# Pasting Properties of Cowpea Flour: Effects of Soaking and Decortication Method

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Pasting properties of flour prepared from 12 diverse cowpea varieties as affected by dry and wet decortication processes were determined using a Brabender viscoamylograph. Dry decorticated flour (DDF) was prepared from seeds wetted, dried, and mechanically dehulled; wet decorticated flour (WDF) was prepared from seeds soaked, manually decorticated, dried, and milled to flour. No pasting peak was obtained during heating of flour slurry to 95 °C for both DDF and WDF for all cowpea varieties. WDF samples had higher paste viscosities than DDF samples. Presoaking of seeds (2, 4, 8, or 16 h) affected paste viscosities, especially hot paste viscosity (HTPV), and particle size distribution. Maximum HTPV and highest quantities of medium-size particles (mesh 40−80, 0.42−0.177 mm) were attained with flour prepared from seeds presoaked for 4 h. Presoaking for more than 4 h did not yield further increase in HTPV. Cowpea flour with at least 65% of medium-size particles exhibited the best hydrothermal properties, leading to increased rate of moisture absorption and higher HTPV during aqueous heating of slurry.

**Keywords:** *Cowpea (Vigna unguiculata) flour; pasting properties; presoaking; decortication*

## INTRODUCTION

Cowpeas (*Vigna unguiculata*) are probably the most popular grain legume in West Africa. Unlike other legumes such as soybeans and groundnuts, which are oil-protein seeds, cowpeas are starch-protein seeds offering a wider pattern of utilization than any other legume in West Africa. They are consumed either as a boiled vegetable alone or in combination with other foods such as rice, maize, and cassava products, or they can be processed into various recipes. Cowpea paste is the principal ingredient for the preparation of two popular West African foods, akara (fried cowpea paste) and moin-moin (steamed cowpea paste). Traditional paste processing from cowpea seeds involves the combined operations of soaking, decorticating, and milling, which are time-consuming and labor-intensive and have to be repeated each time these products are required. Cowpea flour, which can be simply hydrated to make paste, offers a convenient alternative. However, limited success has been achieved in establishing cowpea flour as a convenient starting ingredient, largely because of its failure to give product characteristics as acceptable as those from fresh paste (Dovlo et al., 1976; McWatters and Brantley, 1982; McWatters, 1983; Henshaw and Lawal, 1993).

Functional properties are physicochemical properties that give information on how a food ingredient will behave in a food system. The functionality of cowpea flour can logically be attributed to its chemical components as determined by the genetic architecture of the seed and the postharvest conditions of storage and processing. Properties such as solubility, viscosity, water and fat binding, emulsification, foaming, and gelation are of general interest (Hermansson, 1979).

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While several in-depth studies have been reported on the storage and processing conditions that influence cowpea flour functionality (McWatters and Chhinnan, 1985; Enwere and Ngoddy, 1986; Ngoddy et al., 1986; McWatters et al., 1987, 1988; Phillips et al., 1988), much less has been done to investigate the influence of possible variation in the genetic constitution of cowpea varieties on the functionality of flour. Genetic variability in starch structure and functional properties has been reported in other foods, for example, maize (Shannon and Garwood, 1984; Katz, 1991).

A long-established method for characterizing paste viscosity in starch and starch-containing systems is the Brabender viscoamylograph test in which viscosity is plotted versus time during a standard cycle of heating and cooling with continuous stirring. This technique has been extensively used to study pasting characteristics of cereal starches and flours and to obtain data that relate to their functionality in various food systems. Brown and Harrel (1944) observed a strong positive correlation between maximum viscosity as measured by the amylograph and the baking quality of rye flour. Shuey and Gilles (1964) studied the pasting characteristics of three varieties of durum wheat and found a relationship between the amylograms of cooked semolina and cooked macaroni. In Japanese-type noodles, the paste viscosity of the noodle flour was found to be related to noodle cooking quality (Bean et al., 1974). Halick and Kelly (1959) and Ferrel and Pence (1964) reported amylograph studies relating pasting properties to cooking quality of rice varieties. Various other studies that used the amylograph to study noncereal foods include the following: investigation of α-amylase activity in soybeans (Ofelt et al., 1955; Learmonth and Wood, 1960); studies on potato starch pasting properties (Svegmark and Hermansson, 1991; Wiesenborn et al., 1994); assessment of starches from chickpea, cowpea, and horsegram (El Faki et al., 1983); properties of various legume starches (Tolmasquim et al., 1971); and

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**Table 1. Horticultural Characteristics of Cowpea Varieties**

| variety | seed coat texture | seed shape | hilum color | seed coat color |
|---|---|---|---|---|
| Vita 5[a] | wrinkled | kidney | black | white |
| TVX 3236[a] | wrinkled | rhomboid | brown | cream/brown |
| California Blackeye 5[b] | wrinkled | kidney | black | white |
| White Acre[c] | smooth | globose | cream | creamy white |
| Mississippi Silver[b] | smooth | crowder | brown | brown |
| Better Green Cream[c] | smooth | globose | light green | cream |
| Pinkeye Purple Hull[d] | wrinkled | ovoid | dark red | cream |
| Texas Cream 40[d] | wrinkled | rhomboid | light yellow | white |
| White California Blackeye A[e] | wrinkled | kidney | light yellow | white |
| White California Blackeye B[e] | wrinkled | kidney | light yellow | white |
| IAR-339-1[f] | wrinkled | kidney | brown | white |
| Ife Brown[g] | wrinkled | rhomboid | brown | brown |

[a] International Institute of Tropical Agriculture, Ibadan, Nigeria. [b] Pennington Seed Co., Madison, GA. [c] Southern Frozen Foods, Montezuma, GA. [d] C. T. Smith Co., Pleasanton, TX. [e] Department of Botany and Plant Sciences, University of California, Riverside, CA. [f] National Seed Service, Federal Department of Agriculture, Ibadan, Nigeria. [g] Institute of Agricultural Research and Training, Moore Plantation, Ibadan, Nigeria.

bread-making and physicochemical properties of cassava flour (Defloor et al., 1994).

