Physicochemical, Microbiological, and Akara-Making Properties of Hard-To-Cook Cowpeas

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The effect of long-term storage on the physicochemical, microbiological, and akara-making properties of cowpeas was evaluated. Cowpeas stored at −18 °C (control) or 30 °C/33% relative humidity (RH) had higher soluble solids, higher protein solubility, and lower seed hardness than cowpeas stored at 30 °C/64% RH and 25 °C/75% RH. Cowpeas stored at −18 °C (control) or 30 °C/33% RH resulted in whipped pastes with desirable handling and frying properties that produced attractive akara balls. Hard-to-cook (HTC) seeds, i.e., those stored at 30 °C/64% RH, resulted in whipped pastes that had poor handling and frying properties and akara balls that were darker and browner in color than control products. Adjusting the moisture content and hydration time of meal processed from HTC seeds did not improve batter dispensing properties or akara color but did have a beneficial effect on texture.

Keywords: *Cowpeas; akara; hard-to-cook defect*

INTRODUCTION

Cowpeas (*Vigna unguiculata*) stored under high-temperature and high-humidity conditions develop a hardness that persists after normal cooking. Seeds with this defect are either lost to utilization or require prohibitive amounts of fuel for cooking (Liu et al., 1992a). An alternative process may be required to prepare hard-to-cook (HTC) cowpeas for human consumption.

Akara is a fried nugget-type product that is popular in many West African and South American countries. This savory finger food is made from whipped cowpea paste seasoned with chopped fresh pepper (either hot or mild), chopped fresh onion, and salt. The balls resemble cornmeal hush puppies but are lighter and spongier in texture. Akara may be a possible alternative for using seeds with HTC defect that would otherwise be unacceptable for cooking by traditional methods. However, modifications in formulation or preparation may be required.

The primary objective of this study was to evaluate the effect of long-term storage of cowpea seeds on the physicochemical and microbiological properties of meal processed from them. A secondary objective was to assess the akara-making properties of selected cowpea meals.

MATERIALS AND METHODS

Cowpea Seeds and Storage Conditions. Cowpeas (*V. unguiculata* cv. California blackeye 5) obtained from Kerman Warehouse, Kerman, CA, were held at 2 °C until used. Samples of ~3500 g of cowpea seeds were subjected to four storage environments of −18 °C (control), 25 °C/75% relative humidity (RH), 30 °C/33% RH, and 30 °C/64% RH for periods of 0, 6, 12, and 18 months. The samples were placed in sterilized plastic containers, and inside the containers were also placed glass jars with saturated salt solutions. These solutions were magnesium chloride, sodium nitrite, or sodium chloride which provided RH values of 33, 64, and 75%, respectively. Containers were then held at −18, 25, or 30 °C, resulting in the four storage environments mentioned above. Triplicate samples were stored at each temperature/RH condition.

Cowpea Meal Preparation. After storage, cowpeas were brought to room temperature, submerged in water for 30 s, and then equilibrated at room temperature for 30 min. Partially hydrated cowpeas were then dried in a forced-air batch dryer at 70 °C until the final moisture content was approximately 10%. Dried cowpeas were then mechanically decorticated and cleaned following the method described by Phillips et al. (1988). The water submerging, equilibrating, and drying procedures used for the current study were to improve the decortication efficiency. The decorticated cotyledons were passed through a Retsch microjet ultracentrifugal mill (Model ZM1, F. Kurt Retsch GmbH & Co. KG, Haan, Germany) equipped with a 1.0 mm screen and operated at 10 000 rpm.

Textural Measurement of Cowpea Seeds. The development of HTC condition in stored seeds was determined by soaking cowpeas overnight and then cooking at 100 °C for 90 min. Cooked seeds (100 g) were then tested with an Instron universal testing machine (Model 1122, Instron Corp., Canton, MA) equipped with a 500 kg load cell and operated at a crosshead speed of 50 mm/min and chart speed of 50 mm/min using a Kramer shear−compression test cell. Four replicates of subsamples of each triplicate sample from each storage condition were measured. Two mechanical parameters, maximum force (newtons) and energy per unit mass (joules per gram), were obtained from the force−deformation curves to represent cowpea hardness. Energy per unit mass was calculated by integrating the area under the force−deformation curve up to the maximum force and dividing by the sample weight (Hung et al., 1988).

