Batter Properties of Yellow Pea Flour With Respect to *Akla* Preparation[1]

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ABSTRACT

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The batter properties of yellow pea (*Pisum sativum*) flours were studied with respect to *akla*, a popular West African deep-fat fried product, normally made with cowpeas. Dehulling decreased batter specific gravity and, thus, increased batter volume. Screen size used during grinding did not greatly affect flour particle size distributions or batter apparent viscosities but significantly affected batter specific gravities. Addition of salt to the batter caused a slight decrease in specific gravity and an increase in the stability of batter viscosity. Oil uptake by *akla* increased linearly with the moisture content of the batter. Sensory panel scores showed no significant difference in preference for *akla* made from cowpeas or yellow peas among American panelists. African panelists preferred cowpea *akla*.

In West Africa, cowpeas (*Vigna unguiculata*) are used extensively as a food legume. One product commonly produced from cowpeas is *akla* or *akara*, a deep fried cowpea batter. The cowpea batter is traditionally prepared from soaked cowpeas that have been dehulled by hand to remove the undesirable color found in the hilium. McWatters and co-workers (McWatters and Flora 1980, McWatters and Brantley 1982, McWatters 1983) investigated use of the cowpea variety Dixiecream, which has little pigment in the hilium and, thus, does not require dehulling before use in *akla*.

Dry peas (*Pisum sativum*) are produced in relatively large amounts in temperate climates and have potential as a replacement for cowpeas in Africa. The states of Washington and Idaho produced 149,000 metric tons of dry peas in 1980 (USDA 1982). This production capacity is presently underutilized, whereas cowpeas have limited availability in West Africa largely because of storage problems (Dovlo et al 1976).

The purpose of this study was to investigate the batter properties of mixtures of yellow pea flour and water and to explore their suitability for the production of *akla*.

MATERIALS AND METHODS

Materials

Whole dry yellow peas (*Pisum sativum*), First and Best variety, were obtained from Dumas Seed Company, Pullman, WA. Whole dry cowpeas (*Vigna unguiculata*) were supplied by the Department of Agronomy and Range Science, University of California, Davis. Vegetable oil (Wesson oil, Hunt-Wesson Foods Inc., Fullerton, CA), iodized salt, onion, and ground ginger were purchased from a local grocery store. All chemicals used were of reagent grade.

Milling

Flour was prepared by passing whole seeds through a Quaker City Laboratory attrition mill model 4-E (The Straub Co., Philadelphia, PA). The jam nut level of the attrition mill was adjusted to produce grits instead of flour. The hull was removed from the grits by winnowing. The dehulled yellow pea grits or whole yellow peas were ground to obtain three different flours using a Udy cyclone sample mill (Udy Corp., Boulder, CO) equipped with three different screen sizes: 1-mm, 0.5-mm, or 0.4-mm mesh; the flours were designated as coarse, medium, or fine, respectively. Cowpeas were dehulled and milled into coarse flour in a similar manner. The flour samples were stored in tightly closed bottles at −25°C. Whenever flours were needed, samples were taken from the freezer and held at room temperature 8 hr before use.

Flour Analysis

The moisture content of the flour samples was determined by vacuum drying (AOAC 1980, vacuum method 24-A). Crude protein was determined by AACC macro-Kjeldahl method 46-10 (AACC 1983), using a factor of 6.25 to calculate crude protein content. Ash content was determined by AACC method 08-01 (AACC 1983). The Goldfisch fat extractor (Labcon Company, Kansas City, MO) was used for fat determination following AACC method 30-20 (AACC 1983) using petroleum ether. Neutral detergent fiber content of the flour samples was determined by the method of Van Soest and Wine (1967).

Samples of pea flour were analyzed for particle size distribution using a Ro-tap testing sieve shaker equipped with Tyler screens, numbers 35, 42, 65, 80, 100, 115, 150, 200, and 270. A 100-g flour sample was placed on the largest Tyler screen and shaken for 10 min; the fraction of flour retained on each screen was weighed to 0.01 gram.

Batter Preparation and Properties

A Hobart KitchenAid mixer (model K-5-A, Hobart KitchenAid Division, Troy, OH) equipped with a 5-qt stainless steel bowl and flat beater (catalog no. K5A-B) was used for preparing batters. For preliminary trials performed to select speed and time for whipping, 100 ml of distilled water was added to 80 g of pea flour in a mixing bowl. Whipping was performed at different speeds (4–6) and times (5–20 min). The specific gravity of the batters was determined, and the optimum speed and time were selected as speed 4 and 15 min as this combination produced a minimum specific gravity.

