Effect of Predecortication Drying Temperature on Cowpea Paste Characteristics and Functionality in Preparation of *Akara*

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ABSTRACT

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Cowpeas (*Vigna unguiculata*, cv. California Blackeye No. 5) were conditioned for dry, mechanical abrasive decortication by adjusting the moisture content to 25%, holding for 30 min with occasional stirring, and drying (50, 70, 90, 110, and 130° C) in a rotary forced-air dryer to a moisture content of approximately 10%. Decorticated seeds were ground, hydrated to 58% moisture content, whipped, and evaluated for paste specific gravity, apparent viscosity, and functionality in preparation of *akara* (fried cowpea paste). Paste specific gravity and apparent viscosity (at shear rates greater than 1.7 sec^{-1}) increased with increasing drying temperature; however, no adverse effects on paste dispensing and frying characteristics were observed except with the 110 and 130° C treatments. *Akara* batter from the latter treatments failed to separate into individual balls during dispensing; the end products had tough crusts, undercooked interiors, and unusually high moisture (51%) and low crude fat (14%) contents. *Akara* from all drying treatments was darker (lower Hunter *L* values) and redder (higher Hunter *a* values) than *akara* made from cowpeas that had not been treated (control). Overall, the 50, 70, and 90° C treatments produced *akara* that compared favorably in sensory attributes to the control.

In the production of most products from cowpeas (*Vigna unguiculata*), removal of the hilum and seed coat by decortication is necessary to obtain a light-colored flour. Decortication may be achieved by dry, mechanical abrasion (Reichert et al 1979), but in commercial practice, the yield of usable product from the dry process is undesirably low (Reichert et al 1984). Studies show that cowpea meal exhibits excellent functionality for use in *akara* (fried cowpea paste) if the peas are stored at cool (2° C) or mild (21° C) temperatures (McWatters et al 1987), milled to an intermediate rather than fine particle size (McWatters 1983), and hydrated to an appropriate batter moisture content (McWatters and Chhinnan 1985, Chhinnan et al 1985).

Further efforts to optimize process conditions have focused on improvement in decortication efficiency. Studies show that a predecortication treatment of whole seed, which consisted of wetting and drying, is effective for this purpose (Hudda 1983). The wetting step loosens the tightly adhering seed coat, and the drying step causes the loosened seed coat to become brittle, fragile, and easily removed by dry abrasion. High-temperature drying (100–140° C), which involved initial heating in a peanut roaster and completion of drying in a forced-air oven, was rapid and effective in promoting efficient seed coat removal; however, it was detrimental to the functionality of cowpea meal used as an ingredient in *akara*. Although the temperatures recorded by Hudda (1983) were that of the air in the roaster, the seeds may have actually been subjected to much higher temperatures because the primary function of a roaster is to heat rather than dry a product.

Cowpea paste is the principal ingredient in *akara*; therefore, factors that affect major seed components—starch and protein—also have a direct influence on the quality of end products made from paste. In *akara* preparation, cowpea paste made from either decorticated whole seeds or hydrated meal is whipped to incorporate air. The formation of a foam with appropriate viscosity is essential to achievement of a light, spongy bread-like structure and texture in the fried end product. Thus, paste foam and flow characteristics along with assessment of end product quality are sensitive indicators of cowpea meal functionality.

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A preliminary study was conducted to determine effects of predecortication wetting (20, 25, and 30% H_2O) and drying (50, 60, 70, and 80° C) conditions on the total electrical energy required to dry and decorticate cowpeas, extraction rate (yield), and functionality of cowpea meal processed from pretreated seeds (McWatters et al 1986). Although several cowpea meal and paste characteristics were affected either by moisture level, drying temperature, or their interaction, none were so adversely affected that *akara*-making quality was impaired. The present study was conducted to establish the maximum temperature at which cowpeas could be dried while retaining those paste characteristics that contribute to good *akara* quality. A single moisture level (25%) for the wetting stage and a wide range of predecortication drying temperatures (50–130° C) were utilized for this purpose.

