Research Article

Received: 7 November 2008 Revised: 2 April 2009 Accepted: 3 April 2009 Published online in Wiley Interscience: 18 May 2009

(www.interscience.wiley.com) DOI 10.1002/jsfa.3628

Dehulling characteristics, sensory and functional properties of flours from selected cowpea varieties

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Abstract

BACKGROUND: The knowledge of dehulling characteristics is very important in the selection of cowpeas for flour production. In this study the sensory and functional properties of cowpea flour as influenced by dehulling method (wet and dry/mechanical dehulling) and cowpea variety (white, maroon and mottled) were investigated.

RESULTS: White cowpea showed a significantly different ($P < 0.05$) and higher dehulling rate (DR > 97%) for all dehulling methods. Maroon and mottled cowpeas were poorly dehulled (DR < 10%) when using the wet method (WD). Dry dehulling (DD) was effective on all three varieties (DR > 94%). The highest yield of flour was observed with white cowpea (80% for DD and 96% for WD). The beany odour intensity of flours was dependent on the method of dehulling used. Flour functionality was more significantly influenced by cowpea variety than by dehulling method.

CONCLUSION: Dry dehulling could be recommended for cowpea flour production, as this method was found to be more effective on the selected cowpea varieties. Owing to the observed variation in flour functionality among cowpea varieties, the choice of a particular variety for flour production will depend on the intended use of the flour.

Keywords: cowpea varieties; dehulling; functional properties; flours

INTRODUCTION

Cowpea (*Vigna unguiculata* (L.) Walp.) is a very important legume crop in tropical regions of Africa[1,2] and South and Central America. It is a good source of plant proteins and fibre, especially among rural poor communities.[3,4] However, cowpeas are known to contain antinutritional constituents (mostly tannins) that limit their full utilisation. These constituents are concentrated in the seed coat, and dehulling becomes a very critical operation in the processing of most legumes, including cowpea. Dehulling has been shown to remove up to 98% of the tannin content of cowpea.[5,6] Generally, dehulling of cowpea is a very tedious operation. Based on the ease of dehulling, legumes can be classified as hard or easy to dehull. Removal of the seed coat can be done manually or by pounding with a mortar and pestle.[7] Dehulling through mechanical means is also possible using attrition mills[8] or abrasive-type dehullers.[9] The variability in dehulling characteristics of legume grains may be affected by the grain genotype and physical characteristics.[9] To facilitate the removal of hulls, grains are usually preconditioned. Preconditioning methods to loosen the seed coat may involve heat treatment or soaking in water or a chemical solution for a period of time.[10–12] After heating, the seed coat becomes brittle and can be removed by mechanical means. Roasting of cowpea has been proven to significantly improve protein digestibility.[6]

Production of legume flour is beneficial to most processors, as it improves the ease of processing products. The quality and functionality of the flour are dependent on dehulling, the dehulling method and the variety of cowpea used. Processing conditions of flour were shown to significantly influence its functional properties.[13] Significant variations were observed in pasting properties with respect to cowpea varieties from Ghana[6] and Nigeria.[8] Particle size and its distribution also influence flour functionality. The poor performance of cowpea flour in making *akara* and *moin-moin* was attributed to its fine particle size distribution.[14,15] Fine flour was shown to have decreased hydration and air incorporation and to produce denser and less spongy *akara*. Water absorption of cowpea flour is influenced by the quality of milling.[16]

Cowpea is the most produced and processed among leguminous crops in many tropical countries, including Benin.[17,18] More than one variety is produced and new ones have also been introduced over time. Information on dehulling properties and quality of cowpea flour as influenced by processing conditions and variety

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is of great importance to the food industry and for commercialisation of grains in West Africa. This information will contribute to better valorisation of cultivated cowpea varieties and increase their utilisation. The present study was conducted to determine the most suitable methods for dehulling cowpeas and the effects of these methods on flour functionality.