Apparent viscosity of the pea flour batter was determined using a Brookfield Viscometer model RVT equipped with Helipath stand (Brookfield Engineering Lab., Inc., Stoughton, MA). A T-C spindle rotating at 2.5 rpm was used. The Helipath stand (model A, serial no. 11075) lowered the T-C spindle continuously at 6.5 cm/min into the batter. The batter was placed in a 250-ml beaker of diameter 6.60 cm (Kimax no. 14000) to a height of 7 cm. Brookfield readings were taken 5 min after whipping the batter. The temperatures and pH of batter were 21±1°C and 6.40, respectively. All determinations were performed in triplicate, Brookfield dial readings transformed to centipoise, and means and standard deviations calculated. The specific gravity of all batters was determined using a calibrated 50-ml beaker. After carefully filling the beaker with batter, a small spatula was run through the batter 10 times to remove any air bubbles trapped during filling, and the beaker was filled with additional batter. A straight-edged spatula was used to scrape off excess batter. The batter specific gravity was calculated by the following formula:

$$\text{SG of batter} = \frac{\text{weight of batter in 50 ml beaker (g)}}{\text{weight of water in 50 ml beaker (g)}}.$$

The following batters were prepared: 1) Batters of 80 g of flour and 100 ml of distilled water were prepared using pea yellow flour with and without hull as described above, and viscosity and specific

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gravity were determined. 2) Batters of 80 g of dehulled coarse yellow pea flour and 100 ml of 0, 2, and 4% NaCl solutions were prepared; batter apparent viscosities were determined at 5, 10, 20, 30, 40, 50, and 60 min after whipping. 3) Batters of 60, 70, 80, 90, 100, and 110 g of coarse yellow pea flour and 100 ml of distilled water were prepared, and their apparent viscosities and specific gravities were determined. 4) Batters of 80 g of dehulled coarse pea flour or 80 g of cowpea flour and 100 ml of 0, 0.5, 1, 1.5, 2, and 4% NaCl solutions were prepared, and their specific gravities were determined.

Frying

Batters were fried in a Sunbeam deep-fat fryer with a 4-qt capacity (model T-CF-6, Sunbeam Corp., Chicago, IL). The vegetable oil was heated to 193° C. A frying thermometer was placed in the oil to monitor the frying temperature. For deep-fat frying studies, coarse yellow pea flour and coarse cowpea flour were used. The standardized formula used in *akla* preparation included 80 g of flour, 1.5 g of salt, 0.5 g of ground ginger, 25 g of minced fresh onion, and 100 ml of water. The dry ingredients were mixed in the bowl before addition of water. The mixture was whipped in the KitchenAid mixer at speed 4 for 15 min. The batter was dropped by tablespoonfuls into the oil and deep-fat fried until *akla* balls formed a golden brown crust (6 min). The balls of *akla* were turned three times to ensure even cooking. The fried *akla* were removed from the oil and drained on an absorbent paper towel.

To determine the effect of moisture on oil uptake of *akla*, yellow pea flour batters of different moisture contents were prepared as noted above using a constant volume of 100 ml of water and 60, 70, 80, 90, 100, or 110 g of pea flour. Batter was spread on a preweighed petri dish, dried at 60° C to a constant weight using a forced-draft oven, and moisture content was calculated. The remaining batter was fried as previously described. The percent dry matter of the fried product was also determined as noted above. Assuming that during frying water is lost from the batter and frying oil is absorbed, the oil uptake of the fried product was determined indirectly. On a dry weight basis, the difference in weight between dried batter and dried *akla* was taken as a measure of oil absorbed.

Specific volume of *akla* was determined 1 hr after frying by rapeseed displacement and *akla* weight.

Texture Measurement

Akla for texture measurement was prepared from 80 and 100 g of dehulled yellow pea flour per 100 ml of water. After frying, the samples were held at room temperature (approximately 23° C) for 2 hr before performing the compression test. An electric knife was used to obtain a slice 1-cm thick from the central portion of the *akla* ball. The disk of *akla* that resulted was trimmed to a square shape (1 × 1 cm).

The Fudoh rheometer (model NRM-2002J, Fudoh Kogyo Co., Tokyo, Japan) was used to measure the texture of *akla*. A special compression adapter was set at 7.5-mm (using a plastic block). The compression adaptor is a rod with a small circular plate of 10-mm diameter that sets the compression distance. The instrument sensitivity was set at 200 g. Table speed was 2 cm/min and chart speed was 10 cm/min. The sample was placed on the rheometer table and compressed to 25% of its original height (75% deformation). From the recorder chart, compression force at 50% deformation was determined. Six replicates were determined and mean and standard deviation of the force were calculated.

Sensory Evaluation

An initial preference test was done using coarse dehulled cowpea flour and coarse dehulled yellow pea flour to prepare *akla*. Twenty-three African panelists familiar with *akla* and 26 Americans unfamiliar with the product participated. A scorecard based on a 9-point scale (9 = like extremely; 1 = dislike extremely) was used. Samples were served warm (50–55° C).