Physicochemical Analysis of Cowpea Meal. *Water Absorption.* Water absorption was determined by

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Table 1. Effect of Storage on Physicochemical and Microbiological Properties of Cowpea Meal and Texture of Cooked Seeds[a]

storage condition	time (months)	water absorption (g/g)	soluble solids (g/g)	protein solubility (%)	fungi population (cfu/g)	seed hardness (J/g)
−18 °C	0	2.632[abc]	0.240[a]	61.1[a]	2480	7.1[e]
	6	2.455[cde]	0.240[a]	59.8[a]	266	5.4[e]
	12	2.616[abc]	0.260[a]	55.2[a]	573	6.3[e]
	18	2.777[a]	0.265[a]	54.0[a]	8000	6.1[e]
30 °C/33% RH	6	2.635[abc]	0.220[ab]	57.8[a]	1543	6.6[e]
	12	2.733[ab]	0.225[a]	53.5[a]	1258	7.3[e]
	18	2.644[abc]	0.261[a]	55.1[a]	610	7.8[e]
30 °C/64% RH	6	2.339[def]	0.164[c]	17.2[b]	1667	20.6[c]
	12	2.257[ef]	0.174[bc]	18.4[b]	243	24.8[b]
	18	2.171[f]	0.176[bc]	15.6[b]	1929	34.2[a]
25 °C/75% RH	6	2.607[abc]	0.178[bc]	17.9[b]	751	16.3[d]
	12	2.499[bcd]	0.176[bc]	17.1[b]	5117	27.6[b]

[a] Values in a column not followed by a common letter are significantly different at $P \leq 0.05$.

suspending a weighed quantity of meal sample (2 g) in 20 mL of water and agitating gently on a mechanical shaker for 1 h. The slurry was centrifuged at 48400*g* for 1 h, then collected on Whatman No. 1 filter paper, and drained for 1 h. The wet pellet was weighed and freeze-dried, and the weight of the dry residue was determined. Water absorption, the water absorbed by the insoluble residue, was calculated by determining the difference in weight between the wet pellet and dry residue and then dividing by the dry residue weight (Phillips et al., 1988).

Soluble Solids. Soluble solids content of meals was determined as the difference between original sample weight and weight of the freeze-dried residue following measurement of water absorption.

Protein Solubility. Protein solubility of meals was determined by analyzing cowpea meal and the supernatants from the water absorption samples for nitrogen according to a micro-Kjeldahl method (AOAC, 1984).

Color. Color of cowpea meal was determined using a Gardner colorimeter (Model XL-845, Pacific Scientific, Bethesda, MD) standardized against a yellow reference tile ($L = 79.56$, $a = -2.17$, $b = 22.98$). Sufficient meal sample was placed in a black sample cup (91 mm diameter, CG-9260) to completely fill the cup. The lid was placed on the cup, and Hunter color readings (L, a, b) were recorded. Psychometric color terms of chroma (C), total color difference (ΔE), and hue angle ($\tan^{-1} b/a$) were calculated from values for L (lightness), $+a$ (redness), $-a$ (greenness), $+b$ (yellowness), and $-b$ (blueness) (Hunterlab, 1979).

Microbiological Quality. Microbiological quality of cowpea meal (25 g) was evaluated by adding 225 mL of 0.1% peptone and pummeling in a Colworth Stomacher for 2 min. Duplicate subsamples of each triplicate sample were analyzed. Serially diluted subsamples (0.1 mL) were surface-spread in duplicate on dichloran 18% glycerol agar (DG18 agar) (Hocking and Pitt, 1980). Plates were incubated at 25 °C in darkness for 6 days before colonies were counted. Results are reported as colony forming units (cfu) per gram of meal.

Akara Preparation and Evaluation. Cowpeas stored for 18 months were processed into meal as described above and used to prepare akara. Samples for this phase of the study were prepared from seeds that had textures ranging from soft to hard (selected from Table 1).

Paste Preparation. Because HTC seeds had less soluble solids and absorbed less water during soaking than control seeds, it was necessary to compensate for these characteristics by adjusting the amount of water used in paste preparation. The amount of water added to 200 g of cowpea meal was adjusted to 54% (196 mL), 58% (233 mL), or 62% (279 mL); hydration time varied from 0 to 60 min. Previous studies (McWatters et al., 1988, 1993) showed that meal from fresh seeds hydrated to 58% and held for 0 min after whipping had excellent batter handling properties, i.e., mechanical forming/dispensing, and produced akara balls with desirable shape, color, texture, and sensory attributes; this treatment, therefore, served as the control.

Water was added to cowpea meal in a single portion, and the mixture was stirred gently for 2 min with a rubber spatula. For paste held for 60 min, the mixing bowl was covered tightly with aluminum foil and set aside. For paste used immediately, whipping was accomplished in a mixer (Model N-50, Hobart Corp., Troy, OH) at high speed (no. 3) for 1.5 min. Paste held for 60 min was whipped according to the same procedure.