The pasting properties of cowpea flour during aqueous heating are influenced by varietal differences, chemical components, and processing and storage conditions. Changes in pasting properties would undoubtedly influence functional behavior of cowpea flour in various food systems. The objective of this study was to investigate the effects of presoaking and decortication method on the pasting properties of flour prepared from 12 cowpea varieties.

## MATERIALS AND METHODS

**Cowpeas.** Twelve cowpea varieties were obtained from various research institutes and agricultural institutions in the United States and Nigeria (Table 1).

**Flour Preparation.** *Dry Decorticated Flour (DDF).* Mature, clean dry seeds were conditioned for mechanical decortication by wetting to increase seed moisture content from approximately 10 to 25% as described by McWatters et al. (1988). Seeds were allowed to equilibrate for 30 min with occasional stirring and then dried in a forced-air oven at 70 °C. Seed coats were removed by first cracking in a plate mill (Model 4E, The Straub Co., Hatboro, PA); detached seed coats were then removed in a seed cleaner (Alamco seed cleaner, Allan Machine Co., Ames, IA). Decorticated seeds were milled through a 1.0 mm screen in two passes in a Wiley laboratory mill (Model 4, Arthur H. Thomas Co., Philadelphia, PA) as suggested by Ngoddy et al. (1986).

*Wet Decorticated Flour (WDF).* Seeds were soaked in water for 30 min to soften the seed coat. The seed coats were removed manually by rubbing between the palms and floating off detached seed coats in water. Decorticated seeds were drained, dried, and milled as described for DDF. This wet decortication method simulates the traditional West African method used in the preparation of cowpea paste.

*Dry Decorticated Flour with Presoaking (DDFS).* On the basis of the paste viscosity data, California Blackeye 5 and Texas Cream 40 were selected to reflect varieties with high and low, respectively, hot paste viscosities for both DDF and WDF samples. Decortication was accomplished as described for DDF but with additional presoaking treatments (2, 4, 8, or 16 h). After presoaking, seeds were dried at 70 °C, seed coats were mechanically removed, and decorticated seeds were milled into flour as described for DDF.

**Pasting Properties.** A Brabender viscoamylograph (Model VA-VE/PT-100, C. W. Brabender Instruments, Inc., So. Hackensack, NJ) equipped with a 700 cm.gf cartridge was used to determine the pasting properties of all flour samples. The homogeneous flour slurry (12% w/w, flour:deionized water) was heated from 50 to 95 °C at a uniform rate of 1.5 °C/min with constant stirring at 75 rpm, held at 95 °C for 30 min, then cooled to 50 °C at the same rate, and held at this temperature for another 30 min. Paste viscosities determined were hot paste viscosity (HTPV, viscosity attained at 95 °C), cooked paste viscosity (CKPV, viscosity after holding at 95 °C for 30 min), setback paste viscosity (STBV, viscosity on cooling from 95 to 50 °C), and cooled paste viscosity (CLPV, viscosity after holding at 50 °C for 30 min). Pasting temperature was defined as the temperature at which an increase in viscosity was first observed. Hot paste capacity index (HPCI) was calculated as the ratio of CKPV to HTPV. Paste setback ratio (PSER) was calculated as the ratio of STBV to CKPV and cooled paste stability ratio (CPSR) as the ratio of CLPV to STBV. Duplicate determinations were made for each flour sample.

**Particle Size Distribution.** Particle size distribution of flour was determined by a slight modification of methods described by Phillips et al. (1988) and Ngoddy et al. (1986). Fifty grams of flour was sieved through a set of graded sieves [mesh 20 (0.850 mm), 30 (0.595), 40 (0.420), 50 (0.297), and 60 (0.250) and collecting pan, U.S. standard testing sieve, ASTM E-11 specifications, W. S. Tyler, Inc., Mentor, OH]. The stack of sieves was mechanically shaken for 10 min, and the material on each sieve was collected and weighed. The material in the collecting pan was then transferred to a second set of sieves [mesh 80 (0.177 mm), 100 (0.149), 140 (0.105), 200 (0.074), and 400 (0.037) and collecting pan] and shaken for 10 min. Duplicate determinations were made per sample. Particle size distribution was reported as percent of flour retained in coarse (mesh 20 and 30), medium (mesh 40, 50, 60, and 80) and fine (mesh 100, 140, 200, and 400) sieves.

**Statistical Analysis.** Analysis of variance (ANOVA) was used to determine differences in each of the pasting properties (i.e., HTPV, CKPV, STBV, CLPV, HPCI, PSER, and CPSR) of flour as influenced by varietal differences, presoaking treatments, and decortication methods. Tukey's Studentized range test was performed for post-hoc multiple comparisons. Group differences, expressed in terms of differences in mean vectors of the pasting properties (HTPV, CKPV, STBV, and CLPV), were determined using multivariate analysis of variance (MANOVA). Canonical discriminant analysis (PROC CANDISC, SAS version 6.03, 1988) was subsequently performed to identify paste viscosities that underlie group differences among flours, both DDF and WDF, prepared from different cowpea varieties. The pairwise squared (Mahalanobis) distances and probabilities between varieties and plots of canonical variables were determined.