A second preference test was done in which 80 and 100 g coarse yellow pea flour *akla* were evaluated by 25 American panelists. The paired *t* test was used to evaluate the preference data for statistical significance (Steele and Torrie 1981).

To evaluate differences between *akla* prepared with 80 and 100 g of yellow pea flour and that prepared with 80 and 90 g of yellow pea flour a triangle test with a balanced order of presentation was used. Tables for rapid analysis of triangle test data were employed to determine significance (Roessler et al 1978).

RESULTS AND DISCUSSION

Flour Composition

The proximate composition of pea and cowpea flours is shown in Table I. Protein content of yellow pea flour was slightly higher than in cowpea flour. The ash and carbohydrate contents of yellow peas and cowpeas were similar. However, the fat content of cowpeas was higher than that of yellow peas. Dehulling decreased the fiber content and increased protein content of yellow peas, which was to be expected because the hull of legumes is rich in fiber.

The protein content of whole yellow pea flour is higher than that reported by Kay (1979) but is within the range reported by Gueguen (1983). The protein content found for whole cowpea is in agreement with Kay (1979) and Phillips (1982), and the fat and ash contents are close to values reported by Kay (1979). The differences in composition of yellow pea and cowpea may be in part the result of environmental conditions and agricultural methods used in cultivation of the two legumes.

The aim of milling yellow peas was to produce flour suitable for making *akla*. Screens of 0.4-, 0.5-, and 1.0-mm of the Udy cyclone mill generated yellow pea flours of only slightly different particle size distribution (data not shown). The coarse, medium, and fine flours have approximately 87% flour with particle sizes between 150 and 75 microns (100–200 Tyler mesh). Screen size used in the mill significantly affected the specific gravity but not the apparent viscosity of batters (Table II).

McWatters (1983) found that 68% of the particles of a commercial Nigerian cowpea flour were between 75 and 38 μm (200–400 mesh) and did not function well in *akla* preparation. This was finer than the yellow pea flour in this study.

Batter Properties

The apparent viscosity and specific gravity of batters prepared from whole and dehulled yellow pea flour are shown in Table II.

TABLE I
Proximate Composition of Whole and Dehulled Yellow Pea Flour and Cowpea Flour

	Yellow Pea Flour		Cowpea Flour	
Component	Whole	Dehulled	Whole	Dehulled
Moisture	7.72±0.09	7.62±0.14	9.66±0.02	9.11±0.14
Protein[a]	27.40±0.28	28.06±0.11	24.53±0.31	24.28±0.22
Ash[a]	3.05±0.02	2.97±0.03	3.55±0.02	3.49±0.07
Fat[a]	0.85±0.03	0.91±0.06	2.61±0.42	1.58±0.23
Neutral detergent fiber[a]	8.13±0.88	3.27±0.18	9.24±0.80	2.44±0.07
Carbohydrates[b]	60.98	60.44	59.65	61.54

[a] Values given as percentages on moisture-free basis. Averages of triplicate determinations ± standard deviations.
[b] Carbohydrates by difference (includes neutral detergent fiber).

TABLE II
Effect of Hull and Mill Screen on Batter Properties of Yellow Pea Flours

Mill Screen	Hull	Specific Gravity[a]	Apparent Viscosity[a] (cP)
0.4 mm	+	0.48 a	103,000 a
	–	0.43 b	102,700 a
0.5 mm	+	0.48 a	105,000 a
	–	0.42 bc	99,000 a
1.0 mm	+	0.45 b	109,000 a
	–	0.41 c	106,000 a

[a] Mean values followed by same letters are not significantly different at $P < 0.05$.

The presence of the hull did not greatly affect apparent viscosity but increased the specific gravity of yellow pea flour batters. Thus, dehulling increased batter volume. These results are similar to data on the effect of dehulling on foaming of dry bean flours reported by Desphande et al (1982). Although dehulling is a common practice in the preparation of cowpeas for use in *akla*, McWatters and Flora (1980) were successful in using whole Dixiecream cowpea flour for *akla* batter preparation. The increased protein of dehulled pea flour should result in more soluble protein and increased foaming capacity of the batter.

The effect of NaCl and time after mixing on batter apparent viscosity is shown in Figure 1. Yellow pea batter viscosity decreased drastically during the first 20 min after whipping. The decrease in viscosity is less pronounced for batters with 2 or 4% NaCl, especially after 20 min. Salt is typically added to pea batter as a flavoring agent but also enhances batter stability. Batter stability is important in *akla* preparation, because the batter has to maintain proper consistency during batch frying. Fleming et al (1974), in a study of viscosity and water absorption properties of sunflower and soybean flours, observed that apparent viscosities were higher with 5% NaCl present in the batter than with water alone. They used slurries of 15% (w/w) flour and measured the apparent viscosities of the slurries immediately after preparation.

