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Functional characterization of flour of selected cowpea (*Vigna unguiculata*) varieties: canonical discriminant analysis

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Abstract

Characterization of 28 varieties of cowpea flour, based on Brabender pasting properties of flour slurry (12% w/w flour: water), was achieved by canonical discriminant analysis. Pasting viscosities at various points on the amyiogram, pasting temperature and paste viscosity ratios were obtained for each variety of flour. Significant varietal influence on pasting properties was indicated by ANOVA ($P<0.01$) and MANOVA. The hot paste viscosity at 95 °C (HTPV) and the hot paste capacity index (HPCI) had the highest correlations with the 1st and 2nd canonical variables and together accounted for 78% of total variance in the whole dataset. A plot of the second canonical variable against the 1st canonical variable showed that varieties situated together had HTPV values within close ranges. The hot paste viscosity (HTPV) was the most discriminating paste viscosity and could become an important index of functionality of cowpea flour. © 2002 Elsevier Science Ltd. All rights reserved.

Keywords: Functional characterization; Cowpea flour

1. Introduction

Cowpea flour is a convenient food ingredient with the potential to promote industrial utilization of cowpea. Cowpea flour could replace wet paste as the starting ingredient for some traidtional West African cowpea foods (Henshaw, 2000; Henshaw & Lawal, 1993; McWatters, 1983). Cowpea flour could also become an important ingredient in other food applications, such as baked foods, extruded products, communited meat products and weaning foods (Falcone & Phillips, 1988; McWatters, 1982; Mustaafa, AL-Wessali, AL-Basha, & Al-Amir, 1986, Prinyawiwaticul, McWatters, Beuchat, & Phillips, 1996).

The functionality of cowpea flour would, however, dictate its suitability for various food applications. Functionality of a food or food ingredient is the sum total effect of the properties which affect utilization (Pour El, 1981). According to McWatters (1986), the successful performance of legume flours as food ingredients depends on the functional characteristics and sensory quality they impart to end-products. The pasting properties of a flour are important indicators of functionality, since pasting involves changes which occur during heating of a suspension of the flour. The characteristics of the hot and cold paste affect many textural and sensory properties of end-products.

Canonical discriminant analysis is used for analyzing multivariate data and for generating new sets of variables, these being linear combinations of the original ones (Zagrodzki, Schlegel-Zawadzka, Krosniak, Malec, Bichonski, & Dutkiewics, 1995). The method is designed in such a way as to enhance the hidden properties of the original data and allows the reduction of a multi-dimensional data set to only a few dimensions which can amply explain all data.

The objectives of our study were to characterize the functionality of 28 varieties of cowpea flour and to identify the properties which contribute most to differentiation.

2. Materials and methods

2.1. Materials

Twenty-eight cowpea varieties were used in the study. Eighteen were Nigerian varieties and 10 were USA varieties. The samples were procured from different sources as shown in Table 1.

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Table 1
Cowpea varieties used in the study

	Variety	Origin	Source
A.	Vita 5	Nigeria	IITA[a]
B.	TVX 3236	Nigeria	IITA
C.	California Blackeye 5 (CB5)	USA	Pennington Seed Co., Madison, Georgia
D.	White Acre	USA	Southern Frozen Foods, Montezuma, Georgia
E.	Mississippi Silver	USA	Pennington Seed Co., Madison, Georgia
F.	Better green cream	USA	Southern Frozen Foods, Montezuma, Georgia
G.	Pinkeye purple Hull	USA	C.T. Smith Company, Texas
H.	Texas cream 40	USA	C.T. Smith Company, Texas
I.	White California Blackeye A (WCBA)	USA	University Of California, Davis
J.	White California Blackeye B (WCBB)	USA	University Of California, Davis
K.	IAR-339-1	Nigeria	NNS
L.	Ife Brown	Nigeria	IAR & T[b]
M.	TVX 1948-012F	Nigeria	IITA
N.	IT8ID-994	Nigeria	IITA
O.	Whippoorwill	USA	C.T. Smith Company, Texas
P.	Ife BPC	Nigeria	IAR & I
Q.	1T86D-719	Nigeria	IITA
R.	1T85D-3850–2	Nigeria	IITA
S.	Kanannado	Nigeria	NSS[c]
T.	1188DM-363	Nigeria	IITA
U.	Moola	Nigeria	Market
V.	1T82D-889	Nigeria	IITA
W.	L-25	Nigeria	NSS
X.	1T82E-9	Nigeria	IITA
Y.	L-80	Nigeria	IITA
Z.	1T84S-2246–4	Nigeria	IITA
1.	1T86D-1010	Nigeria	IITA
2.	Coronet	USA	University Of California