## RESULTS AND DISCUSSION

**Pasting Properties: Varietal Differences and Effects of Decortication Method.** The 12 diverse cowpea varieties showed distinct differences in external physical characteristics (Table 1). Pasting properties of cowpea flour for both DDF and WDF are presented in Table 2. Considerable variation in paste viscosities at different points of the viscoamylograms, i.e., HTPV, CKPV, STBV, and CLPV, was observed. For instance, for the DDF samples, HTPV values ranged from 75 Brabender units (BU) for the White Acre variety to 245 BU for the Mississippi Silver variety. For the WDF samples, HTPV values ranged from 100 BU for White Acre to 270 BU for California Blackeye 5. Results from the analysis of variance (ANOVA) indicate that differences in paste viscosities exist (at $p = 0.05$, Table 2) and are undoubtedly due to varietal differences, regardless of the decortication method employed. In addition to ANOVA, multivariate analysis of variance (MANOVA) was performed to determine if there is a difference

**Table 2. Pasting Properties of 12% Cowpea Flour Slurries**[a]

| process[b] | variety | HTPV[c] | CKPV[d] | STBV[e] | CLPV[f] | HPCI[g] | PSER[h] | CPSR[i] | pasting temp (°C) |
|---|---|---|---|---|---|---|---|---|---|
| DDF | Vita 5 | 117.5 cd | 195 c | 247.5 cdef | 242.5 cde | 1.66 bc | 1.27 abc | 0.98 a | 79.6 |
| | TVX 3236 | 140 bcd | 232.5 bc | 295 c | 290 c | 1.66 bc | 1.27 abc | 0.98 a | 81.1 |
| | California Blackeye 5 | 230 a | 305 a | 355 b | 350 b | 1.33 c | 1.16 bcd | 0.99 a | 80.9 |
| | White Acre | 75 e | 135 d | 195 f | 195 e | 1.80 bc | 1.44 a | 1.00 a | 80.6 |
| | Mississippi Silver | 245 a | 310 a | 412.5 a | 420 a | 1.27 c | 1.33 ab | 1.02 a | 77.9 |
| | Better Green Cream | 110 de | 202.5 bc | 267.5 cd | 267.5 cd | 1.84 bc | 1.32 ab | 1.00 a | 79.6 |
| | Pinkeye Purple Hull | 107.5 de | 217.5 bc | 255 cde | 247.5 cde | 2.02 ab | 1.17 bcd | 0.97 a | 82.7 |
| | Texas Cream 40 | 77.5 e | 200 c | 217.5 def | 210 de | 2.58 a | 1.09 cd | 0.97 a | 81.5 |
| | White California Blackeye A | 110 de | 200 c | 210 ef | 200 e | 1.83 bc | 1.05 d | 0.95 a | 81.9 |
| | White California Blackeye B | 170 b | 240 b | 270 cd | 260 cd | 1.41 bc | 1.13 cd | 0.96 a | 81.1 |
| | IAR-339-1 | 157.5 b | 227.5 bc | 300 bc | 290 c | 1.44 bc | 1.32 ab | 0.97 a | 80.3 |
| | Ife Brown | 150 bc | 210 bc | 260 cde | 260 cd | 1.40 c | 1.24 bcd | 1.00 a | 79.6 |
| WDF | Vita 5 | 122.5 de | 215 cd | 282.5 ef | 265 ef | 1.76 abc | 1.31 abc | 0.94 a | 78.8 |
| | TVX 3236 | 170 b | 270 b | 360 bc | 340 cd | 1.59 cde | 1.33 abc | 0.94 a | 80.0 |
| | California Blackeye 5 | 270 a | 330 a | 417.5 a | 400 b | 1.22 f | 1.27 abc | 0.96 a | 80.3 |
| | White Acre | 100 e | 190 d | 275 ef | 275 ef | 1.90 ab | 1.45 a | 1.00 a | 79.2 |
| | Mississippi Silver | 260 a | 337.5 a | 460 a | 460 a | 1.30 ef | 1.36 ab | 1.00 a | 79.2 |
| | Better Green Cream | 102.5 e | 190 d | 260 f | 260 f | 1.85 abc | 1.37 ab | 1.00 a | 80.9 |
| | Pinkeye Purple Hull | 120 e | 237.5 bc | 345 bc | 340 cd | 1.98 a | 1.45 a | 0.99 a | 82.2 |
| | Texas Cream 40 | 172.5 b | 277.5 b | 332.5 bcd | 320 cde | 1.61 bcd | 1.20 bc | 0.96 a | 80.3 |
| | White California Blackeye A | 130 cde | 250 bc | 280 ef | 267.5 ef | 1.93 a | 1.12 c | 0.96 a | 81.9 |
| | White California Blackeye B | 165 bc | 257.5 bc | 320 cde | 302.5 def | 1.56 cde | 1.24 abc | 0.95 a | 80.3 |
| | IAR-339−1 | 177.5 b | 280 b | 370 b | 365 bc | 1.58 cde | 1.32 abc | 0.99 a | 78.4 |
| | Ife Brown | 157.5 bcd | 220 cd | 290 def | 285 def | 1.40 def | 1.32 abc | 0.98 a | 79.2 |

[a] For all DDF samples (or all WDF samples), mean values in a column not followed by the same letter are significantly different ($p = 0.05$). Viscosity is reported as BU (Brabender unit). [b] DDF, dry decorticated flour; WDF, wet decorticated flour. [c] HTPV, hot paste viscosity at 95 °C. [d] CKPV, cooked paste viscosity after holding at 95 °C for 30 min. [e] STBV, setback paste viscosity on cooling from 95 to 50 °C. [f] CLPV, cooled paste viscosity after holding at 50 °C for 30 min. [g] HPCI, hot paste capacity index (CKPV/HTPV). [h] PSER, paste setback ratio (STBV/CKPV). [i] CPSR, cooled paste stability ratio (CLPV/STBV).

among DDF or WDF samples, considering simultaneously the effects of all paste viscosities evaluated in this study. The $p$ value of MANOVA's statistics are Wilks' lambda ($p = 0.0001$ and 0.0001), Pillai's trace ($p = 0.0001$ and 0.0001), Hotelling-Lawley trace ($p = 0.0001$ and 0.0001) and Roy's greatest root ($p = 0.0001$ and 0.0001), respectively, for the DDF and WDF samples. These $p$ values substantiate the existence of differences among flours as also observed in ANOVA.