Specific gravity of batters as a function of NaCl is shown in Figure 2. The addition of salt reduced the specific gravity of both yellow pea and cowpea batters. The specific gravity of yellow pea flour batters was lower than the specific gravity of cowpea batters at all salt concentrations. This may be due in part to the higher protein content of yellow peas. Also, the albumin (water-soluble) and globulin (salt-soluble) contents of pea are 20 and 66%, respectively, of the total protein (Gueguen 1983). The albumin and globulin contents of cowpeas are 10 and 90%, respectively (Kay 1979). The higher proportion of globulins in the cowpeas would be expected to result in greater decreases in batter specific gravity as seen in Figure 2 because of the larger amount of these salt-soluble proteins going into solution upon salt addition.

The apparent viscosity of batters at different pea flour concentrations is shown in Figure 3. As expected, batters of 52.4% pea flour (110 g of pea flour/100 ml of H_2O) showed the highest apparent viscosity, and batters with 37.5% pea flour (60 g of pea flour/100 ml of H_2O) had the lowest apparent viscosity. In a study of viscosity of slurries of sunflower and soybean flour, Fleming et al (1974) noted a similar relationship.

Low-viscosity batters tended to form semi-round instead of the desired round *akla* balls when deep-fat fried. Batters of 52.4% pea flour (110 g of flour/100 ml of H_2O) were very thick and viscous (apparent viscosity 219,600 cP) and when fried, resulted in *akla* with a dry hard texture. Yellow pea batter used to prepare reference *akla* (80 g of flour/100 ml of H_2O) had an apparent

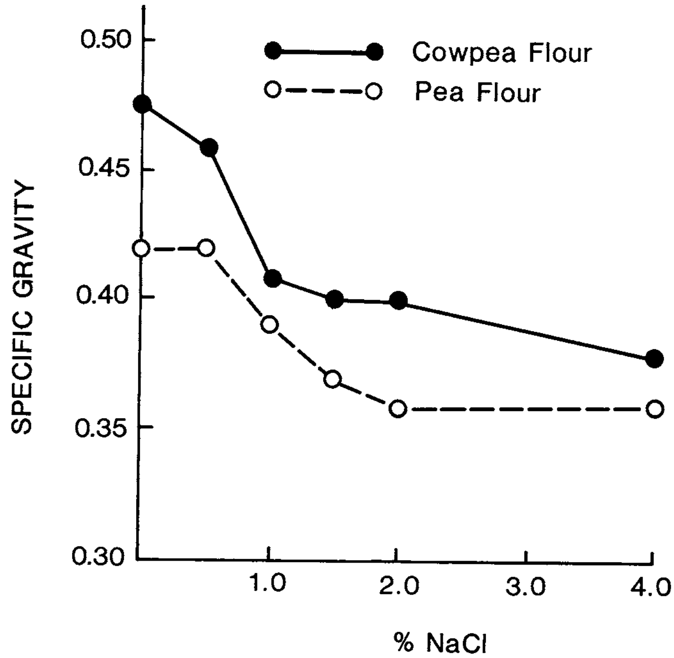

Fig. 2. Effect of NaCl on specific gravity of yellow pea and cowpea batters.

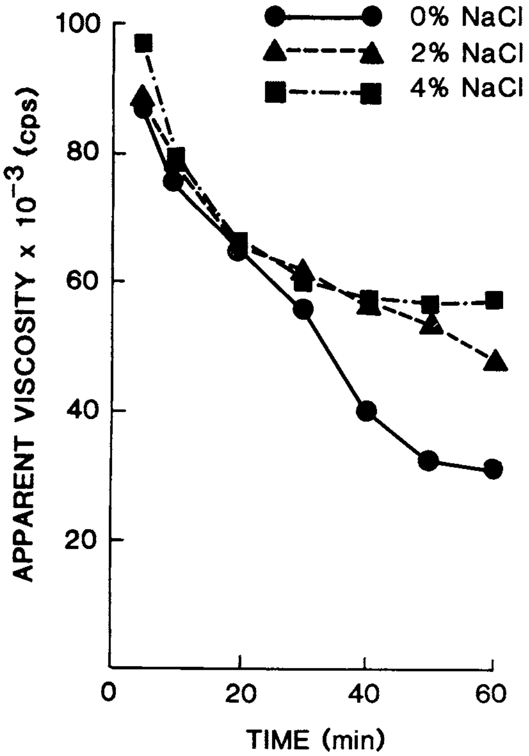

Fig. 1. Effect of NaCl and time after whipping on apparent viscosity of yellow pea batters.

