea meal did not significantly affect yield stress of whipped cowpea pastes. Significant changes, however, were noted in paste containing FPDPF. Yield stress of all pastes containing FPDPF was higher than that of pastes containing PDPF. This would be partially explained by the pastes' respective volume and specific gravity characteristics. As the amount of FPDPF was increased, the yield stress of whipped paste decreased; this was accompanied by a decrease in the apparent viscosity.

All paste formulations were characterized by a nonlinear relationship between the true shear rate and shear stress (Table 3), which also indicated that they were non-Newtonian. Attempts to determine apparent viscosity (η_a) of pastes containing FPDPF at a greater than 2.5 rpm were unsuccessful because the viscometer readings were off-scale. The apparent viscosity of all paste formulations decreased with increased true shear rate (shear thinning), indicating that they were pseudoplastic. In general, η_a values of pastes containing FPDPF were higher than that of control and pastes containing PDPF. At any given shear rate, η_a increased with increased amounts of PDPF (except at 50% PDPF supplementation) but generally decreased with increased FPDPF. As reported by Kinsella (1976), viscosity can be a useful index of structural changes in proteins and, subsequently, of the rheological properties of modified food systems. The differences in flow properties (i.e., n, k, τ_0, η_a) between CM−PDPF and CM−FPDPF could have been due to the conformational and compositional changes of peanut protein as a result of fungal fermentation. An increase in the smaller molecular size and changes in the charges of proteins may have caused an increase in particle dimension and particle−particle contacts, when hydrated, which in turn increased viscosity.

Color. Data for color of cowpea pastes and akara supplemented with peanut flour are presented in Table 4 and Figures 3 and 4. Unsupplemented whipped paste and akara were significantly lighter (higher L^*) than products containing PDPF and/or FPDPF. All akara formulas containing PDPF and/or FPDPF had significantly lower b^* values (yellowness) than that of the control sample. Total color differences (ΔE) of whipped pastes and akara (external and internal) containing FPDPF were greater than those of pastes and akara containing PDPF and control samples. The marked increase in ΔE of paste containing 12.5% FPDPF was attributed to lowest L^* and highest a^* and b^* values. Only slight differences in color were observed as the amount of PDPF in paste formulations was increased.

Table 4. Observed Changes in Color (L^*, a^*, b^*) Readings of Whipped Cowpea Paste and Akara Containing Peanut Flour[a]

					akara					
		whipped paste			external			internal		
sample[b]	peanut flour (%)	L^*	a^*	b^*	L^*	a^*	b^*	L^*	a^*	b^*
control	0	82.1 a	0.60 bcd	19.4 f	41.9 a	8.67 e	28.4 a	55.2 a	0.39 d	18.3 a
CM−PDPF	12.5	80.2 b	0.51 cd	20.6 d	40.3 b	7.58 f	23.0 b	48.8 b	0.18 d	16.1 bc
	25.0	79.8 d	0.73 bc	20.6 d	42.1 a	8.70 e	23.4 b	48.3 b	0.23 d	15.0 d
	37.5	79.7 e	0.53 cd	20.1 e	37.3 c	8.67 e	20.5 d	46.2 c	1.02 c	15.6 c
	50.0	79.9 c	−0.27 e	19.9 e	35.0 d	10.12 d	21.3 c	44.4 d	1.39 bc	16.7 b
CM−FPDPF	12.5	75.8 i	1.78 a	22.5 a	30.0 fg	11.19 c	13.1 fg	42.3 f	1.57 ab	13.7 e
	25.0	76.1 h	0.43 d	21.4 b	31.8 e	12.34 ab	16.1 e	43.4 e	1.28 bc	13.7 e
	37.5	76.4 g	0.83 b	20.9 c	30.3 f	11.53 bc	13.6 f	42.7 f	1.15 bc	13.7 e
	50.0	77.0 f	0.47 cd	19.6 f	29.7 g	12.75 a	12.8 g	42.8 f	1.95 a	14.6 d

[a] Mean values in a column not followed by the same letter are significantly different ($\alpha = 0.05$). [b] See Figure 1 for key.