MATERIALS AND METHODS

Cowpea Seeds, Process Conditions, and Meal Preparation

Cowpeas (*Vigna unguiculata*, cv. California Blackeye No. 5) were obtained from Pennington Seed Co., Madison, GA, graded, and held at 2° C until used. Batches of 3.6 kg were adjusted to 25% moisture content by the addition of water and held for 30 min with occasional stirring. Samples were dried at 50, 70, 90, 110, or 130° C in a rotary forced-air dryer for 224, 80.5, 50, 31.5, or 25 min, respectively, to a final moisture of approximately 10%. The time required to reduce the moisture content of conditioned seeds to ~10% was established in a separate set of trials for each temperature because of the difficulty in monitoring the moisture content of the seeds during drying.

Dry seeds were decorticated mechanically for 2 min in a PRL-mini rollover dehuller (Nutana Machine Co., Saskatoon, Canada) equipped with carborundum stones rotating at 1,000 rpm (Reichert et al 1984). After passing through a seed cleaner, decorticated cotyledons were ground in a Retsch microjet ultracentrifugal mill (model ZMI, F. Kurt Retsch GmbH & Co. KG, Haan, FRG) equipped with a 1.0-mm screen and operated at 10,000 rpm. Previous work (McWatters 1983) with unheated cowpeas showed that the 1.0-mm screen produces a particle size distribution in the milled product that results in highly acceptable *akara*. Each drying temperature pretreatment was conducted in triplicate. Cowpeas that were not subjected to the wetting and drying pretreatment were included as a control; decortication time for the control was 4 min.

Cowpea Paste Preparation, Specific Gravity, and Apparent Viscosity

Paste was prepared by a single addition of sufficient water to 200 g of cowpea meal to adjust the moisture content to 58%. The mixture was stirred gently with a rubber spatula for 2 min. The paste was whipped in a mixer (model N-50, Hobart Corp., Troy, OH) at high speed (no. 3) for 1.5 min. Specific gravity of the resulting foam was determined in triplicate by the method of Campbell et al (1979).

The flow behavior of whipped paste was determined at 23° C using a Brookfield digital viscometer (Brookfield Engineering Laboratories, Inc., Model HATD, Stoughton, MA). The sample chamber was filled with approximately 13 ml of foam using a syringe. Because all foam samples were handled in the same manner, it was assumed that any effect due to transfer with the syringe was consistent for all samples. All measurements were made using a no. 27 spindle at 0.5, 1, 2.5, 5, 10, 20, 50, and 100 rpm. Shear rate (sec^{-1}) was calculated by multiplying rpm values by 0.34, whereas shear stress was calculated by multiplying the viscometer reading by 1.7. The factors 0.34 and 1.7 were supplied by the viscometer manufacturer.

The following expression was fitted to the shear stress and shear rate data, and the parameters b and n were estimated:

$$\tau = b(\dot{\gamma})^n \quad (1)$$

where τ = shear stress, $\dot{\gamma}$ = shear rate, b = flow consistency index, and n = flow behavior index.

Apparent viscosity (ratio of shear stress to shear rate), η_α, at any specific shear rate was calculated by transforming the above equation as follows (Chhinnan et al 1985):

$$\eta_a = b(\dot{\gamma})^{n-1} \quad (2)$$

Akara Preparation, Sensory Evaluation, and Objective Measurements

Paste for *akara* was prepared as described above for viscosity tests. For each batch, 38 g of chopped green pepper, 38 g of chopped onion, and 8.5 g of salt were mixed together and stirred into the whipped paste. The mixture was transferred to an automatic dispenser/continuous fryer (Donut Mini-Matic 110, Belshaw Bros., Inc., Seattle, WA) equipped with a nugget plunger, then fried for 2 min in peanut oil at 193° C. Fried products were drained on absorbent paper, cooled to room temperature, and covered with aluminum foil until they were evaluated for sensory quality. Samples for sensory analysis were prepared in the morning and evaluated at midafternoon.