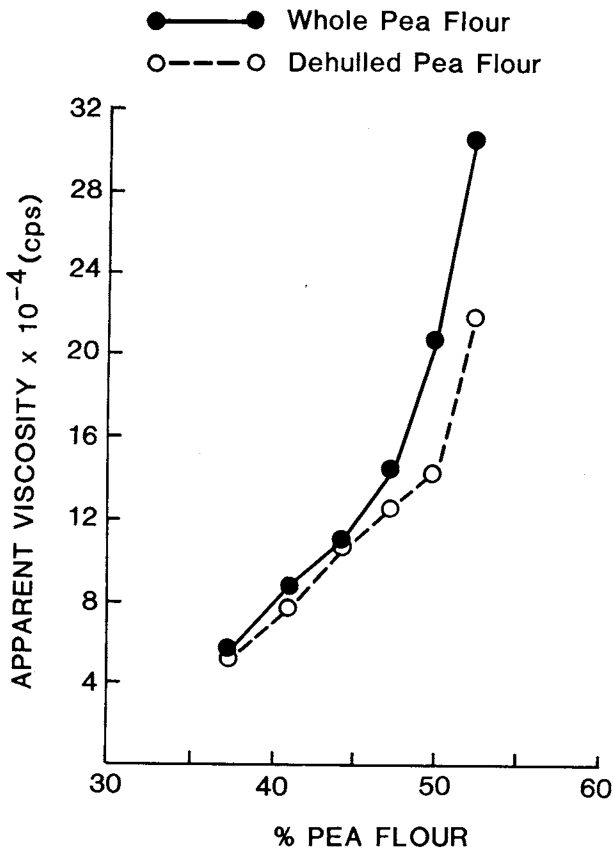

Fig. 3. Effect of yellow pea flour concentration on batter apparent viscosity.

viscosity of 107,000 cP. McWatters (1983) reported that cowpea batter of 89,500 cP (40% flour concentration) produced cowpea *akla* with uniform ball shapes. In this study, whole yellow pea flour batter of 41.2% flour concentrations (70 g/100 ml of H_2O) had apparent viscosity similar to those reported by McWatters (1983).

The specific gravity of pea batter as a function of pea flour concentration is shown in Figure 4. The specific gravity varied almost linearly with increasing concentration of pea flour in the batter for both whole and dehulled pea flour. Batters with low flour concentration (60 g of flour/100 ml of H_2O) were of large volume (low specific gravity) and made up of smaller air cells than those observed in high concentration batters.

Fried Product Properties

In the initial sensory test, American panelists commented on the greasiness of *akla*. It was observed that yellow pea batters of high moisture content absorbed large amounts of oil during frying resulting in undesirable greasiness. The effect of batter moisture on oil uptake of *akla* is shown in Figure 5. The data show a positive relationship between moisture content of batter and oil absorbed. If these data are replotted in terms of the percentage of oil absorbed as a function of *akla* moisture content a negative linear relationship is noted. Wheeler and Stingley (1963) and McWatters and Flora (1980) noted similar relationships in cake doughnuts and cowpea *akara* (*akla*), respectively. In the latter study whipping time was the variable under investigation. As whipping time increased an increase in batter volume resulted which in turn gave lower moisture fried products with higher oil contents. The increase in volume upon increased whipping time noted by McWatters and Flora (1980) is analagous to the reduction in specific gravity seen here when moisture level of the batter is increased (Fig. 4). This suggests that the specific gravity of the batter is an important factor in oil absorption.

The effect of batter moisture on the structure of pea *akla* is illustrated in Figure 6. The *akla* from high-moisture batter (60 g of flour/100 ml of H_2O) had a thick crust and open texture. Akla from intermediate moisture batter (80 g of flour/100 ml of H_2O) had a fine to moderately open, even texture. Akla made from low-moisture batter (100 g of flour/100 ml of H_2O) had a thin crust and a fine, compact, even texture. Batter of intermediate moisture made *akla* that was most typical of traditional cowpea *akla*.

The effect of batter specific gravity on *akla* specific volume is shown in Figure 7. Batters having lowest specific gravities (0.27 and 0.29) when fried produced *akla* with lower specific volumes than expected. It was noted that batters with lowest specific gravities were fluid and not able to retain the round shape of *akla* balls. These batters probably did not have sufficient strength to withstand the expansion of aircells and increased water vapor pressure in the batter during frying.