[a] IITA, International Institute of Tropical Agriculture, Ibadan, Oyo State, Nigeria

[b] IAR & T, Institute of Agricultural Research and Training, Obafemi Awolowo University, Moor Plantation, Ibadan, Oyo State, Nigeria.

[c] NSS, National Seed Service, Federal Ministry of Agriculture, Iwo Road, Ibadan, Oyo State, Nigeria.

2.2. Flour processing method

Flour was produced by a dry decorticating method. Mature clean seeds were conditioned by wetting to increase moisture from approximately 10 to 25%, as described by McWatters, Chinnan, Hung, & Branch (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., Hartburg, PA, USA); detached seed coats were removed in a seed cleaner (Alanco seed cleaner, Allan Machine, Co, Ames, IA, USA). Decorticated seeds were milled in a Wiley Laboratory Mill (Model, 4, Arthur H. Thomas, Co; Philadelphia, USA), as suggested by Ngoddy, Enwere, & Onuorah (1986). Flour samples were packaged in glass jars and stored at 4 °C.

2.3. Pasting properties

A Brabender viscoamylograph (Model VA—VEPT-100, C. W. Brabender Instruments, Inc., SS. Hackensack, NJ, USA), equipped with a 700 cm gf cartridge, was used to determine pasting properties of all flour samples. A homogeneous flour slurry (12% w/w, flour: deionized water) was heated from 50 °C to 95 °C at a uniform rate of 1.5 °C/min with constant stirring at 75 rpm. Heated slurry was held at 95 °C for 30min, then cooled to 50 °C at the same rate and held at this temperature for another 30 mm. Pasting > viscosities obtained were hot paste viscosity at 95 °C (HTPV), cooked paste viscosity on holding at 95 °C for 30 min (CKPV), set-back viscosity on cooling to 50 °C (STBV) and cooled paste viscosity on holding at 50 °C for 30 min (CLPV). Pasting temperature (PT) was defined as the temperature at which a rise in viscosity was first observed. Hot paste capacity index (HPCI) was calculated as the ratio of HTPV to CKPV. 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 sample.

2.4. Statistical analysis

Analysis of variance (ANOVA) was used to determine differences in pasting properties (i.e. HTPV, CKPV, STBV, CLPV, PT, HPCI, PSER and CPSR) of flour, as influenced by variety. Tukey's studentized range test was performed for post-hoc multiple comparisons. Group differences, expressed in terms of pasting properties, were determined using muhivariate analysis of variance (MANOVA). Canonical discriminant analysis (Proc. CANDISC, SAS version 6.03, 1988) was subsequently performed to identify pasting properties that underlie group differences of flour of different cowpea varieties. The plot of 1st and 2nd canonical variables were determined.