One treatment replication and a control were evaluated per day. Four-point rating scales were developed for the attributes of shape, exterior color uniformity, sponginess, moistness, tenderness, and flavor. Samples were arranged in random order on oven-proof white plates, reheated at 204° C for 4 min in a conventional oven, and evaluated while warm by a 10-member panel. Sensory evaluation was conducted in individual booths under incandescent lighting. All panelists had served on previous *akara* panels and had been trained in the use of sensory evaluation procedures.

Objective textural quality of *akara* was evaluated using Texture Profile Analysis (Friedman et al 1963, Szczesniak 1973). A cube approximately 1 cm was cut from the center portion of the *akara* ball and then compressed to 25% of its original height (75% compression) two times in a reciprocating motion in an Instron universal testing machine equipped with a 50-kg load cell (model 1122, Instron Inc., Canton, MA). The tests were conducted at crosshead and chart speeds of 50 and 200 mm/min, respectively. Textural parameters were derived from force-deformation curves based on the Friedman et al (1963) definition. Hardness is the force necessary to attain a given deformation and was interpreted as the maximum force of the first compression. Cohesiveness is a measure of the extent to which a material can be deformed before it ruptures and was measured as the area ratio of the second and first compression peaks.

The external color of *akara* was measured objectively by determining the Hunter color values *L, a,* and *b*. A Gardner XL-845 colorimeter set against a yellow reference standard (L = 79.46, $a = -1.98$, $b = 22.7$) was used. Individual *akara* balls were placed in a sample container that had a glass bottom, and opaque sides and lid. The container was placed over the aperture of the colorimeter. Four readings of the top and bottom sides of four *akara* balls from each treatment were obtained by rotating the container at 90° angles.

Moisture and crude fat content of *akara* balls ground to pass a 14-mesh screen were determined in triplicate as previously described (McWatters 1983).

Statistical Analysis

Least square fit of the Statistical Analysis System (SAS 1985) was used in estimating the flow consistency and flow behavior indexes of whipped cowpea paste. Other data were analyzed using analysis of variance and Duncan's multiple range test procedures (SAS 1985).

RESULTS AND DISCUSSION

The flow characteristic parameters (b and n in equation 1) estimated from the shear rate and shear stress data of foams prepared from the control and various predecortication drying temperature treatments are presented in Table I. Data for the 130° C treatment are not included because the viscometer readings at spindle rpms of 2.5–100 were off-scale. In a Newtonian fluid, such as water, flow behavior index (n) is unity and flow consistency index (b) corresponds to viscosity. The flow characteristics of different samples can be examined only by comparing the flow behavior and consistency index values in pairs and not independently. For example, the flow behavior index values of the 70 and 90° C samples are not significantly different from each other; however, their flow consistency index values are different. Thus, foams from the 70 and 90° C treatments, in rheological terms, are different from each other and from the other treatments.

Another approach in studying rheological data is to examine apparent viscosity values (Table II). For Newtonian fluids, apparent viscosity is equal to viscosity and is independent of shear rate. Apparent viscosity for all samples decreased with increasing shear rate, which indicated that they were non-Newtonian. The apparent viscosity value for the control was lower at each shear rate than those of the various drying temperature treatments. Effect of predecortication drying temperature was nonuniform at lower shear rates; however, at higher shear rates (greater than 1.7 sec^{-1}) increasing temperature resulted in increased values of apparent viscosity.

Paste specific gravity increased gradually with increasing predecortication drying temperature; however, no adverse effects on meal hydration properties and paste cookability were noted until the 110° C drying temperature was reached (Table III). Attractive *akara* that was similar to the control in shape and color resulted from the 50, 70, and 90° C treatments (Fig. 1); these treatments produced *akara* that had similar moisture (43–45%) and crude fat (25–28% dry basis) contents to those of the control (47% moisture, 23% crude fat). High-temperature pastes (110 and 130° C) did not float when dispensed into the frying oil, failed to separate into individual balls, and developed a case-hardened surface during frying. *Akara* from the latter treatments had high moisture (51%) and low crude fat (14%) contents because moisture removal was impeded by case hardening. The end product from the 130° C treatment had such a distorted shape, tough crust, and undercooked interior (Fig. 2) that it was not included in sensory evaluation and objective tests for color and texture.