MATERIALS AND METHODS

Plant materials

Three of the most cultivated cowpea varieties in Benin, one each of white, maroon and mottled seed coat colour, were selected for this study. The physical characteristics of the selected cowpea varieties are summarised in Table 1. Samples were obtained at harvest from cowpea farmers with the help of Agricultural Extension Officers in Porto-Novo, Benin. The name and number of each variety were also provided by the local Agricultural Extension Office.

Methods

Dehulling process

The selected cowpea varieties were dehulled by wet and dry dehulling methods. For wet dehulling, cowpeas (1 kg) were soaked in fresh or hot water for about 5–10 min depending on the variety. The soaked grains were then dehulled manually or using a mortar and pestle. Single grains were rubbed between the fingers during soaking to check for ease of dehulling. Easy removal of the hull of a single grain indicated that dehulling operations could start. Manual dehulling was done by rubbing the grains between the palms. Dehulling in a mortar was done carefully to prevent breakage of the cotyledons. The soaked grains were pounded for about 5 min. After dehulling, the hulls were removed by floatation and the cotyledons were oven dried overnight at around 60 °C.

Cowpeas were either dry heated (roasted) or not dry heated (non-roasted) prior to dry dehulling. For roasted samples, cowpeas (1 kg) were dry heated for about 7 min in a cooking pot on a stove under a steady supply of heat. The grains were stirred continuously to ensure uniform heat distribution and prevent burning. For non-roasted samples, water was sprinkled on the grains, which were then mixed for about 5 min and oven dried overnight at 60 °C. After drying, the seed coat became loose and could be easily removed. Treated samples were then dehulled mechanically by passing them through a corn attrition mill and winnowed to separate the hulls from the cotyledons.

Table 1. Physical characteristics of cowpea varieties

	Cowpea variety (local name and number)		
Parameter	*Tchawe* (IT89KD-374-57)	*Delekiwa* (IT84D449)	*Tou* (NA)[a]
Moisture content (g kg^{-1})	108.7	101.0	82.2
Weight of 1000 grains (kg)	0.18 ± 0.01	0.15 ± 0.01	0.14 ± 0.01
Seed coat colour	White	Maroon	Mottled
Texture	Smooth	Smooth	Smooth
Dehulling using water	Easy	Hard	Moderate
Geometry	Slab	Spherical	Spherical
Seed dimensions (mm)[b]	L 10.4 ± 1.23	D 3.60 ± 0.59	D 4.26 ± 0.75
	W 7.96 ± 0.87		
	T 4.99 ± 0.79		

[a] NA, number not available during period of study.
[b] L, length; W, width; T, thickness; D, diameter.

Dehulling rate analysis

About 300 g of dehulled material was randomly taken. Rejects (undehulled cowpea grains) were sorted out and weighed. Cowpea grain is considered to be completely dehulled when about 90% of the seed coat is removed after dehulling. The dehulling rate was measured as the percentage of dehulled cowpeas (whole and split).

Cowpea flour processing

Cowpea samples with high dehulling rate (DR $>$ 70%) were milled into flour using a disc attrition mill. Each sample was passed through the mill at least five times to obtain a very fine and smooth flour (more than 70% of flour particles $<$125 μm). The processed cowpea flours were then packaged in high-density polyethylene bags and stored at room temperature and humidity until further analyses. In total, nine different samples of cowpea flour were obtained. The moisture content of the flours after processing was between 70 and 90 g kg^{-1}.

Particle size distribution

The particle size distribution of each flour was analysed using a Retsch AS 200 mechanical shaker (Retsch, Haan, Germany) fitted with 200, 160 and 125 μm screen sieves. About 150 g of cowpea flour was shaken for 10 min. After shaking, the cowpea flour retained on each sieve was weighed.

Colour and odour

Cowpea flours were subjected to a trained panel of 15 members for colour evaluation. A four-point hedonic scale (from 4 = very good to 1 = very bad) was used. The odour of cowpea flours was evaluated using the method described by Owory and Hagenimana.[19] A 10 g portion of cowpea flour was mixed with 100 mL of water in a transparent plastic container and covered. To assess the odour of the flour, each panellist placed the container close to his/her nose, removed the cover and took a deep breath to smell the solution. The perceived odour intensity of the flour was scored using a six-point hedonic scale (from 6 = high intensity to 1 = low intensity/imperceptible).