3. Results and discussion

The pasting patterns of the 28 varieties of flour were similar, varying mainly in the magnitude of viscosities attained within each heating, holding and cooling periods. There was no pasting peak viscosity recorded for any of the flours. Typical amylogram patterns are shown in Fig. 1. Results of pasting properties are given in Table 2. Overall mean values for pasting viscosities and standard deviations were HTPV, 155 B U (47.4), CKPV, 236 BU (46.7), STBV, 306 BU (65.5) and CLPV, 302 B U (67). Results of ANOVA show that there were significant differences in all pasting properties, ($P \leqslant 0.01$), except in paste set-back ratio (PSER). Simultaneous consideration of all parameters by MANOVA confirmed a significant varietal influence on pasting properties. This is indicated by MANOVA statistics, i.e. Wilkis Lambda ($P = 0.000$ (1), pillais trace ($P = 0.0001$), Hotelling–Lawley's trace, ($P = 0,0001$) and Roy's greatest root ($P = 0.0001$). Table 3 presents the results of canonical discriminant analysis and shows that 4 canonical discriminant functions (CDF) were sufficient to explain 93% of total variance. From Tables 3 and 4, it is clear that the first CDF, which accounts for 41% of variance, consists mainly of HPCI, with a correlation of 0.43 and the second for 37% of variance, consist of HTPV with a correlation of 0.86. The third and fourth CDFS explained 15% and consist mainly of CLPV and CKPV, with correlations 0.44 and 0.66, respectively. The hot paste viscosity (HTPV) is thus the most discriminating pasting viscosity, based on the weight of its contribution to the first and second CDFS. The hot paste viscosity (HTPV) indicates the degree of starch swelling which occurred during the heating cycle. A plot of the 28 varieties, based on the first and second CDF, as shown in Fig. 2, indicates a grouping of varieties with similar HTPV values. Varieties California Blackeye 5 (C), Mississippi silver (E), Kannanado (S), Ife BPC (P), L-25 (W), and Moola (U) are situated together in the plot; all these have HTPV values of over 180 BU. The lowest HTPV amongst this group was observed in L-25 (187.5 BU; Table 2). The second group, which comprised 14 varieties, had HTPV values less than 180 BU but greater than 120 BU. The lowest HTPV among this group was observed In TVX 1948-012F (127.5 BU). The last group comprised seven varieties; all had HTPV values below 120 BU. The lowest HTPV recorded was 75 BU for the variety White Acre (D).

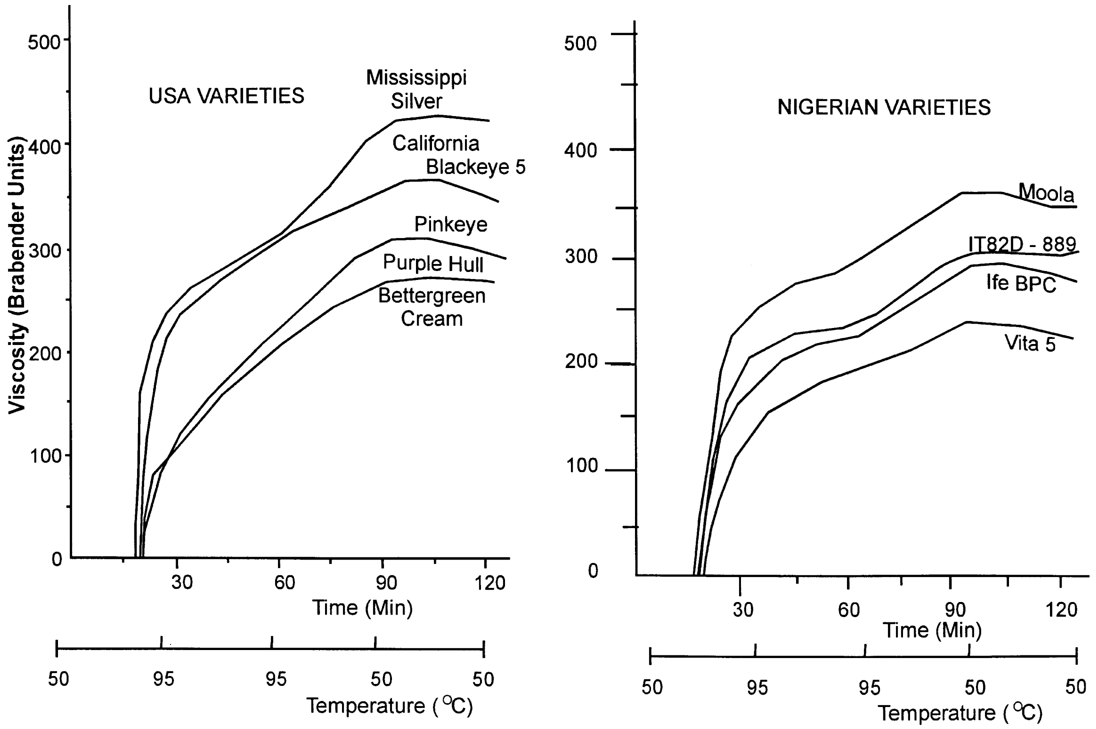

Fig. 1. Typical Bradender amylogram patterns of cowpea flour.