TABLE I
Flow Behavior (n) and Flow Consistency (b) Indexes for Foams Prepared from Meals Processed from Cowpeas Subjected to Various Predecortication Drying Temperatures[a]

Drying Temperature (° C)	Flow Behavior Index (n), Dimensionless	Flow Consistency Index (b), Pa·sec^n
Control (untreated)	0.572 (0.012)[b]	21.9 (1.02)
50	0.350 (0.024)	39.8 (1.04)
70	0.427 (0.020)	37.5 (1.03)
90	0.417 (0.024)	46.8 (1.03)
110	0.608 (0.034)	38.0 (1.04)

[a]Values were estimated from shear stress and shear rate data.
[b]Numbers in parentheses refer to standard errors of estimates.

TABLE II
Effect of Predecortication Drying Temperatures on Apparent Viscosity[a] of Whipped Cowpea Paste

	Apparent Viscosity (Pa·sec)[b]				
		Drying Temperature (° C)			
Shear Rate (sec^{-1})	Control (untreated)	50	70	90	110
0.17	46.8	126.1	102.8	130.7	75.9
0.34	34.7	80.4	69.4	86.9	57.9
0.85	23.4	44.2	41.3	51.3	40.5
1.70	17.3	28.2	27.7	34.4	30.9
3.40	12.9	17.9	18.7	23.0	23.5
6.80	9.6	11.5	12.3	15.4	18.0
17.00	6.5	6.4	7.5	9.4	12.6

[a]Calculated from equation (2).
[b]1 Pa·sec = 1,000 centipoise (cP).

Sensory evaluation of *akara* for the attributes of shape, sponginess, tenderness, and flavor showed that the 50, 70, and 90° C samples received ratings that were similar to the control and significantly higher than scores for the 110° C sample (Table IV). There were no significant differences in scores for uniformity of exterior color. Moistness of *akara* was perceived as decreasing with increased drying temperature. Panelists frequently commented that the 110° C sample was less uniform in shape, more dense and compact in structure, less moist, and tougher than the other samples.

Objective textural results are shown in Table V. *Akara* from the 70° C treatment had the lowest hardness value (most tender) and the highest cohesiveness value. Although *akara* from the 110° C treatment was similar to the control and 90° C sample in hardness, it was the least cohesive. The correlation coefficient between hardness and the sensory score for tenderness was −0.85 ($P \leqslant 0.05$). The correlation coefficient between cohesiveness and the sensory score for sponginess was 0.86 ($P \leqslant 0.05$).

Objective data for the external color of *akara* from the control and four predecortication drying temperatures showed that *akara* prepared from the control was the lightest; the 50, 70, and 90° C group was intermediate; and the 110° C sample was the darkest (Table VI). The lower *b* value for the 110° C sample indicates that it was less yellow than the other samples. All of the samples to which heat had been applied during the predecortication treatment produced *akara* that had significantly higher *a* (redness) values and was visibly browner than the control.

The performance of cowpea meal as the primary ingredient in *akara* was highly acceptable if the temperature used for drying

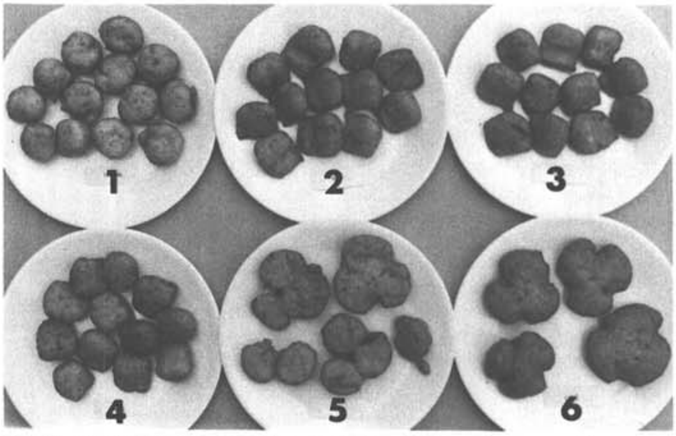

Fig. 1. *Akara* balls prepared from meal made from cowpeas subjected to various predecortication drying temperatures: **1,** control (untreated); **2,** 50° C; **3,** 70° C; **4,** 90° C; **5,** 110° C; **6,** 130° C. Plate diameter = 217 mm; average diameter of individual *akara* ball = 38 mm.