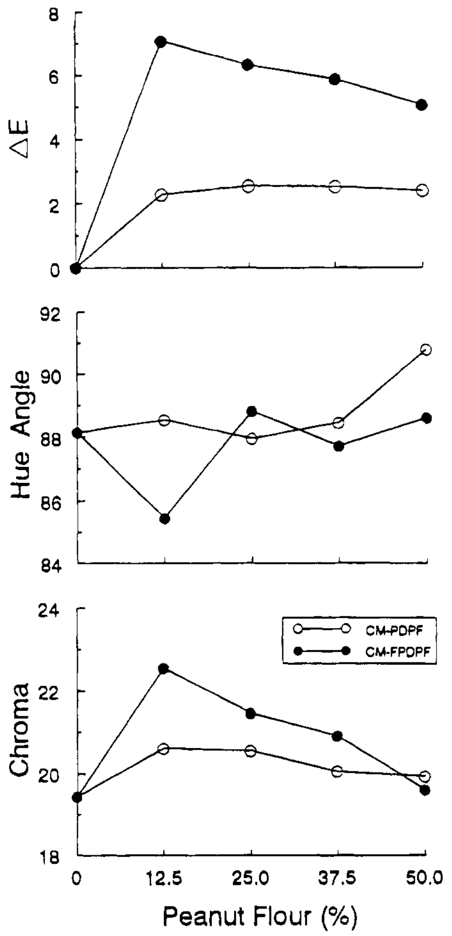

Figure 3. Effect of peanut flour supplementation on psychometric color values for whipped cowpea paste. See Figure 1 for key.

Increased FPDPF in paste formulations, however, caused a decrease in ΔE. The slight increase in ΔE of akara (external and internal) containing PDPF compared to the control sample was the result of lower L^* and b^* values.

Hue angle values of all paste and akara samples were lower than 90°, except for that (90.79°) of paste containing 50% PDPF. Angles of 0° and 90°, respectively, represent red and yellow hues, and objects with an angle between 0° and 90° are more orange-red. Addition of PDPF and/or FPDPF to akara formulations resulted in lower hue angles for the external surfaces compared to that of the control formula. As the amount of FPDPF in formulations increased, a more intense orange-brown color was observed on the external surface of akara, as indicated by lower hue angles. Addition of up to 50% FPDPF caused the external surface of akara to become dark brown.

Little change in chroma (saturation) was observed in pastes as the amount of PDPF was increased. The slight decrease in saturation of paste as the amount of FPDPF was increased was due to lower a^* and b^* values. Loss of saturation of the external surface of akara balls containing PDPF and/or FPDPF was attributed primarily to a decrease in b^* values. No drastic changes in chroma values were observed for the internal surface of akara balls as a result of increased amounts of PDPF and/or FPDPF in formulations.

Texture Characteristics. The texture of akara was influenced by the presence of peanut flour, PDPF and/or FPDPF (Table 5). Akara balls containing PDPF (50%) and/or FPDPF (12.5 and 25.0%) required significantly more force and energy to shear-compress than did the control sample. Since the textural quality of akara depends on the functional behavior of paste, the increased firmness of akara containing peanut flour may have been due to the combined effects of higher η_a, lower paste volume, and higher specific gravity of pastes. Incorporating air into the paste during whipping is necessary for the desirable spongy texture of akara. Paste with low volume, high specific gravity, and high η_a undoubtedly has few air droplets. The foam quality and foaming capacity of cowpea paste have been shown to affect the textural quality of akara balls (Dovlo et