Table 2
Pasting properties of selected varieties of cowpea flour[a]

S/N	Variety	HTPV	CKPV	STBV	CLPV	PT (°C)	HPCI	PSER	CPSR
1.	Vita 5	117.5de	1950b	247.5bed	242.5abc	79.6	0.60	1.27	0.98
2.	TVX3236	140.0efg	232.5cde	295.0fgh	290.0cdefg	81.1	0.60	1.27	0.98
3.	California Blackeye 5	230.0nm	305.0gh	355.0mijk	350.0ijk	80.9	0.75	1.16	0.99
4.	White Acre	75.0a	135.0a	195.0a	195.0a	80.6	0.55	1.44	1.00
5.	Mississppi Silver	245.0n	310.0h	412.5lmn	420.0i	79.9	0.79	1.33	1.02
6.	Better green cream	110.0cde	202.5bc	267.5def	267.5cdef	79.6	0.54	1.32	1.00
7.	Pinkeye purple hull	107.5bed	217.5bed	255.0bede	247.5bed	82.7	0.49	1.17	0.97
8.	Texas cream 40	77.5ab	200.0bc	217.5abc	210.0ab	81.5	0.30	1.09	0.97
9.	White California Blackeye A	110.0cde	200.0bc	210.0ab	200ab	81.9	0.55	1.05	0.95
10.	White California Blackeye B	170.0hijk	240.0def	270.0def	260.0cde	81.1	0.71	1.13	0.96
11.	IAR-339-1	157.5fghi	227.5bcde	300.0efgh	290.0cdefg	80.3	0.69	1.32	0.97
12.	Ife brown	150.0fghi	210.0bed	260.0cde	260.0	79.6	0.71	1.24	1.00
13.	TVX 1948-012F	127.5def	225.0bede	337.5hijk	355.0ik	80.0	0.57	1.50	1.05
14.	1T8ID-994	162.5ghij	310.0h	455.0h	450.0i	80.0	0.52	1.47	0.99
15.	Whippoorwi II	160.0ghij	240.0def	283.8defg	282.5cdefg	74.8	0.66	1.18	0.99
16.	IfeBPC	195.0gl	235.0cde	297.0efgh	290.0cdefg	79.6	0.83	1.27	0.97
17.	IT86D-719	157.5fghi	257.5ef	337.5hijk	330.0hijk	78.5	0.67	1.31	0.97
18.	IT850-3850-2	137.5defg	272.5ef	370.0kl	370.0k	78.5	0.50	1.35	1.00
19.	Kanannado	235.0mn	227.5bede	280.0defg	280.0cdefg	80.0	1.03	1.23	1.00
20.	IT88DM-363	205.0lm	302.5gh	380.0klm	370.0k	79.2	0.67	1.25	0.97
21.	Moola	240.0n	297.5gh	365.0jk	360.0jk	81.9	0.81	1.23	0.99
22.	IT82D-889	165.0ghij	235.0cde	307.5fgh	305.0efgh	79.6	0.69	1.31	0.99
23.	L-25	187.5jkl	215.0bed	310.0fghi	297.5efgh	79.6	0.87	1.44	0.96
24.	IT82E-9	160.0ghij	220.0bed	312.5fghi	312.5fghi	80.0	0.73	1.42	1.00
25.	L-80	135.0defg	210.0bed	292.5defgh	292.5defg	79.6	0.64	1.39	1.00
26.	IT84S-2246-4	140.0efgh	230.0bede	320.0gh	320.0ghij	81.3	0.60	1.39	1.00
27.	IT86D-I010	172.5hijk	320.0h	425.0mn	425.0l	79.6	0.54	1.33	1.00
28.	Coronet	80.0abc	147.5a	210.0ab	205.10ab	83.0	0.54	1.42	0.98
	X	155.4	236.4	306.0	302.8	80.0	0.64	1.29	0.99
	S.D.	47.4	46.7	65.5	67.2	1.6	0.13	0.11	0.02

[a] HTPV = Hot paste viscosity at 95 °C; CKPV = Cooked paste viscosity after holding at 95 °C for 30 min; STBV = Set-back viscosity on cooing from 95 to 50 °C; CLPV = Cooled paste viscosity after holding at 50 °C for 30 min; PT(°C) = Pasting temperature; HPCI = Hot paste capacity index; PSER = Paste setback ratio; CPSR = Cooled paste stability ratio; BU = Brabender units; X = Mean; S.D. = Standard deviation.