The increase in viscosity that occurs when starch or starchy materials are sufficiently heated in excess water is the result of swelling of starch granules during gelatinization. Gelatinization is an order−disorder phase transition that involves diffusion of water into the starch granules, hydration and swelling, uptake of heat, loss of birefringence and crystallinity, and amylose leaching (Olkku and Rha, 1978; Biliaderis et al., 1980). The changes that occur after starch gelatinization are termed pasting (Hoseney, 1986). The temperature range over which gelatinization occurs is characteristic of the particular type of starch. The observed differences in paste viscosity among cowpea varieties in this study are therefore indicative of variation in the hydration and swelling capacities of their starches. According to Miller et al. (1973), viscosity increase is due mainly to the formation of an extrudate network around starch granules. According to Schoch and Maywald (1968), the Brabender hot paste viscosity patterns of various legume starches were determined by two factors: first, the extent of swelling of the starch granules, and second, the resistance of swollen granules to dissolution by heat or fragmentation by shear.

The pasting pattern of cowpea starch in a heterogeneous system such as in flour may, however, be quite different from that obtained in a single-component system such as in extracted starch. This thought is confirmed by comparisons of the pasting pattern of extracted cowpea starch with that of cowpea flour obtained in this study (data not shown). Distinct pasting peaks and high paste viscosities of cowpea starch were observed by Tolmasquim et al. (1971) and El Faki et al. (1983), while in this study, no pasting peak and lower paste viscosities were obtained from flour pasting at similar starch concentrations.

Cowpea flour contains other substances such as protein, lipid, and minerals that may interact with starch to varying degrees. Protein and starch are known to interact due to attraction of their opposite charges and during gelatinization form complexes (Pomeranz, 1985). These substances may also influence the hydration rate of starch granules by binding water in competition with starch (Whistler and Daniel, 1985). Paste characteristics of cowpea flour would, therefore, be affected by these interactions and by other factors such as the components of the starch granules (i.e., the amylose:amylopectin ratio), starch granule size, and other physical and chemical properties.

Results from canonical discriminant analysis identified HTPV as the variable that best explains the differences among flours for both DDF and WDF processes. The canonical correlation (cc) between the HTPV values and the linear composite (HTPV + CKPV + STBV + CLPV) values was highly positive. Analysis of dimensionality (data not shown) indicated that only two dimensions can explain over 90% of the variance. For the DDF samples, the first dimension, which accounts for 75.7% of the variance, mainly consists of HTPV (cc = 0.93) and CKPV (cc = 0.73). For the WDF samples, the first dimension, which accounts for 73.0% of the variance, mainly consists of HTPV (cc = 0.94) and STBV (cc = 0.77). Higher HTPV values were obtained in most varieties for the WDF samples than for the DDF samples, except for the Better Green Cream and White California Blackeye B varieties (Table 2). A drastic increase (ca. 122%) in HTPV was observed for the Texas Cream 40 variety, which had HTPVs of 77.5 BU for DDF and 172.5 BU for WDF. The major difference between the DDF and WDF processes is the amount of water imbibed by the seeds prior to decortication, drying, and milling. In the DDF process, seeds were merely surface wetted to increase the moisture content from 10% to 25%, while in the WDF process, seeds were soaked in

**Table 3. Pasting Properties of Flour Slurries from Cowpea Seeds Presoaked for Different Times**[a]

| variety | flour sample[b] | soaking time (h) | HTPV | CKPV | STBV | CLPV | HPCI | PSER | CPSR | pasting temp (°C) |
|---|---|---|---|---|---|---|---|---|---|---|
| Texas Cream 40 | DDF | 0 | 77.5 c | 200 e | 217.5 e | 210 e | 2.58 a | 1.09 d | 0.97 a | 81.5 |
| | WDF | 0.5 | 172.5 b | 277.5 d | 332.5 d | 320 d | 1.61 bc | 1.20 bc | 0.96 a | 80.5 |
| | $DDFS_2$ | 2.0 | 177.5 b | 340 c | 437.5 bc | 425 bc | 1.92 b | 1.29 a | 0.97 a | 80.3 |
| | $DDFS_4$ | 4.0 | 260 a | 445 a | 545 a | 525 a | 1.71 bc | 1.22 ab | 0.96 a | 80.2 |
| | $DDFS_8$ | 8.0 | 177.5 b | 347.5 bc | 392.5 c | 390 c | 1.96 b | 1.13 c | 0.99 a | 79.6 |
| | $DDFS_{16}$ | 16.0 | 260 a | 382.5 b | 457.5 b | 442.5 b | 1.47 c | 1.19 bc | 0.97 a | 79.2 |
| California Blackeye 5 | DDF | 0 | 230 d | 305 d | 355 e | 350 e | 1.33 a | 1.16 b | 0.99 a | 80.9 |
| | WDF | 0.5 | 270 c | 330 cd | 417.5 d | 400 d | 1.23 ab | 1.27 ab | 0.96 a | 80.4 |
| | $DDFS_2$ | 2.0 | 325 b | 410 b | 522 b | 510 b | 1.26 ab | 1.28 ab | 0.98 a | 80.4 |
| | $DDFS_4$ | 4.0 | 435 a | 460 a | 600 a | 590 a | 1.06 bc | 1.30 a | 0.98 a | 80.4 |
| | $DDFS_8$ | 8.0 | 305 bc | 360 c | 445 c | 447.5 c | 1.18 abc | 1.24 ab | 1.01 a | 80.4 |
| | $DDFS_{16}$ | 16.0 | 410 a | 405 b | 500 b | 495 b | 0.99 c | 1.23 ab | 0.99 a | 80.0 |