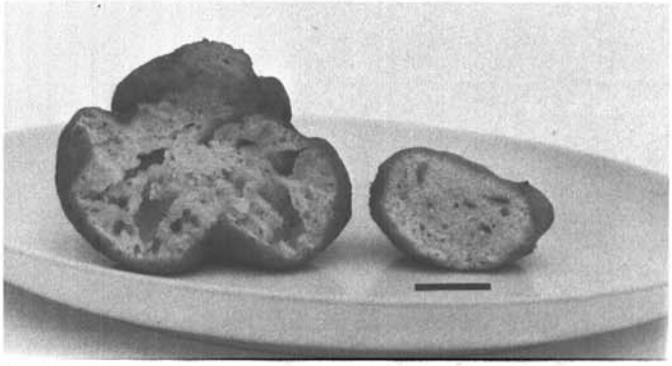

Fig. 2. Interior of *akara* sample from 130° C predecortication drying temperature (left) and control (untreated, right). Bar = 15 mm.

TABLE III
Effect of Drying Temperature Used in Predecortication Treatment of Cowpeas on Specific Gravity and Dispensing/Frying Characteristics of Whipped Paste Prepared from Meal Processed from Decorticated Cowpeas

Drying Temperature (°C)	Specific Gravity of Whipped Paste[a]	Dispensing/Frying Characteristics of Paste
Control (untreated)	0.617 d	Good separation upon contact with frying oil; produced *akara* balls with attractive round shape and light brown crust color.
50	0.565 e	Good separation upon contact with oil; produced *akara* balls with attractive round shape and golden brown crust color.
70	0.571 e	Good separation upon contact with oil; produced *akara* balls with attractive round shape and golden brown crust color.
90	0.671 c	Good separation upon contact with oil; produced *akara* balls with attractive round shape and golden brown crust color.
110	0.979 b	Poor meal hydration properties; paste sank upon contact with frying oil and failed to separate during frying; produced distorted *akara* balls with dark crust color.
130	1.082 a	Extremely poor meal hydration properties; paste sank upon contact with frying oil and failed to separate during frying; produced distorted *akara* balls with extremely dark crust color and uncooked crumb.

[a]Values not followed by the same letter are significantly different ($P \leq 0.05$).

TABLE IV
Effect of Drying Temperature Used in Predecortication Treatment of Cowpeas on Sensory Ratings of *Akara* Made from Meal Processed from Decorticated Cowpeas

Drying Temperature (°C)	Scores[a] for Sensory Attributes					
	Shape[b]	Exterior Color Uniformity[c]	Sponginess[d]	Moistness[e]	Tenderness[f]	Flavor[g]
Control (untreated)	3.7 a	3.0 a	2.9 a	2.7 ab	3.2 b	3.4 a
50	3.0 b	3.5 a	3.0 a	3.1 a	3.7 a	3.6 a
70	3.1 b	3.4 a	2.9 a	2.6 bc	3.4 ab	3.6 a
90	3.3 ab	3.1 a	2.6 a	2.2 cd	3.0 b	3.4 a
110	2.2 c	2.9 a	1.8 b	1.9 d	2.1 c	2.5 b

[a]Values in a column not followed by the same letter are significantly different ($P \leq 0.05$).
[b]1, very distorted; 2, slightly distorted; 3, reasonably uniform; 4, uniform.
[c]1, uneven browning; 2, slightly uneven; 3, reasonably uniform; 4, uniform browning.
[d]1, slightly spongy; 2, moderately spongy; 3, spongy; 4, very spongy.
[e]1, slightly moist; 2, moderately moist; 3, moist; 4, very moist.
[f]1, tough; 2, moderately tough; 3, moderately tender; 4, tender.
[g]1, severely off (objectionable); 2, slightly off; 3, reasonably typical of *akara*; 4, good (typical of *akara*).