Sensory Evaluation

The taste panel data for the preference test for pea *akla* and cowpea *akla* are presented in Table III. The American panelists, unfamiliar with the product, rated yellow pea *akla* slightly higher than cowpea *akla*. These panelists commented that cowpea *akla* had a strong beany flavor. They also commented that *akla* balls were too greasy. The African panelists who were familiar with the strong beany flavor of cowpea *akla* showed a preference for it over the pea product. However, the mean preference score of 7.7 by African taste panelists does indicate that they liked the yellow pea *akla* moderately.

A triangle test was performed to determine the effect of moisture content of batter on sensory properties of yellow pea *akla*. Panelists determined differences between *akla* prepared using 80 or 100 g of yellow peas and also between 80 and 90 g of pea *akla*. There was a significant difference ($P < 0.001$) between *akla* of 80 and 100 g of pea flour (9 correct identifications out of 10 judgments) and also between 90 and 80 g of pea *akla* (13 correct identifications out of 13 judgments). This indicated that by changing the moisture content of pea batter it was possible to change the sensory properties of pea *akla*.

The triangle test showed that there were significant differences

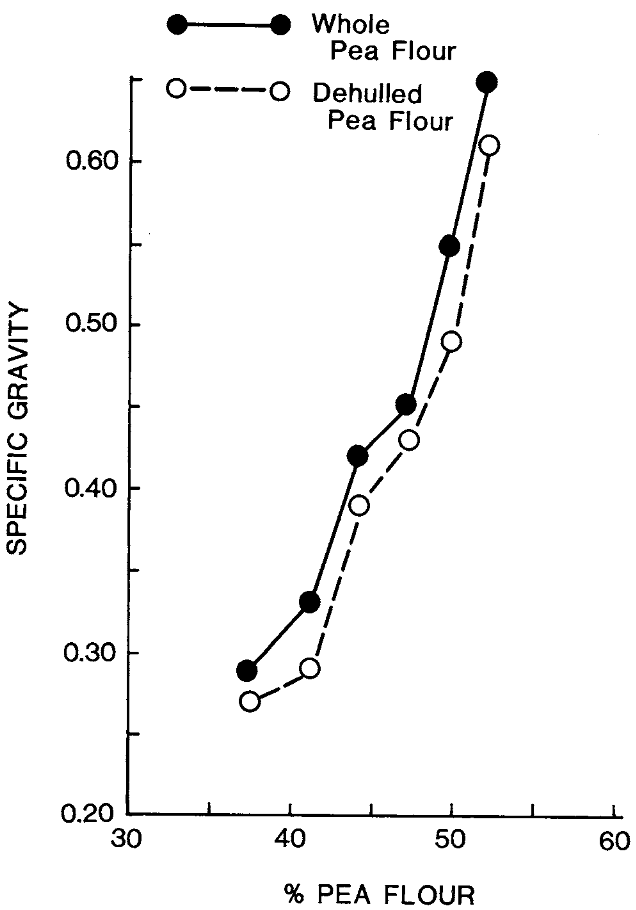

Fig. 4. Effect of yellow pea flour concentration on batter specific gravity.

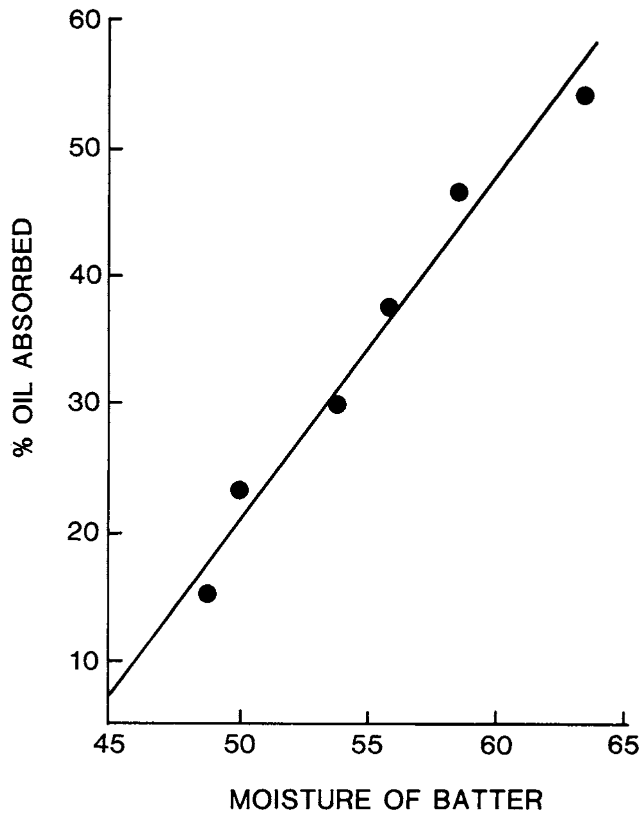

Fig. 5. Effect of moisture content of yellow pea batter on oil uptake during frying.

between the three selected treatments. Akla from two treatments, 80 and 100 g of pea flour batter, were selected for a second preference test. The results of the taste panel evaluation are summarized in Table IV. The preference data suggest that *akla* from 80 and 100 g of pea flour were equally acceptable by taste panelists. Panelists making comments concerning 80 g pea *akla* noted the desirable crust and soft moist texture but undesirable greasiness of the product. Panelists who commented on the 100 g *akla* noted that it had a dry texture and reduced greasiness.