Functional property analyses of cowpea flours

Protein solubility

Soluble protein content was determined using the Kjeldahl method.[20] Each flour sample was split into two fractions, one for total protein determination and the other for soluble protein determination using a potassium hydroxide treatment. For the latter, 1.5 g of flour sample was weighed into a beaker and 75 mL of 2 g L^{-1} (0.18 mol L^{-1}, pH 12.5) potassium hydroxide was added. The sample was then stirred for 20 min on a magnetic plate and centrifuged at 550 × *g* for 15 min. The supernatant was carefully filtered through glass wool into a beaker and centrifuged again. A 15 mL aliquot of the resulting supernatant was transferred into two Kjeldahl tubes for duplicate analyses (this gave a 0.3 g aliquot of the original sample). Then 12.5 mL of concentrated sulfuric acid and 2 mL of hydrogen peroxide were added to each tube for nitrogen determination. Total nitrogen contents in

Table 2. Dehulling characteristics of maroon, mottled and white cowpea varieties

	Dehulling rate (%)				
Cowpea variety	SFHD	SFDP	SHDP	DDR	nDDR
Maroon	9.25 ± 1.06a	36.64 ± 1.51c	54.24 ± 1.84e	94.43 ± 1.66g	95.73 ± 1.50i
Mottled	7.33 ± 1.17a	34.36 ± 1.53c	54.28 ± 1.32e	96.60 ± 1.77g	96.80 ± 1.24i
White	98.28 ± 0.61b	97.55 ± 0.88d	98.89 ± 0.83f	97.48 ± 1.05h	98.52 ± 1.05j

Values are mean ± SD of three replicates. Means in a column with different letters are significantly different ($P < 0.05$). SFHD, soaked in fresh water/hand dehulled; SFDP, soaked in fresh water/dehulled by pounding; SHDP, soaked in hot water/dehulled by pounding; DDR, roasted/dry dehulled; nDDR, non-roasted/dry dehulled.

the supernatant (prepared as above) and original sample were determined. Protein solubility was calculated by expressing the soluble protein fraction (from the supernatant) as a percentage of the total protein in the cowpea flour.

Water absorption

The water absorption capacity of cowpea flours was determined by a modification of the methods reported by Beuchat[21] and Sosulski and McCurdy.[22] Briefly, 1 g of flour was mixed with 10 mL of distilled water using a stirring rod in a centrifuge tube for 30 s. The sample was then allowed to stand for about 30 min. The resulting mixture was centrifuged (Denley BS 400 centrifuge, BS4402/D, Denley, England) at 300 × g for 15 min for water absorption. Free water was decanted and the amount absorbed was determined by weight difference. Results are reported as the mean of duplicate determinations on a dry matter basis.

Least gelation capacity

The least gelation capacity (LGC) of cowpea flours was determined according to Coffman and Garcia.[23] Sample suspensions of 2–20% (w/v, dry weight basis) were prepared in 5 mL of distilled water. The test tubes containing the suspensions were heated in a boiling water bath for 1 h and then rapidly cooled under running cold water. The tubes were further cooled for 2 h at 4 °C. In each case the LGC was determined as the concentration at which the sample did not fall or slip when the test tube was inverted.

Foam volume and stability

Cowpea slurries (150 mL, 100 g flour L^{-1}) were prepared with distilled water and whipped in a Waring blender 8010ES Model (HGBTWTS3, Torrington, Connecticut, USA) at high speed for 1 min. The foam volume of each whipped slurry was measured in a 250 mL measuring cylinder. The foam stability was measured after 1 h. All determinations were done in duplicate.

Statistical analyses

All experiments were done in triplicate. Analyses of variance were performed to determine the effects of variety and dehulling treatment on the quality of processed cowpea flours. Duncan's test was employed for separation of means. Excel and SPSS Version 11.0 (SPSS Inc, Chicago, IL, USA) were used for these analyses. Differences in means were observed at 5% significance level.