TABLE V
Effect of Drying Temperature Used in Predecortication Treatment of Cowpeas on Objective Texture Values of *Akara* Made from Meal Processed from Decorticated Cowpeas

Drying Temperature (°C)	Hardness[a] (N)	Cohesiveness[a]
Control (untreated)	14.5 ab	0.34 c
50	12.4 bc	0.38 b
70	10.9 c	0.44 a
90	14.3 ab	0.32 c
110	16.5 a	0.24 d

[a]Values in a column not followed by the same letter are significantly different ($P \leq 0.05$).

cowpea seeds from which the meal was made did not exceed 90° C. Ngoddy et al (1986) used a different type of dryer and mill than that used in the present study and recommended that the temperature for drying cowpeas to be used in *akara* not exceed 60° C. These workers also reported that a higher drying temperature (80° C) could be used for cowpeas intended for use in *moin moin* (steamed cowpea paste). During the steaming process, *moin moin* paste forms a gel-like structure that conforms to the shape of the cooking container. Therefore, formation and retention of product shape are not as critical to the quality of the end product as in preparation of *akara*.

Although it would be desirable to predict the performance of cowpea paste or foam in preparation of an end product (*akara*), accurate predictions based on rheological properties alone are not possible at this time. Flow behavior of non-Newtonian fluids, as it applies to cowpea paste, is very complex and normally difficult to relate to the functional properties of the food system in question. However, it is suggested that preliminary judgment about satisfactory performance of cowpea paste can be made if its apparent viscosity is less than 23.0, 15.4, or 9.4 Pa·sec at shear rates of 3.4, 6.8, or 17.0 sec^{-1}, respectively.

Although it is difficult to relate findings from studies using other legumes and process conditions to these results obtained with cowpea, heat treatment and its associated effect on protein-water interactions have been shown to influence rheological patterns of dry bean flour (Gerschenson and Bartholomai 1986) and soybean proteins (Lin and Ito 1986), foaming properties of field pea flour and protein concentrate (Megha and Grant 1986), and moisture loss from cooked meat systems containing soybean protein isolate (Lopez de Ogara et al 1986). Structural changes of plant proteins brought about by heat denaturation are usually reflected in changes in physicochemical and functional properties (Wu and

TABLE VI
Effect of Drying Temperature Used in Predecortication Treatment of Cowpeas on External Color of *Akara* Made from Meal Processed from Decorticated Cowpeas

Drying Temperature, °C	Color Terms[a]				
	L	*a*	*b*	ΔE	ΔH
Control (untreated)	37.1 a	4.2 c	14.5 a	43.6 c	14.6 c
50	34.1 b	5.8 ab	14.5 a	46.8 b	16.1 ab
70	35.4 b	6.1 a	15.1 a	45.4 b	15.9 b
90	34.8 b	5.8 ab	14.7 a	46.0 b	15.9 b
110	32.4 c	5.4 b	13.6 b	48.5 a	16.8 a

[a] Values in a column not followed by the same superscript are significantly different ($P \leq 0.05$). L = lightness, $+a$ = redness, $-a$ = greenness, $+b$ = yellowness, $-b$ = blueness. $\Delta E = [(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2]^{1/2}$, $\Delta H = [(\Delta E)^2 - (\Delta L)^2 - (\Delta C)^2]^{1/2}$, where prefix Δ refers to the difference between sample and reference standard.

Inglett 1974). Although the protein components of cowpeas used in this study may have undergone organizational and structural changes due to heat treatment, there was little evidence of modification in *akara*-making quality in the temperature range of 50–90° C. Therefore, a processor of cowpea meal could select a time and temperature for drying within this range that would be the most practical from an economic standpoint while retaining essential functional properties of the milled product.

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