Preference tests indicated that texture as well as greasiness affected the acceptability of *akla*. Therefore, a rheometer was used to determine if there were differences in texture between the 80 and 100 g yellow pea *akla* used in the second preference test. Akla from 80 g of pea flour was more compressible than *akla* made from 100 g of yellow pea flour (Table V). These data coupled with the sensory data suggest that texture is a major factor affecting the acceptability of *akla*.

The fact that texture and greasiness were mentioned by the panelists suggests that both parameters influence the acceptability of the product. However, the two factors apparently counter balance one another as there was no significant difference in acceptability between products that differ in texture (Table V) and amount of oil absorbed (36% oil absorbed for the 80-g product vs. 24% for the 100-g product).

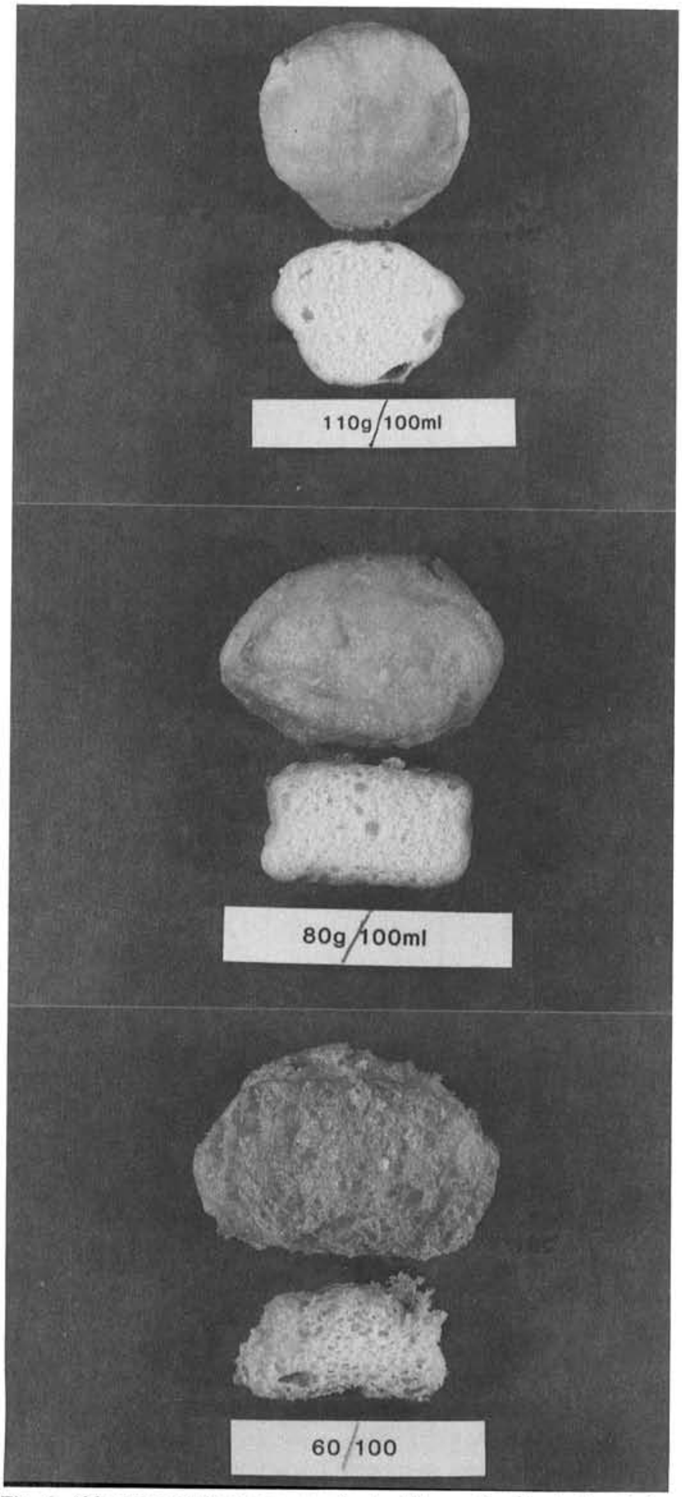

Fig. 6. *Akla* prepared from a range of water/flour ratios illustrating their effect on product structure.