RESULTS AND DISCUSSION

Dehulling characteristics of white, maroon and mottled cowpeas

The knowledge of dehulling characteristics is very important in the selection of cowpeas for flour production. The DR, measured as the percentage of dehulled cowpeas (whole and split), was used to evaluate the dehulling characteristics of treated cowpea seeds. Results from this study showed significant variations in DR with respect to variety and dehulling method (Table 2). White cowpea recorded a significantly different and higher DR for all dehulling methods (DR > 97%). In general, DRs for maroon and mottled cowpeas were comparatively low (7–54%) when the wet method was used for dehulling. The use of a mortar and pestle was found to improve the DR, which increased from 7% for manual dehulling to 35% for dehulling by pounding when cowpeas were soaked in fresh water. Soaking in hot water prior to dehulling by pounding further increased the DR to 54%. Dry mechanical dehulling was effective on all three varieties (DR > 94%).

Influence of dehulling methods on yields of cowpea flours

Flours were processed from dry dehulled white, maroon and mottled cowpeas and from wet dehulled white cowpea. Wet dehulled maroon and mottled cowpeas were not processed into flour because of their low DRs. The yield of cowpea flour was determined as the percentage of flour recovered after dehulling and milling with respect to the initial weight of the starting material. The amount of flour recovered varied significantly according to the dry dehulling method and cowpea variety (Table 3). Flour yields from dry mechanically dehulled maroon, mottled and white cowpeas were 72.76, 74.67 and 80.13% respectively. These values are close to those obtained by Akinjayeju and Bisiriyu[8] after mechanical dehulling of varieties from Nigeria. Wet dehulled white cowpea gave a higher yield of flour (95.89%,

Table 3. Influence of dry dehulling method on cowpea flour production yields

	Yield (%)	
Cowpea variety	DDR	nDDR
Maroon	72.76 ± 1.20a	73.15 ± 1.02c
Mottled	74.67 ± 1.12a	75.06 ± 1.24d
White	80.13 ± 1.80b	80.52 ± 1.35e

Values are mean ± SD of three replicates. Means in a column with different letters are significantly different ($P < 0.05$). DDR, roasted/dry dehulled; nDDR, non-roasted/dry dehulled.

Table 4. Flour production yields for wet dehulled white cowpea

	Wet dehulling method		
Parameter	SFHD	SFDP	SHDP
Flour yield (%)	95.89 ± 1.4a	95.90 ± 1.2a	95.76 ± 1.5a

Values are mean ± SD of three replicates. Means with different letters are significantly different ($P < 0.05$). SFHD, soaked in fresh water/hand dehulled; SFDP, soaked in fresh water/dehulled by pounding; SHDP, soaked in hot water/dehulled by pounding.

Table 4) than its dry dehulled counterpart (80.13%, Table 3). A reduction in flour yield when using the mechanical (dry dehulling) method was also observed by Akinjayeju and Bisiriyu,[8] and this was mainly attributed to losses occurring during dehulling. During dry/mechanical dehulling, not only were the hulls removed but a certain proportion of fine fraction was also produced. All these resulted in losses which accounted for the lower yield. Proper adjustment of the clearance between the plates in the mill could help minimise the loss of flour produced during dehulling.

Evaluation of particle size distribution, colour and odour of processed cowpea flours

The effects of different dehulling methods on the colour and odour of white, maroon and mottled cowpea flours are summarised in Tables 5 and 6.

Maroon and mottled cowpea flours showed similar whiteness intensity for colour (Table 5). Flours from dry dehulled white cowpea had relatively higher scores (3.50–3.91) for colour, suggesting that they were whiter and more attractive. Dry dehulled maroon and mottled cowpea flours showed lower scores (2.10–2.95), indicating that these samples had reduced whiteness intensity. Flour from wet dehulled white cowpea was also desirable (mean score 3.73, Table 6). Among the three varieties, flour from white cowpea would appear to have greater potential for commercialisation owing to its whiter colour.