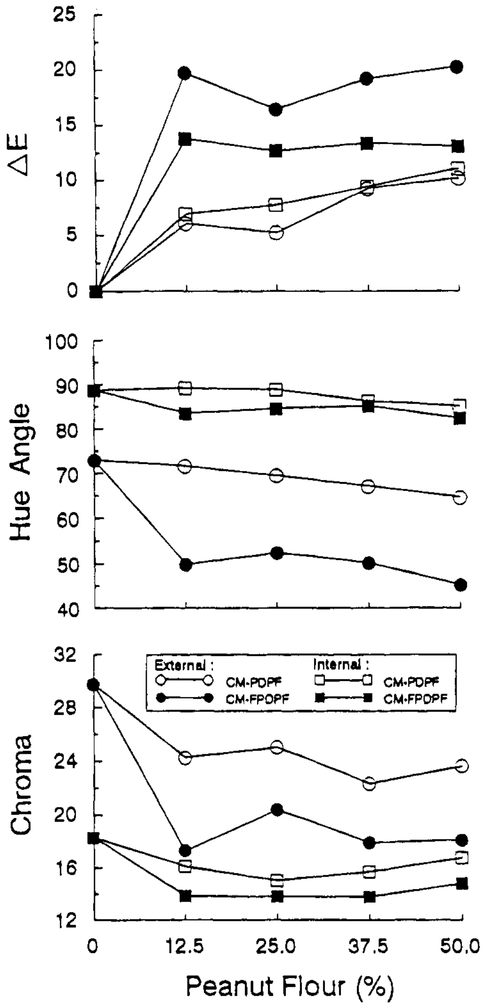

Figure 4. Effect of peanut flour supplementation on psychometric color values for akara. See Figure 1 for key.

Table 5. Effect of Peanut Flour Supplementation on Texture Characteristics of Akara Balls[a]

sample[b]	peanut flour (%)	maximum force (N/g)	energy/mass (10^{-3} J/g)
control	0	14.5 (2.14) cd	168.4 (15.86) cd
CM–PDPF	12.5	15.7 (1.27) cd	196.3 (1.90) c
	25.0	11.7 (1.25) e	149.0 (9.86) d
	37.5	13.2 (1.51) de	154.0 (6.97) d
	50.0	24.5 (3.68) b	243.8 (3.81) b
CM–FPDPF	12.5	31.7 (3.54) a	364.0 (41.34) a
	25.0	24.0 (2.53) b	277.3 (13.09) b
	37.5	16.9 (1.28) c	200.2 (16.47) c
	50.0	13.7 (0.70) de	152.0 (1.56) d

[a] Numbers in parentheses refer to standard deviations of six replicates. Mean values in a column not followed by the same letter are significantly different ($\alpha = 0.05$). [b] See Figure 1 for key.

Table 6. Effect of Peanut Flour Supplementation on Moisture, Total and Absorbed Oil, and Protein Contents of Akara Balls[a]

sample[b]	peanut flour (%)	moisture (%)	oil[c] (%)		protein[c] (%)
			total	absorbed	
control	0	38.2 (0.06) g	37.8 (0.09) b	36.7 (0.09) a	15.3 (0.09) g
CM–PDPF	12.5	44.6 (0.05) b	28.6 (0.26) e	24.1 (0.26) c	19.2 (0.18) f
	25.0	38.7 (0.14) f	35.0 (0.23) c	27.0 (0.23) b	19.3 (0.14) f
	37.5	39.7 (0.05) e	34.0 (0.14) d	22.6 (0.14) d	20.9 (0.59) d
	50.0	33.3 (0.04) i	42.0 (0.15) a	27.2 (0.15) b	19.7 (0.07) e
CM–FPDPF	12.5	44.0 (0.06) c	14.9 (0.04) h	10.7 (0.04) h	22.0 (0.15) c
	25.0	42.1 (0.06) d	21.5 (0.07) g	14.1 (0.07) f	22.7 (0.15) b
	37.5	45.5 (0.04) a	23.1 (0.21) f	12.5 (0.21) g	24.3 (0.66) a
	50.0	37.5 (0.15) h	34.9 (0.10) c	21.2 (0.10) e	22.4 (0.17) b

[a] Numbers in parentheses refer to standard deviations of three replicates. Mean values in a column not followed by the same letter are significantly different ($\alpha = 0.05$). [b] See Figure 1 for key. [c] Dry weight basis.

al., 1976). The presence of 50% PDPF in the formulation resulted in significantly higher force and energy needed to shear-compress than for products supplemented with 12.5, 25.0, and 37.5% PDPF. No definite relationship between the η_a of paste and texture characteristics of akara balls containing PDPF was observed. As the amount of FPDPF increased, accompanied by decreased η_a of the paste, the maximum force and energy to shear-compress akara decreased.