Table 3
Canonical discriminant analysis of pasting properties of selected varieties of cowpea flour

Function	Eigenvalue	%Variance	Cumulative % variance
1	106.3	41.05	41.05
2	95.9	36.75	77.80
3	24.2	9.36	87.16
4	14.9	5.79	92.95
5	10.9	4.23	97.18
6	5.8	2.23	99.41
7	1.0	0.40	99.81
8	0.49	0.19	100.00

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. Gelanitization involves diffusion of water into starch granules, hydration and swelling, uptake of heat, loss of birefrigence and crystallinity and amylose leaching (Biliaderis, Murices, & Vose, 1980; Olldui & Rha, 1978). The temperature range over which gelatinization occurs is characteristic of the particular starch type (Pomeranz, 1985). The changes produced after gelatinization are termed pasting (Hoseney, 1986).

A starch paste is therefore gelatinized starch with various degrees of solubilized starch. Starch solubilization during gelatinization is continuous, and is not complete until its granular structure is completely soluble. In excess water, this would be at temperatures in excess of 120 °C that is pressure cooking (Hoseney, 1986). Thus, in any food system, complete solubilization of starch is not usually achieved. In the viscoamylograph, as in all food systems except those cooked under pressure, the temperature cannot exceed 100 °C or the system will boll, so heating in the amylograph is discontinued at 95 °C. The properties of starch paste are responsible for the unique characteristics of any foods.

Examples include the viscosity and mouthfeel of gravy and soups, texture of pudding and baked foods (Whistler & Daniel, 1985). The setting of baked foods is believed to be partially due to starch gelatinization.

Holding of heated flour paste at 95 °C led to an increase in paste viscosities, as evidenced by the higher values of CKPV for all varieties except one, Kanannado. In Table 2, it is observed that the values of HPCI

Table 4
Correlations between discriminating pasting properties and canonical discriminant functions[a]

Variable	Function s							
	1	2	3	4	5	6	7	8
HTPV	−0.24	0.86	0.01	0.15	0.07	0.20	0.16	0.32
CKPV	0.24	0.62	−0.03	0.66	0.11	−0.01	0.15	0.25
STBV	0.40	0.69	0.04	0.20	0.24	0.10	−0.25	0.05
CLPV	0.39	0.66	0.44	0.12	0.20	−0.02	−0.17	0.34
PT	−0.11	−0.16	0.14	0.36	0.86	0.13	0.12	−0.13
HPCI	−0.43	0.44	−0.00	−0.52	−0.14	0.52	0.18	0.11
PSER	0.12	0.01	0.62	−0.55	0.04	0.20	−0.43	−0.22
CPSR	0.03	0.02	0.11	−0.22	−0.05	−0.15	0.63	0.73

[a] HTPV = Hot paste viscosity at 95 °C; CKPV = Cooked paste viscosity after holding at 95 °C for 30 min; STBV = Set-back viscosity on cooling from 95 to 50 °C; CLPV = Cooled paste viscosity after holding at 50 °C for 30 min; PT(°C) = Pasting temperature; HPCI = Hot paste capacity index; PSER = Paste set-back ratio; CPSR = Cooled paste stability ratio.

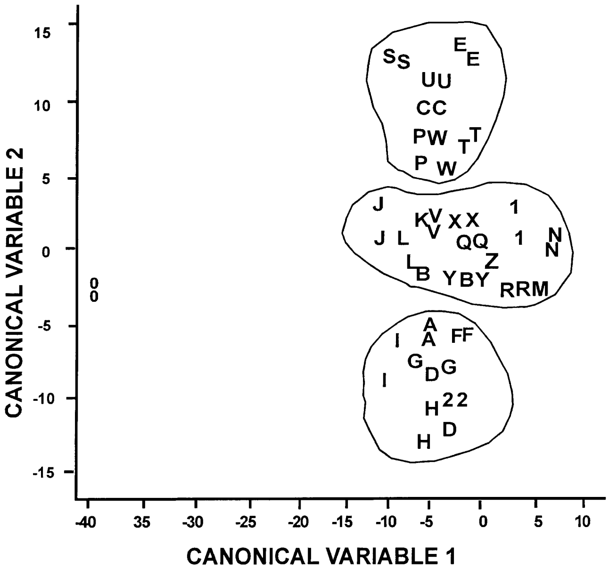

Fig. 2. Plot of relationship between the 28 cowpea varieties. Letters represent varieties as listed in Table 1.