Table 5. Influence of dry dehulling method on sensory properties of cowpea flours

Cowpea variety	Colour		Odour	
	DDR	nDDR	DDR	nDDR
Maroon	2.81 ± 0.70a	2.10 ± 1.05c	3.82 ± 1.43e	4.70 ± 1.00f
Mottled	2.95 ± 0.40a	2.82 ± 0.40c	3.75 ± 1.54e	3.56 ± 1.60f
White	3.50 ± 0.46b	3.91 ± 0.94d	3.85 ± 1.02e	3.50 ± 1.25f

Values are mean ± SD of three replicates. Means in a column with different letters are significantly different ($P < 0.05$). DDR, roasted/dry dehulled; nDDR, non-roasted/dry dehulled.

Table 6. Sensory properties of white cowpea flours from wet dehulling methods

	Wet dehulling method		
Parameter	SFHD	SFDP	SHDP
Colour	3.73 ± 0.60a	3.70 ± 0.20a	3.75 ± 0.51a
Odour	4.22 ± 1.36b	4.25 ± 0.34b	4.21 ± 1.16b

Values are mean ± SD of three replicates. Means in a column with different letters are significantly different ($P < 0.05$). SFHD, soaked in fresh water/hand dehulled; SFDP, soaked in fresh water/dehulled by pounding; SHDP, soaked in hot water/dehulled by pounding.

Odour intensity scores for heat-treated dry dehulled cowpea flours varied between 3.50 and 4.70 (Table 5), which suggests that the beany odour was perceived at very low intensity. However, from the analysis of dehulling methods, the beany odour was more perceptible in wet dehulled white cowpea (4.22, Table 6) than in its heat-treated dry dehulled counterpart (3.85, Table 5). The perception of beany odour in flour may negatively affect the quality and acceptability of foods incorporating the flour. Dry heat treatment of cowpea prior to dehulling could therefore be employed to reduce the intensity of beany odour in the production of cowpea flour. However, this will depend on the intended final use of the flour, since heat application may influence some functional parameters of processed flours, as observed further in this study, and subsequently the quality of the final product.

All processed flours had a similar particle size distribution, suggesting a consistency in flour production methods. More than 70% of the flour particles were less than 125 µm in size (data not shown), suggesting that relatively fine flours were obtained. Cowpea flour is currently finding good application in baking and also in food fortification, where it is used to improve the protein quality of existing infant foods based primarily on cereals. Finely processed cowpea flours may be suitable for use in baking and flour mix production, depending on the functional properties displayed. These flours could also be used to process *adowe* (seasoned and cooked cowpea puree consumed in Benin).[17]

Influence of dehulling on functionality of cowpea flours

The functional properties of cowpea flours as influenced by variety and dehulling method are presented in Figs 1–4.

Water absorption of cowpea flour showed significant variation among varieties (Fig. 1). In general, water absorption of flours from dry dehulled white cowpea was higher (214–216%) than that of flours from mottled and maroon cowpeas (194–196%). Varying the wet dehulling method did not show any significant effect on water absorption of flour (Fig. 2). However, wet dehulled white cowpea flour had relatively higher water absorption (220–218%)

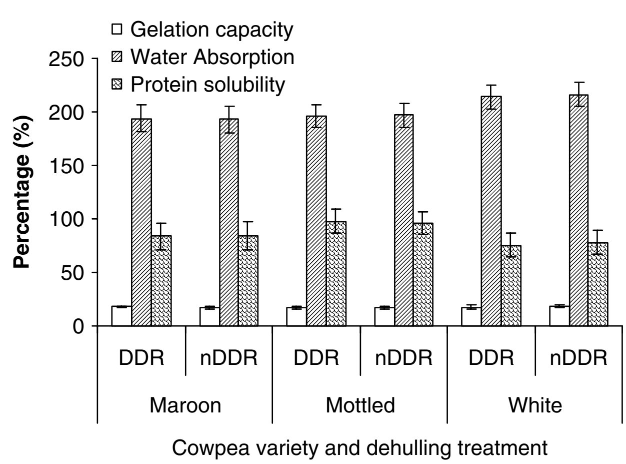

Figure 1. Influence of dry dehulling method (DDR, roasted/dry dehulled; nDDR, non-roasted/dry dehulled) on gelation capacity, water absorption and protein solubility of maroon, mottled and white cowpea flours.