Paste Volume and Viscosity Measurements. Whipped paste was transferred to a 1000 mL graduated beaker; the beaker was tapped 10 times on a towel to settle the contents and to remove air spaces. Whipped paste volume was then recorded. Paste viscosity was measured at room temperature (~23 °C) with a viscometer (Model HATD, Brookfield Laboratories, Stoughton, MA) equipped with a no. 27 spindle at 0.5, 1, 2.5, 5, 10, 20, 50, and 100 rpm (McWatters et al., 1993). Apparent viscosity at 1 and 5 rpm was calculated according to the method of Rao and Weber (1988).

Akara Preparation. Seasonings of chopped onion (38 g), chopped bell pepper (38 g), and salt (8.5 g) were stirred together and folded into the whipped paste. The mixture was transferred to an automatic dispenser equipped with a nugget plunger (Donut Mini-Matic 110, Belshaw Brothers, Inc., Seattle, WA) and attached to a continuous fryer. Balls were fried for 2 min in peanut oil at 193 °C and were turned once after 1 min of frying. Fried products were drained on paper towels, cooled to room temperature, and packaged in resealable plastic bags (Dow Consumer Products, Inc., Indianapolis, IN).

Instrumental Color Measurement. Instrumental color measurements of the exterior surface of six akara balls per batch per treatment were obtained using the same Gardner colorimeter, sample cup, and reference tile as for cowpea meal. Individual akara balls were placed in the sample cup, which was covered with the lid. Four readings per ball were obtained by rotating the cup at 90° angles. Psychometric color terms of chroma (C),

Table 2. Effect of Process Conditions on the Characteristics of Whipped Paste and Akara Prepared with Meal Processed from Stored Cowpea Seeds[a]

sample	water added (%)	holding time (min)	cooked cowpea seed hardness (J)	foam vol (mL)	apparent viscosity		batter handling	color characteristics				texture characteristics	
					1 rpm	5 rpm		lightness	chroma[b]	total color diff[c]	hue angle[d]	force (n)	av energy (J/g)
control	58	0	6.9	688	65.7	19.5	excellent	40.3[a]	31.7[b]	43.8[f]	75.1[a]	152[e]	0.18[bc]
soft	54	0	7.0	480	146.2	68.3	good	37.0[b]	31.1[b]	47.4[e]	71.5[b]	178[de]	0.17[c]
		60	6.6	378	164.5	64.8	fair	35.8[b]	30.8[b]	48.8[de]	69.2[c]	216[cd]	0.21[b]
	58	60	7.3	663	51.4	17.1	excellent	40.6[a]	33.2[a]	44.0[f]	72.9[ab]	179[de]	0.19[bc]
hard	54	0	30.3	355	off scale	off scale	poor	33.4[cd]	33.4[a]	52.2[bc]	64.4[e]	401[a]	0.28[a]
	58	0	38.8	375	60.3	16.4	poor	31.8[d]	29.2[c]	52.9[b]	65.9[de]	218[c]	0.19[bc]
		60	30.3	375	101.1	29.4	poor	34.6[bc]	31.5[b]	50.2[cd]	67.9[cd]	198[cd]	0.16[c]
	62	60	33.5	450	85.8	20.8	poor	28.8[e]	31.2[b]	56.6[a]	62.0[f]	314[b]	0.29[a]

[a] Values in a column not followed by a common letter are significantly different at $P \le 0.05$. [b] Chroma = $(a^2 + b^2)^{1/2}$. [c] Total color difference (ΔE) = $[(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2]^{1/2}$. [d] Hue angle = $\tan^{-1} b/a$.

total color difference (ΔE), and hue angle were calculated from L, a, b values.

Instrumental Texture Measurement. The same samples used for objective color measurements were used for texture tests. Individual akara balls, which ranged in weight from 10 to 12 g, were evaluated using the same conditions as described for textural measurement of whole seeds except the chart speed was 100 mm/min. Individual balls were placed in the center of the Kramer cell for testing. The maximum force (newtons) and energy per unit mass (joules per gram) required to shear and compress akara balls were calculated from the force–deformation curves as described above for the whole seeds.

Statistical Analysis. Statistical analysis of instrumental color and texture data was performed using ANOVA and Duncan's multiple-range test procedures of the Statistical Analysis System (SAS, 1985).

RESULTS AND DISCUSSION

The effect of storage of cowpea seeds at various temperatures and RH on the physicochemical properties of cowpea meal produced from them and the texture of cooked seeds is presented in Table 1. Seeds that had been stored at 30 °C/33% RH remained soft, having low hardness values (6.6–7.8 J/g) that were similar to the control (6.2 J/g). Seeds stored at 30 °C/64% RH and 25 °C/75% RH were notably harder (16.3–34.2 J/g) than those stored at −18 °C or 30 °C/33% RH.