[a] For all samples prepared from Texas Cream 40 (or from California Blackeye 5), mean values in a column not followed by the same letter are significantly different ($p = 0.05$). [b] DDF, dry decorticated flour; WDF, wet decorticated flour; $DDFS_2$, $DDFS_4$, $DDFS_8$, $DDFS_{16}$, dry decorticated flour prepared from seeds presoaked for 2, 4, 8, or 16 h, respectively. See Table 2 for other abbreviations.

water and remained in water while the seed coats were manually removed. To better understand the basis of the increase in HTPV and other paste viscosities by the WDF process, two varieties (Texas Cream 40 and California Blackeye 5) were used in a subsequent experiment to investigate the effects of soaking; the results are discussed in the next section.

HPCI is defined as CKPV/HTPV and, without exception, the CKPV values are greater than HTPV values; therefore, an HPCI value of 1.0 or greater indicates the degree of resistance of swollen starch granules to mechanical disintegration upon holding at 95 °C for 30 min. HPCI ranged from 1.27 to 2.58 and from 1.22 to 1.98, respectively, for the DDF and WDF samples. The method of decortication did not drastically affect HPCI, except for Texas Cream 40, for which HPCI of 2.58 for DDF is much greater than that (1.61) for WDF. High HTPV of flour (e.g., from California Blackeye 5, Mississippi Silver, White California Blackeye B, IAR-339-1, and Ife Brown) was not necessarily accompanied by high HPCI. Furthermore, cowpea flour with lower HTPV tended to exhibit a better hot paste stability pattern, at least under the conditions employed in this study. From a practical standpoint, flour with high HTPV and HPCI would be advantageous in products requiring viscosity increase after cooking such as soups, sauces, and puddings.

Other paste viscosities, i.e., CKPV, STBV and CLPV, were also affected by the decortication methods; higher viscosities were obtained for the WDF samples than for the DDF samples, except for the Better Green Cream variety. The wet decortication process appears to increase retrogradation tendency (PSER > 1.0, Table 2) in most of the varieties as indicated by the increase in viscosity on cooling to 50 °C (STBV). When a starch paste or gel is cooled, portions of it tend to revert to a more insoluble form, a phenomenon referred to as "retrogradation." This phenomenon is the result of H-bonding between starch molecules that have both hydroxyl groups and hydrogen acceptor sites (Del Rosario and Pontiveros, 1983). The extended linear amylose fractions of starch are believed to be mainly responsible for retrogradation, since these fractions are more free to orient themselves than are the larger, more compact branched amylopectin molecules. Retrogradation rate is affected by amylose and amylopectin concentrations, molecular size, temperature, and pH. A possible explanation for increased retrogradation tendency in WDF is that during manual decortication of seeds in water, some amylase action was initiated. This would lead to a higher amount of linear fraction or lower molecular weight fragments which enhance reassociation of molecules on cooling of paste. Partial fractionation of starch types also occurs during food preparation and affects the character of the starch paste and the resulting food (Whistler and Daniel, 1985). High retrogradation tendency is a feature of cowpea starch as reported by other studies (El Faki et al., 1983; Tolmasquim et al., 1971). Retrogradation is of considerable practical significance since it affects staling and other textural changes that occur in starchy foods. The cooled paste stability ratio (CPSR = CLPV/STBV, Table 2) was 1.0 or very close to 1.0 for both DDF and WDF samples for all varieties, indicating that the cooled paste viscosity was not affected by the continuous stirring during holding at 50 °C for 30 min.

Pasting temperatures of cowpea flour slurries ranged from ca. 78 to 83 °C for all varieties (Table 2). The temperatures were generally higher than those reported for onset of gelatinization in cowpeas. According to El Faki et al. (1983), the gelatinization temperature range of cowpea starch was 65−73 °C, while 64−78 °C was reported for cowpea starch from five different varieties by Tolmasquim et al. (1971). The reasons for this could be twofold: first, limiting effects of the nonstarch components on gelatinization may have shifted the onset to higher temperatures; second, the pasting temperature obtained from the Brabender viscoamylograms was based on viscosity changes of flour slurries. However, the gelatinization temperature ranges as reported by El Faki et al. (1983) and Tolmasquim et al. (1971) were based on loss of birefringence, which usually occurs before appreciable swelling and increased viscosity take place. Variation in pasting temperature between DDF and WDF samples was small for all varieties.