Proximate Composition. The proximate composition of akara is given in Table 6. The control akara contained 38.2% moisture, 37.8% fat, and 15.3% protein. The light, spongy character of control akara provided a porous structure that accounted for greater oil absorption during frying than observed for akara containing peanut flour. Akara containing 12.5% FPDPF contained the lowest total (14.9%) and absorbed oil (10.7%) content. Addition of PDPF and/or FPDPF increased the protein content of akara. Although supplementation with 50% of either PDPF and FPDPF was expected to result in the highest protein content, the low moisture and high oil content of these samples resulted in proportional reductions in protein content. At 37.5% PDPF and FPDPF supplementation, the protein content of akara increased by approximately 37 and 60%, respectively, over the control sample.

Conclusions. This study demonstrated that akara preparation was simplified considerably by using a cream-type cowpea without decortication. The presence of the seed coat did not adversely affect paste machinability and cooked-product characteristics. Incorporation of up to 37.5% peanut flour, PDPF and/or FPDPF, into the akara formulations was successfully achieved. Addition of peanut flour significantly affected the physical and compositional properties of paste and akara. Akara supplemented with peanut flour contains higher protein and B-vitamin contents than most commercially available finger foods and is similar in texture to hush puppies (fried cornmeal balls); therefore, this product would have potential for introduction into the U.S. market. Product formula optimization and consumer acceptance tests will be necessary to confirm this hypothesis.

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LITERATURE CITED

Ahmed, A. R.; Ramanatham, G. Effect of natural fermentation on the functional properties of protein-enriched composite flour. *J. Food Sci.* **1988**, *53*, 218–221.

AOAC. *Official Methods of Analysis*, 14th ed.; Association of Official Analytical Chemists: Washington, DC, 1984.

ASAE. Method of determining and expressing fineness of feed materials by sieving. *ASAE Standard*: *ASAE S319*; American Society of Agricultural Engineers: St. Joseph, MI, 1983; pp 325–326.

Campbell, A. M.; Penfield, M. P.; Griswold, R. M. *The Experimental Study of Food*, 2nd ed.; Houghton Mifflin: Boston, MA, 1979; p 475.

Chandrasekhar, A.; Desikachar, H. S. R. Sorghum quality studies. Part I. Rolling quality of sorghum dough in relation to some physico-chemical properties. *J. Food Sci. Technol.* **1983**, *20*, 281–284.

Cheftel, J. C.; Cuq, J. L.; Lorient, D. Amino acids, peptides, and proteins. In *Food Chemistry*, 2nd ed.; Fennema, O. R., Ed.; Marcel Dekker: New York, 1985; pp 245–369.

Cherry, J. P.; McWatters, K. H. Whippability and aeration. In *Protein Functionality in Foods*: Cherry, J. P., Ed.; American Chemical Society: Washington, DC, 1981; pp 149–176.

Chhinnan, M. S.; McWatters, K. H.; Rao, V. N. M. Rheological characterization of grain legume pastes and effect of hydration time and water level on apparent viscosity. *J. Food Sci.* **1985**, *50*, 1167–1171.

Dovlo, F. E.; Williams, C. E.; Zoaka, L. *Cowpeas*: *Home preparation and use in West Africa*; Publication IDRC-055e; International Development Research Center: Ottawa, Canada, 1976; pp 1–96.

Hung, Y.-C.; McWatters, K. H.; Phillips, R. D.; Chinnan, M. S. Effects of predecortication drying treatment on the microstructure of cowpea products. *J. Food Sci.* **1990**, *55*, 774–776, 807.

Khan, M. N.; Rhee, K. C.; Rooney, L. W.; Cater, C. M. Bread baking properties of aqueous processed peanut protein concentrates. *J. Food Sci.* **1975**, *40*, 580–583.