Cowpea meal prepared from seeds stored at 30 °C/64% RH absorbed less water (2.17–2.34 g of water/g of meal) during soaking than seeds stored at all other conditions (2.46–2.78 g of water/g of meal, Table 1). However, samples prepared from seeds stored at 25 °C/75% RH absorbed water (2.50–2.61 g of water/g of meal) to an extent not significantly different from other conditions. Meal prepared from hard seeds (those stored at 30 °C/64% RH and 25 °C/75% RH) also had significantly lower protein solubility (15.6–18.4%) than soft seeds (53.5–61.1%). Fewer solids were lost during soaking (Table 1) of hard seeds (0.16–0.18 g/g of meal) than soft seeds (0.22–0.27 g/g of meal). Conditions of storage did not significantly influence populations of viable yeasts and molds (2.4×10^2 to 8.0×10^3 cfu/g) (Table 1). The predominant mold on many samples was *Wallemia sebi*. This moderate xerophile is not uncommonly detected in stored grain and legume products.

The amount of water added to the meal prepared from the HTC seeds was increased to compensate for the low water absorption (Table 1). The effects of varying process conditions, i.e., water added and holding time, on the characteristics of whipped paste and akara prepared with meal processed from stored cowpea seeds are listed in Table 2. Data are arranged according to the hardness of cooked cowpea seeds.

Meal prepared from soft seeds (seeds stored at 30 °C/33% RH for 12–18 months) hydrated to 58% and held for 60 min produced batter most like the control with regard to foam volume, apparent viscosity, and handling properties. Soft-seed meal adjusted to 54% moisture and held for 0 or 60 min had good to fair batter handling properties but had lower foam volume and higher viscosity than the control. Akara balls made from the soft seed (58% moisture/60 min holding time treatment) were similar to the control in most color characteristics (lightness, total color difference, hue angle) and in textural characteristics (force and energy required to shear and compress). Reducing the moisture content of meal from soft seeds to 54% resulted in akara balls that were darker (lower lightness values) and browner (lower hue angle) than the control. The color intensity (chroma) and textural characteristics of akara balls from this treatment were similar to the control.

Batter handling properties of meal from hard seeds (seeds stored at 30 °C/65% RH for 12–18 months) were poor regardless of moisture content and were not improved by increasing the paste hydration time. None of the meal batters prepared from HTC seeds could be formed/dispensed mechanically but rather had to be spooned individually into the frying oil. Compared to akara balls from the control or soft-seed meal, which floated during frying and were light and spongy, all of the hard-seed-meal balls sank and were dense and compact. The poor functional properties of the hard-seed-meal batters were reflected in the color and textural characteristics of the cooked akara balls. Akara from the meal batters prepared from hard seeds differed more in total color from the control than did soft-seed products. This difference was attributed to the darker (lower lightness values) and browner (lower hue angles) character of their color rather than to intensity (chroma). The hard-seed-meal products required significantly more force to shear and compress than the control. However, adjusting the moisture content of meal from HTC seeds to 58% resulted in akara balls that required a similar amount of average energy to shear and compress as the control.

Functionality of cowpea batter for akara-making is related primarily to the minor proteins, i.e., albumins (Phillips et al., 1988). Results of the present study (Table 2) and a related study (Liu et al., 1992b) show that both water absorption and protein solubility are dramatically reduced in seeds stored at high humidity. Efforts to compensate for the loss or unavailability of components essential to the functional behavior of cowpea paste were unsuccessful. Because adjustments in process conditions (moisture content and hydration time) could not overcome the detrimental effects of storage at high humidity (64 or 75% RH), it is recommended that cowpeas be stored at low-humidity conditions (e.g., 33% RH) to retain akara-making quality.

CONCLUSIONS

Cowpeas stored at −18 °C or 30 °C/33% RH had more soluble solids, higher protein solubility, and lower cooked seed hardness than cowpeas stored at 30 °C/64% RH or 25 °C/75% RH. Cowpeas stored at −18 °C or 30 °C/33% RH and processed into meal resulted in whipped pastes with desirable handling and frying properties that made attractive akara balls. Cowpeas stored at 30 °C/64% RH and processed into meal resulted in whipped pastes that had poor handling and frying properties and akara balls that were darker and browner than control products. Adjusting the moisture content and hydration time of meal processed from HTC seeds did not improve batter dispensing properties or akara color but had a beneficial effect on texture quality. Adjusting process conditions may have potential for using HTC seeds; however, further study is required.

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