**Pasting Properties: Effects of Presoaking.** The effects of presoaking for different times on the pasting properties of flour from Texas Cream 40 and California Blackeye 5 (CB5) are shown in Table 3. Paste viscosities of DDF flour slurries increased with increased presoaking time, and the general response patterns were similar in both varieties. Presoaking of seeds for 4 h increased HTPV for Texas Cream 40 from 77.5 to 260 BU, while in CB5, HTPV increased from 230 BU to a maximum of 435 BU. Increases in CKPV, STBV, and CLPV with presoaking time were also observed. However, soaking beyond 4 h did not give further increases in all paste viscosities. Despite the similarity in behavior patterns of flour from the two varieties, the distinction of one over the other remains apparent. Greater HPCI values were recorded for Texas Cream 40 than for CB5; the minimum HPCI for Texas Cream 40 was 1.47 for $DDFS_{16}$ (Table 3), which is greater than the maximum HPCI (1.33) for the CB5 DDF. Given the same treatment and process, some varieties would perform better or worse than others. These results

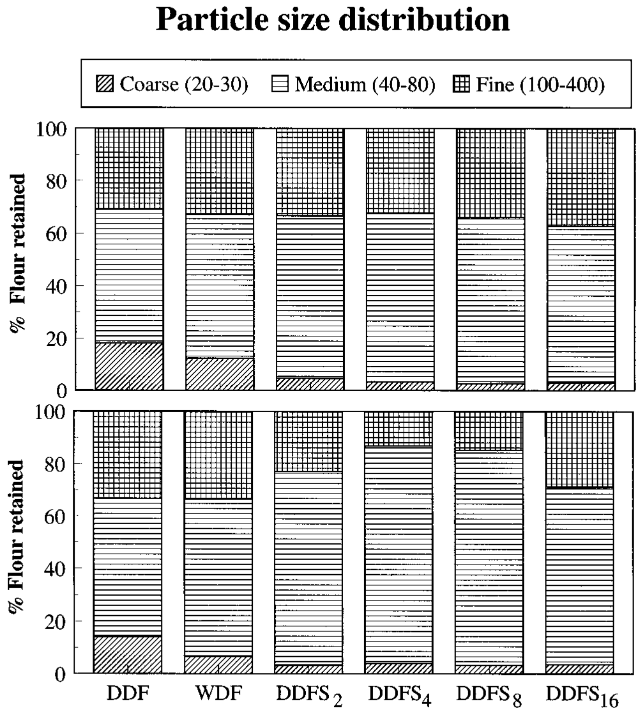


**Figure 1.** Particle size distribution of flours prepared from Texas Cream 40 (top) and California Blackeye 5 (bottom) cowpeas. See Table 3 for key.

suggest that differences among varieties inherently exist irrespective of processing methods.

Theoretically, comparison of the paste viscosity before reaching 95 °C (at peak) and at 95 °C indicates the ease of cooking of starch. In this study, since there was no distinct paste peak viscosity, the HTPV could be a useful index for ease of cooking. The Texas Cream 40 $DDFS_4$ attained HTPV of 260 BU in the first 30 min of heating from 50 to 95 °C, which is only about 60% of that (435 BU) from CB5 $DDFS_4$ (Table 3). These findings may possibly explain differences in other processing qualities which have been observed among cowpea varieties, for example, cooking time (Akinyele et al., 1986; Demooy and Demooy, 1990). An increase in the PSER values (retrogradation tendency) was also observed, as a result of presoaking. Presoaking did not considerably influence pasting temperatures of flour slurries from both varieties.

The effects of soaking on flour paste viscosities as discussed in the foregoing are thought to be due to softening of seeds because of water imbibition. Water imbibition is a physical process related to the properties of seed macromolecules (Sefa-Dedeh and Stanley, 1979). Furthermore, soaking allows for the dissolution of intercellular cementing substances in the middle lamella, such that on drying a more porous structure is obtained. The fragmentation of seed during milling is then such as to give particle sizes in which the distribution of seed macromolecules (especially protein and starch) is closer to that of the intact cell. Figure 1 shows the distribution of flour particle size in the different size ranges of fine, medium, and coarse. The percent of medium-size particles (mesh 40−80) increased with soaking time up to 4 h, while coarse (mesh 20−30) and fine (mesh 100−400) particles decreased. The highest quantity of medium-size particles was obtained in both varieties for $DDFS_4$: 65% for Texas Cream 40 and 83% for CB5. The same samples had the highest paste viscosities. The medium-size particles thus appear to have the best hydrothermal properties. These particles were able to absorb more water and attain a higher degree of swelling and gelatinization. Studies by Priestly and Avumatsodo (1977) indicated that complete gelatinization of starch occurred in cowpea seeds cooked after presoaking for 5 h, while unsoaked seeds only achieved 60% gelatinization.

In a previous study, McWatters (1983) observed that cowpea flour milled to an intermediate rather than fine particle size hydrated better to an appropriate batter moisture content required for the preparation of akara (fried cowpea paste). Similar observations were reported by Ngoddy et al. (1986). The ability of medium-size particles of cowpea flour to absorb water and swell better may be related to the ratio of starch to protein in these particles. As previously discussed, interactions between starch and protein (major components of cowpea flour) appear to be very crucial in determining the dynamics of moisture available for phase transitions like gelatinization; in addition, the contributions of cowpea proteins to swelling and pasting could be an important factor in these changes. From the foregoing, it might be useful to quantify the proportions of these components in the different particle size ranges and to determine their individual roles in the changes occurring during flour pasting.