Kinsella, J. E. Functional properties of proteins in foods: A survey. *Crit. Rev. Food Sci. Nutr.* **1976**, *7*, 219–280.

McWatters, K. H. Compositional, physical, and sensory characteristics of akara processed from cowpea paste and Nigerian cowpea flour. *Cereal Chem.* **1983**, *60*, 333–336.

McWatters, K. H. Functional characteristics of cowpea flours in foods. *J. Am. Oil Chem. Soc.* **1990**, *67*, 272–275.

McWatters, K. H.; Brantley, B. B. Characteristics of akara prepared from cowpea paste and meal. *Food Technol.* **1982**, *36* (1), 66–68.

McWatters, K. H.; Flora, F. A deep-fried product from southern peas. *Food Technol.* **1980**, *34* (11), 71–74.

McWatters, K. H.; Chinnan, M. S.; Hung, Y.-C.; Branch, A. L. Effect of predecortication drying temperature on cowpea paste characteristics and functionality in preparation of akara. *Cereal Chem.* **1988**, *65*, 23–27.

McWatters, K. H.; Resurreccion, A. V. A.; Fletcher, S. M. Response of American consumers to akara, a traditional West African food made from cowpea paste. *Int. J. Food Sci. Technol.* **1990**, *25*, 551–557.

McWatters, K. H.; Hitchcock, H. L.; Resurreccion, A. V. A. Effect of frozen storage on the quality of akara, fried cowpea (*Vigna unguiculata*) paste. *J. Food Qual.* **1991**, *14*, 165–174.

McWatters, K. H.; Enwere, N. J.; Fletcher, S. M. Consumer response to akara (fried cowpea paste) served plain or with various sauces. *Food Technol.* **1992**, *46* (2), 111–114.

Ngoddy, P. O.; Enwere, N. J.; Onuorah, V. I. Cowpea flour performance in akara and moin-moin preparations. *Trop. Sci.* **1986**, *26*, 101–119.

Nnanna, I. A.; Phillips, R. D.; McWatters, K. H.; Hung, Y.-C. Effect of germination on the physical, chemical, and sensory characteristics of cowpea products: flour, paste, and akara. *J. Agric. Food Chem.* **1990**, *38*, 812–816.

Phillips, R. D.; McWatters, K. H. Contribution of cowpeas to nutrition and health. *Food Technol.* **1991**, *45* (9), 127–130.

Phillips, R. D.; Chinnan, M. S.; Branch, A. L.; Miller, J.; McWatters, K. H. Effects of pretreatment on functional and nutritional properties of cowpea meal. *J. Food Sci.* **1988**, *53*, 805–809.

Prinyawiwatkul, W. Development and characterization of a novel peanut-based snack food. M.S. thesis, University of Georgia, Athens, 1992.

Prinyawiwatkul, W.; Beuchat, L. R.; Resurreccion, A. V. A. Optimization of sensory qualities of an extruded snack based on cornstarch and peanut flour. *Lebensm. Wiss. Technol.* **1993a**, *26*, 393–399.

Prinyawiwatkul, W.; Beuchat, L. R.; McWatters, K. H. Functional property changes in partially defatted peanut flour caused by fungal fermentation and heat treatment. *J. Food Sci.* **1993b**, *58*, 1318–1323.

SAS. *SAS User's Guide*: *Statistics*, version 5 ed.; SAS Institute: Cary, NC, 1985.

Triebold, H. O.; Aurand, L. W. *Food Composition and Analysis*; Van Nostrand Reinhold: New York, 1963.

Williams, C. E. Cowpea flour innovation in a traditional dish and its acceptability in selected areas of Oyo division. Ph.D. dissertation, University of Ibadan, Nigeria, 1980.

Yasumatsu, K.; Sawada, K.; Moritaka, S.; Toda, J.; Ishii, K. Whipping and emulsifying properties of soybean products. *Agric. Biol. Chem.* **1972**, *36*, 719–727.

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