(HTPV/CKPV) were less than one for all varieties, except again for Kanannado, which had a lower CKPV than HTPV. The HPCI could be used to indicate two properties of starch granules, namely rate of swelling and stability of swollen granules. Firstly, HPCI is a measure of the rate of swelling of starch granules during heating and therefore a measure of the proportion of maximum viscosity attainable under atmospheric heating. Secondly, the HPCI is a measure of stability of swollen starch granules to mechanical disintegration under the effect of continuous stirring in the amylograph bowl. From the results of this study, an HPCI of 0.6 but less than 1.0 indicates a thirly high rate of starch swelling and a high stability of swollen granules. Values less than 0.6 indicate a slow rate of starch swelling and high stability of swollen granules. HPCI values of over 1.0 are an indication of a high swelling rate and low stability of swollen granules. From a practical standpoint, therefore, flour with a high HTPV and HPCI above 0.6 but less than 1.0 would be advantageous in products such as soups, sauces and puddings. Based on these reasons, results in Table 2 indicate that stability of swollen starch granules was less variable than swelling rate, which was highly variable. This may account for the significant difference in HTPV values. Varieties with slow rates of starch granule swelling, exemplified by varieties such as White Acre, Texas cream 40, Better green cream and Coronet had HPCI values of less than 0.6 and HTPV values of 110 BU or less. Since initial crowding of swollen granules determines changes in consistency or rate of apparent viscosity increase, it follows that varieties with a higher rate of granule swelling would attain a higher HTPV. A high rate of granule sweffing and low stability of swollen granule is exemplified in the variety, Kanannado, with a HTPV of 235 BU, CKPV or 227.5 BU and HPCI of 1.03, indicating shear thinning and drop in viscosity on holding.

Set-back viscosity (STBV) values were higher than CKPV for all varieties (Table 2). Consequently, paste set-back ratio values were over 1.0 for all flour samples. When a starch paste is cooled, portions of it tend to revert to a more insoluble form, a phenomenon referred to as retrogradation. Retrogradation is the result of hydrogen bonding between starch molecules that have both hydroxyl and hydrogen acceptor sites (Del Rosario & Pontiveros, 1983). The extended linear amylose fraction of starch is believed to be mainly responsible for retrogradation, since amylose molecules are more free to orient themselves together than are the more compact amylopectin molecules. Retrogradation rate is affected by amylose and amylopectin concentrations, molecular size, temperature and pH. Del Rosarlo & Pontiveros (1983) reported that retrogradation rate in cowpea starch increased from 15% at 30 °C to 70% at 10 °C. The high retrogradation tendency in cowpea starch observed in this study agrees with previous reports of high retrogradation in cowpea and other legume starches

(El Faki, Desikachar, Paramahans, & Tharanathan, 1983; Hoover & Mamiel, 1995; Hoover & Sosulski, 1991; Tjahadi & Breene, 1984). Retrogradation is of considerable practical importance since it affects textural changes in starchy foods.

The CLPV was related to STBV by calculating cooled paste stability ratio (CPSR). Results indicated CPSR values very close to 1.0 for all varieties. This implies that the cooled paste was stable under the continuous stirring action during holding at 50 °C and that retrogradation did not continue without further lowering of the temperature.

4. Conclusions

Twenty-eight varieties of cowpea flour differed significantly in pasting properties. The hot paste viscosity at 950 °C (HTPV) was the most discriminating property that underlies variety differences. Plots of the first and second canonical variables showed that varieties appeared in three clear groupings based on their HTPV values. The results suggest that inherent physicochemical properties of cowpea dictate functionality of flour. Further studies are required to identily these properties.

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