**Relationship among the Cowpea Varieties Based on Canonical Discriminant Analysis.** The relationships between the 12 varieties based on Mahalanobis distances ($D^2$) are shown in Tables 4 and 5 for the DDF and WDF processes, respectively. Because HTPV was identified as the variable best explaining the existing variety differences, the following discussion is mainly focused on HTPV. For the DDF process, the varieties with very low (e.g., White Acre and Texas Cream 40) and the highest (Mississippi Silver) HTPV values had very large $D^2$ (i.e., 399.69 and 400.45, Table 4) between them. Since the Mahalanobis $D^2$ between two groups attains its largest value when there is maximum separation, it follows that, on the basis of the combined variables (HTPV, CKPV, STBV, and CLPV) considered, White Acre and Texas Cream 40 are significantly different ($p = 0.0001$) from Mississippi Silver. Similarly, for WDF, the varieties White Acre and CB5 with the lowest and highest HTPV, respectively, recorded the largest $D^2$ of 381.1 ($p = 0.0001$, Table 5). A visualization of the relationship among the varieties was also obtained from plots of the first and second canonical variables (Figures 2 and 3). Combining the information obtained from the $D^2$ between two varieties and the positions of the varieties on the plots, it appears that varieties with similar HTPV and CKPV for DDF and with similar HTPV and STBV for WDF are positioned closer to one another. This can be interpreted to mean that varieties closer together would have similar flour pasting properties; the opposite would be true for varieties that are situated far apart. Irrespective of the process, the positions of varieties were more or less the same. The only exception was Texas Cream 40 (H), which was shifted in position by the WDF process (Figure 2 versus Figure 3). This is because a drastic viscosity increase was recorded in HTPV and STBV for this particular variety with the WDF process. In both plots, varieties CB5 (C) and Mississippi Silver (E) maintained their positions and were quite apart from the remaining 10 varieties.

There appear to be four groups into which the varieties may be separated. The first group comprises two varieties: CB5 (C) and Mississippi Silver (E). These two have HTPV values of over 200 BU for both DDF and WDF. The second group includes the varieties TVX 3236 (B), White California Blackeye B (J), IAR-339-1 (K), and Ife Brown (L); these all have HTPV values

**Table 4. Pairwise Squared (Mahalanobis) Distances between Cowpea Varieties and Probability Levels (DDF Process)[a]**

| | a | b | c | d | e | f | g | h | i | j | k | l |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| a | | 15.64 | 168.54 | 39.94 | 217.72 | 9.29 | 21.94 | 56.92 | 21.46 | 46.63 | 25.89 | 14.28 |
| b | 0.0830 | | 105.98 | 99.57 | 141.43 | 14.72 | 20.17 | 70.45 | 41.17 | 35.91 | 14.69 | 22.2 |
| c | 0.0001 | 0.0002 | | 358.08 | 36.21 | 197 | 189.31 | 301.82 | 189.87 | 53.14 | 76.15 | 105.2 |
| d | 0.0061 | 0.0002 | 0.0001 | | 399.69 | 49.15 | 86.24 | 97.32 | 75.12 | 156.9 | 111.5 | 77.31 |
| e | 0.0001 | 0.0001 | 0.0084 | 0.0001 | | 229.62 | 260.51 | 400.45 | 293 | 124.3 | 100.9 | 147.65 |
| f | 0.2245 | 0.0948 | 0.0001 | 0.0030 | 0.0001 | | 14.41 | 43.29 | 38.70 | 79.48 | 42.47 | 37.96 |
| g | 0.0363 | 0.0451 | 0.0001 | 0.0004 | 0.0001 | 0.0992 | | 15.43 | 18.82 | 72.04 | 61.71 | 55.73 |
| h | 0.0018 | 0.0008 | 0.0001 | 0.0002 | 0.0001 | 0.0047 | 0.0855 | | 32.14 | 138.85 | 134.76 | 115.2 |
| i | 0.0385 | 0.0055 | 0.0001 | 0.0007 | 0.0001 | 0.0068 | 0.0537 | 0.0122 | | 49.58 | 65.47 | 41.62 |
| j | 0.0036 | 0.0086 | 0.0023 | 0.0001 | 0.0001 | 0.0005 | 0.0008 | 0.0001 | 0.0029 | | 20.79 | 18.61 |
| k | 0.0231 | 0.0952 | 0.0006 | 0.0001 | 0.0002 | 0.0050 | 0.0014 | 0.0001 | 0.0011 | 0.0418 | | 9.63 |
| l | 0.1011 | 0.0352 | 0.0002 | 0.0006 | 0.0001 | 0.0072 | 0.0020 | 0.0001 | 0.0053 | 0.0552 | 0.2119 | |

[a] Values above the diagonal are the distances, and values below are the probability levels. Letters represent varieties as follows: a, Vita 5; b, TVX 3236; c, California Blackeye 5; d, White Acre; e, Mississippi Silver; f, Better Green Cream; g, Pinkeye Purple Hull; h, Texas Cream 40; i, White California Blackeye A; j, White California Blackeye B; k, IAR-339-1; l, Ife Brown.