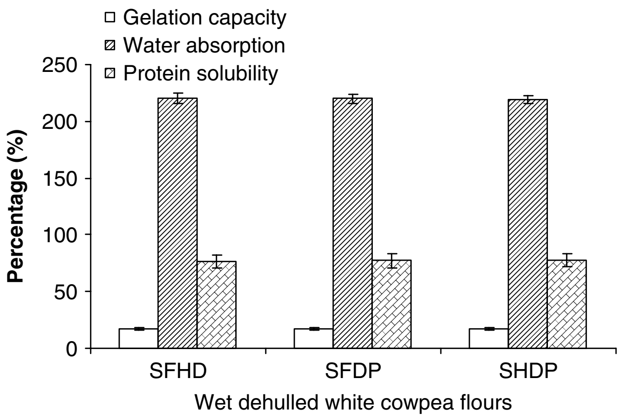

Figure 2. Influence of wet dehulling method (SFHD, soaked in fresh water/hand dehulled; SFDP, soaked in fresh water/dehulled by pounding; SHDP, soaked in hot water/dehulled by pounding) on water absorption, gelation capacity and protein solubility of white cowpea flours.

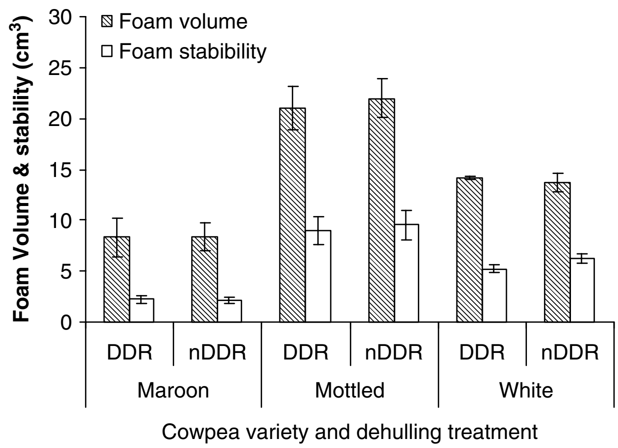

Figure 3. Influence of dry dehulling method (DDR, roasted/dry dehulled; nDDR, non-roasted/dry dehulled) on foam volume and stability of maroon, mottled and white cowpea flours.

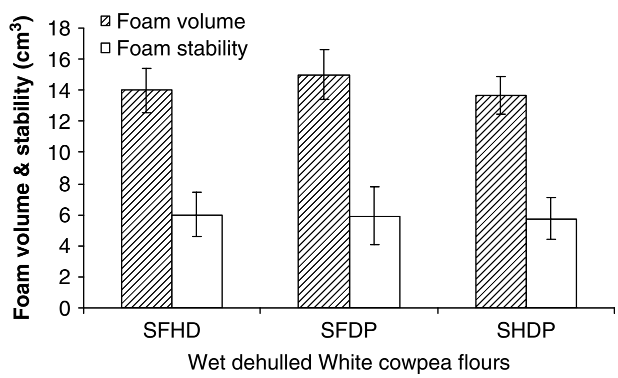

Figure 4. Influence of wet dehulling method (SFHD, soaked in fresh water/hand dehulled; SFDP, soaked in fresh water/dehulled by pounding; SHDP, soaked in hot water/dehulled by pounding) on foam volume and stability of white cowpea flours.

than its dry dehulled counterpart. Dry heat treatment of cowpea (roasting or oven drying) prior to dehulling reduced the water absorption capacity of the flour. Plahar *et al.*[6] observed a similar effect of heating on water absorption capacity. Water absorption is an important parameter affecting the quality of the end product. One factor found to be associated with poor quality of *akara* (fried cowpea paste) was low water absorption.[14]