TABLE III
Sensory Evaluation of *Akla*: Initial Preference Test

	Mean Preference Score[a]	
Type of *Akla*	**Americans**	**Africans**
Yellow pea	6.7 a	7.7 a
Cowpea	6.1 a	8.5 b

[a]Based on a nine-point scale with 9 = like extremely; 1 = dislike extremely. There were 26 American panelists and 25 African panelists. For a given panel, mean score followed by the same letter is not significantly different ($P<0.05$). *Akla* prepared with 80 g of flour and 100 ml of H_2O.

TABLE IV
Second Preference Test by American Panelists

Treatment (gm yellow pea flour/100 ml water)	Mean Preference Score[a]	Standard Deviation
80	6.12 a	1.49
100	6.68 a	1.42

[a]Based on a nine-point scale with 9 = like extremely; 1 = dislike extremely. Mean score followed by the same letter is not significantly different ($P<0.05$) $n = 25$.

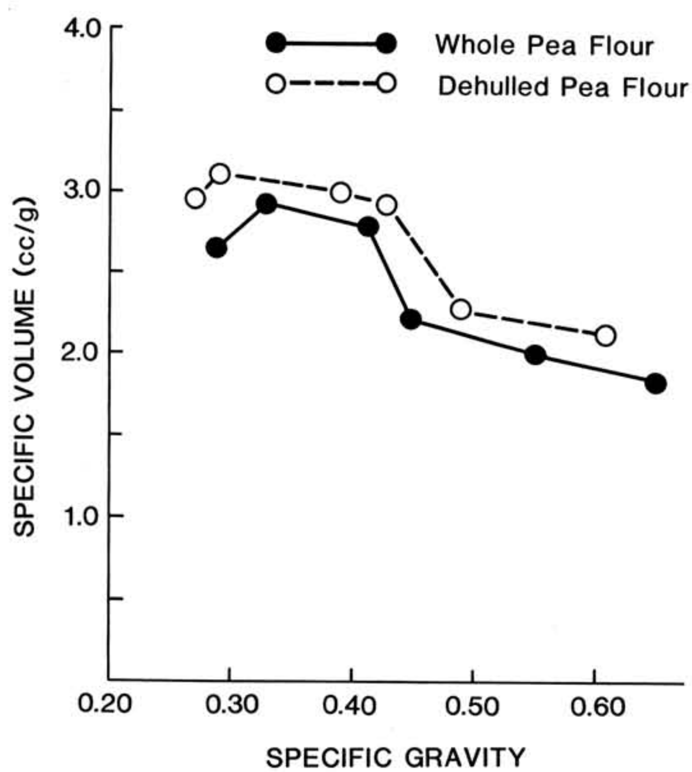

Fig. 7. *Akla* specific volume as a function of batter specific gravity.

TABLE V
Specific Volume and Compressibility of *Akla*

Treatment	Compression Force (g)[a]	Specific Volume (cm^3/g)[a]
80[b]	98.13 a ± 11.90	3.00 a ± 0.05
100[c]	198.22 b ± 31.76	2.22 b ± 0.06

[a] Mean values ± standard deviation. Mean values followed by the same letter in the same column within the same test are not significantly different at the 5% level.
[b] *Akla* from 80 g of pea flour and 100 ml of H_2O.
[c] *Akla* from 100 g of pea flour and 100 ml of H_2O.

CONCLUSIONS

The influence of several factors on the specific gravity and apparent viscosity of yellow pea flour batter was investigated. The presence of the hull in the batter resulted in increased specific gravity and, thus, decreased batter volume. A Udy cyclone mill equipped with screens of 0.4-, 0.5-, and 1-mm produced yellow pea flour of only slightly different particle size distribution. The flours produced with these three screens produced batters that were not significantly different in specific gravity.

Addition of salt (2–4% NaCl) caused a decrease in specific gravity and increased apparent viscosity stability of batters, possibly via increased protein solubilization.

Moisture content of the yellow pea flour batter had a linear relationship with oil absorption of *akla*. Although lowering moisture content of batters reduced oil absorption of the fried product, texture characteristics were also affected, i.e., low-moisture batters produced a heavy textured *akla*.

Sensory panel scores showed that there was no significant difference in preference for *akla* from dehulled cowpea or dehulled yellow pea among American panelists. However, cowpea *akla* was significantly preferred by African panelists at the 5% level.

A second preference test with American panelists using dehulled yellow pea flour at 44.4% concentration (80 g of pea flour/ 100 ml of H_2O) and 50% (100 g of pea flour/ 100 ml of H_2O) indicated that the acceptability for pea *akla* is influenced by both the texture and greasiness of the fried product as shown by comments from taste panelists.

This study showed that yellow pea flour could successfully be used to prepare *akla*. Of the batter parameters investigated, moisture content had the greatest effect on *akla* quality.

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