**Table 5. Pairwise Squared (Mahalanobis) Distances between Cowpea Varieties and Probability Levels (WDF Process)[a]**

| | a | b | c | d | e | f | g | h | i | j | k | l |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| a | | 46.25 | 267.32 | 22.11 | 276.21 | 14.87 | 60.15 | 43.74 | 18.22 | 26.41 | 61.08 | 27.88 |
| b | 0.0037 | | 134.48 | 91.78 | 111.64 | 95.91 | 50.43 | 16.87 | 51.25 | 18.17 | 4.24 | 62.68 |
| c | 0.0001 | 0.0001 | | 381.10 | 45.05 | 361.64 | 331.87 | 108.88 | 228.24 | 130.53 | 118.60 | 181.66 |
| d | 0.0356 | 0.0003 | 0.0001 | | 346.35 | 4.75 | 46.22 | 110.40 | 72.98 | 84.12 | 100.26 | 59.10 |
| e | 0.0001 | 0.0001 | 0.0041 | 0.0001 | | 354.94 | 239.83 | 134.57 | 269.64 | 158.09 | 85.01 | 217.36 |
| f | 0.0927 | 0.0003 | 0.0001 | 0.5071 | 0.0001 | | 71.58 | 97.10 | 54.45 | 70.71 | 105.83 | 40.57 |
| g | 0.0015 | 0.0028 | 0.0001 | 0.0037 | 0.0001 | 0.0008 | | 104.48 | 106.12 | 94.23 | 54.92 | 122.35 |
| h | 0.0045 | 0.0698 | 0.0002 | 0.0001 | 0.0001 | 0.0002 | 0.0002 | | 24.24 | 3.14 | 21.67 | 40.05 |
| i | 0.0582 | 0.0026 | 0.0001 | 0.0007 | 0.0001 | 0.0021 | 0.0002 | 0.0277 | | 17.82 | 67.45 | 42.41 |
| j | 0.0218 | 0.0585 | 0.0001 | 0.0004 | 0.0001 | 0.0008 | 0.0003 | 0.6785 | 0.0613 | | 25.65 | 24.17 |
| k | 0.0014 | 0.5567 | 0.0001 | 0.0002 | 0.0004 | 0.0002 | 0.0021 | 0.0375 | 0.0010 | 0.0237 | | 64.34 |
| l | 0.0186 | 0.0013 | 0.0001 | 0.0016 | 0.0001 | 0.0058 | 0.0001 | 0.0061 | 0.0050 | 0.0280 | 0.0012 | |

[a] Values above the diagonal are the distances, and values below are the probability levels. Letters represent varieties as follows: a, Vita 5; b, TVX 3236; c, California Blackeye 5; d, White Acre; e, Mississippi Silver; f, Better Green Cream; g, Pinkeye Purple Hull; h, Texas Cream 40; i, White California Blackeye A; j, White California Blackeye B; k, IAR-339-1; l, Ife Brown.

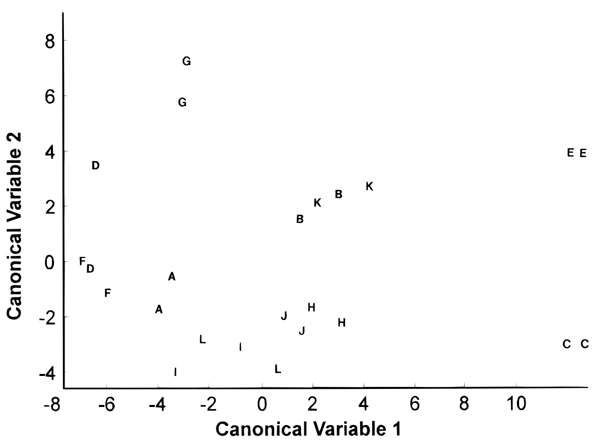


**Figure 2.** Plot of relationship between the 12 cowpea varieties based on canonical discriminant analysis (DDF process). Letters represent varieties as shown in footnotes of Table 4.

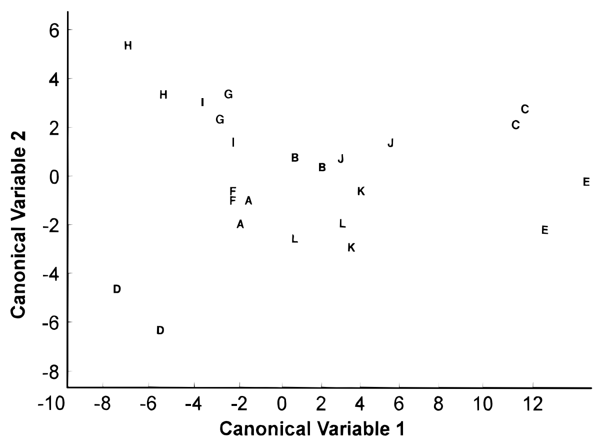


**Figure 3.** Plot of relationship between the 12 cowpea varieties based on canonical discriminant analysis (WDF process). Letters represent varieties as shown in footnotes of Table 4.

between 140 and 177.5 BU for DDF and WDF. The third group, made up of Vita 5 (A), Better Green Cream (F), Pinkeye Purple Hull (G), and White California Blackeye A (I), has HTPV values between 107 and 130 BU. The fourth group, made up of Texas Cream 40 (H) and White Acre (D), had HTPV less than 100 BU for DDF. Texas Cream 40 was actually shifted to the second group by the WDF process, while Better Green Cream and White Acre would constitute the fourth group for the WDF process. These groupings hold true on the basis of the properties of paste measured in this study, since it provides some clear separation among the varieties. However, a different statistical procedure would be required for a more conclusive classification, because the canonical discriminant analysis relates more to identifying variables useful for differentiation than to classification.

## SUMMARY AND CONCLUSIONS

Significant differences in pasting properties of flour were found among 12 diverse cowpea varieties. A dry decortication process with presoaking of seeds (DDFS) gave higher HTPV than DDF without presoaking. Presoaking was shown to affect particle size distribution of flour. Samples presoaked for 4 h had the highest quantity of medium-size particles as well as the highest HTPV. Cowpea flour with at least 65% of medium-size particles exhibited optimum hydrothermal properties, resulting in increased paste viscosities. HTPV was the variable that best explains the differences among flours for both DDF and WDF samples. This variable could be used as an index to measure cowpea flour quality by relating it to some desired quality parameter in products for which flour is incorporated. Differences among the varieties persist irrespective of treatments and processing method. Observed differences in pasting properties may be an indication of differences in other processing qualities. These results suggest inherent physicochemical differences among the varieties, and such could be exploited in developing more functional varieties for specific processing requirements.

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