Protein solubility is very important from a nutritional point of view. Results from this study showed that varieties differed significantly in protein solubility of cowpea flour. Flours from dry dehulled mottled cowpea yielded the highest protein solubility (mean value 97%). These were followed by maroon (85%) and white (77%) cowpea flours treated in the same way (Fig. 1). Protein solubilities of wet dehulled white cowpea flours were not significantly different (Fig. 2). However, heat treatment prior to dehulling slightly increased the protein solubility of flour from white cowpea. Several factors, including protein structure, extent of protein denaturation and pH, could significantly influence protein solubility.[24,25] The highest protein solubility observed for mottled cowpea flour may be attributed to the difference in variety, which could be related to the nature and conformational structure of its protein. The slight increase in protein solubility following dry heat treatment may be attributed to the destructive effect of heat on trypin inhibitors, as described by Sefa-Dedeh *et al.*[26]

The LGC is a measure of the minimum amount of flour required to form a gel in a given volume of water. Neither variety nor dehulling method had a significant influence on the LGC of cowpea flours (Figs 1 and 2). The mean LGC for all treatments was around 17%. The particle size distribution of flour has been shown to significantly influence its LGC properties.[27] The similarity observed in LGC may be attributed to the similarity in particle size distribution of the processed cowpea flours.

Cowpea variety showed a significant influence on foam volume and stability of processed flours (Fig. 3). Mottled cowpea flours gave higher foam volumes (mean value 21.5 cm^3) than white (14 cm^3) and maroon (8.37 cm^3) cowpea flours. Foam stability showed a similar trend. The least stable foam was observed for maroon cowpea flour. Different wet dehulling methods did not have any significant effect on foam volume and stability, as observed for white cowpea in Fig. 4. However, slightly higher foam volumes (13.67–15 cm^3) were observed for wet dehulled flours compared with their heat-treated dry dehulled counterparts. Good foam volume and stability are desirable properties in *akara* making, as they significantly influence the texture of the final product and therefore its acceptability. The sponginess of *akara* was attributed to high air incorporation during mixing.[14] Results from our study thus imply that heat treatment of cowpea grains prior to milling into flour may not be suitable for the production of cowpea-based food products such as *akara*. The choice of dehulling method for cowpea is thus dependent on the intended use of the resulting flour.

CONCLUSION

The variation in dehulling characteristics with respect to selected cowpea varieties is in agreement with previous findings, which also demonstrated that physical properties and variety affect dehulling characteristics of legume grains.[10,28] The variation in DR of cowpea could mainly be attributed to varietal differences, especially in seed coat thickness. Based on dehulling properties, maroon and mottled cowpeas could be classified as hard to dehull. Both wet and dry dehulling methods were effective on white cowpea, which could therefore be classified as easy to dehull. Dehulling is a very important operation in cowpea processing, since it could help to remove up to 98% of antinutritional factors such as tannins in cowpea.[6] Therefore, for effective dehulling, the method used must be chosen carefully based on variety.

Functional properties of cowpea flour were shown to be more dependent on variety than on dehulling treatment. Mottled cowpea showed the best results, with the highest protein solubility. This variety also presented better foaming properties. White cowpea showed desirable water absorption capacity. Maroon cowpea showed intermediate values of the measured functional properties. Dry heat treatment prior to dehulling decreased the water absorption and foam volume of flours, while protein solubility was slightly increased.

Maroon and mottled cowpeas are not suitable for wet dehulling. Dry dehulling could be recommended for cowpea flour production, as this method was found to be more effective on the studied cowpea varieties. Owing to the observed variation in flour functionality among cowpea varieties, the choice of a particular variety for flour processing will depend on the intended use of the flour. Based on the functionality displayed, white and mottled cowpea flours could be recommended for use in fortification of low-protein foods and for baking application.

ACKNOWLEDGEMENT

Acknowledgment is made to the USAID Funded Bean–Cowpea Collaborative Research Support Program (CRSP) Project of the Department of Nutrition and Food Science, University of Ghana for funding this research.

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