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Effect of Post-Dehulling Treatments on Anti-Nutritional and Functional Properties of Cowpea (*Vigna Unguiculata*) Flour

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ABSTRACT: Recently, cowpea (*Vigna unguiculata*) has been cited for imparting specific positive health potentiating responses when properly positioned in the diet. However, inherent anti-nutritional factors in cowpea have long been recognized as concerns and require appropriate processing conditions to ameliorate adverse effects. The study focuses on effect of post-dehulling treatments on anti-nutritional and functional properties of cowpea flour. Three genotypes of cowpea (IT99K-573-2-1, IT96D-610, and IT07K-292-10) were dehulled. Dehulled cowpeas were boiled, roasted or autoclaved and prepared into flour. Raw (dehulled) cowpea genotype served as control. Anti-nutritional and functional properties of the products were determined using standard procedures. Anti-nutrient concentration of cowpeas differed significantly ($p \leq 0.05$) among genotypes. Tannin, phytate and oxalate concentration ranged from 31.15 to 121.80g/kg, 22.31 to 48.04 g/kg and 0.01 to 0.026g/kg respectively. Coloured beans (IT96D-610), had significantly lower anti-nutritional content than those of white beans (IT99K-573-2-1 and IT07K-292-10). All heat treatments significantly reduced the levels of investigated anti-nutrients compared to their respective control. Water absorption capacity and oil absorption capacity were found in the range of 2.12–3.07 mL/g and 1.37-1.73 mL/g, respectively. Swelling power, starch solubility, loose bulk density and packed bulk density varied between 10.79 to 18.42g/g, 0.16 to 1.52g/g, 0.64 to 0.73g/mL and 0.84 to 0.94 g/mL respectively. Colour parameters (L^*, a^*, b^*, h_{ab}, C^*) showed significant variations among the genotypes. The combined varietal and processing variation induced significant modification in the inherent anti-nutrients and functional properties of dehulled cowpea as attested by the highly significant ($p \leq 0.05$) correlations observed. Processing of cowpea seeds in these forms presents an opportunity for extending their use beyond the dehulled seeds in food system.

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Cowpea (*Vigna unguiculata*) is a leguminous plant which belongs to the family *Fabaceae*. It originated in Africa and is widely distributed in tropical and temperate climates and differs in shape, size and colour of seed coat (Ashogbon and Akintayo, 2013). It is a major staple food crop in sub-Saharan Africa, especially in the dry savannah regions of West Africa. Nigeria is the largest producer of cowpea and consumer account for 61% of production in Africa and 58% worldwide and more than 4 million tonnes of peas of all sorts are consumed worldwide, with 387,000 tons consumed in Africa (IITA, 2013).The main centres of cultivation of cowpea in Nigeria are Kano, Katsina, Bauchi, Bornu, Sokoto and Niger States in the North; and Ibadan, Owo and Benin in the West (Arawande and Borokini, 2010). It is a good source of calories and provides a significant amount of dietary protein (18-35%) and lysine as reported by Sosulski *et al*. (1987). It is also considered as an incredible source of many other health-promoting components, such as soluble and insoluble dietary fibre, phenolic compounds, minerals, and many other functional compounds, including B group vitamins (Liyanage *et al*., 2014). Asides, it is important to note the major limiting factors of the consumption of cowpea in human diet include poor digestibility, a deficiency of sulphur-containing amino acids (methonine and cysteine) and the presence of anti-nutritive factors such as trypsin inhibitors, tannin, phytates, lecitins, and saponin (Vadivel and Jonadhanan, 2001). Nevertheless, several traditional methods of bean preparation in African and Asian countries have found wide acceptability. These methods produce highly specialized and culturally distinctive products and are recognized for improving bean digestibility and reducing anti-nutritional factors. One of such methods involves removal of the outer covering of the seeds referred to as dehulling. It is done most times to improve the quality of the cowpea product. Besides, several post-dehulling treatments including soaking, cooking, roasting, autoclaving and germination have been reported on legumes in the scientific literature to further reduce the inherent anti-nutrients (Ehlers and Hall, 1997). However, no comprehensive study has been reported about the possible changes in anti-nutritional concentrations of the dehulled seeds of cowpea subjected to these processes. Presentation of cowpea flour in these forms presents an opportunity for extending the use of cowpeas beyond the dehulled seeds in food system. Asides the nutritional quality of cowpea flour, it is also imperative to find out if such flour will possess desirable properties for food

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applications and consumer acceptability. For plant proteins to be useful and successful in food application they should ideally possess several characteristics, referred to as functional properties. Therefore, the present study evaluates the anti-nutrient concentration and functional properties of the dehulled cowpea seeds subjected to boiling, roasting or autoclaving process.

MATERIALS AND METHODS

Materials: Three genotypes of cowpea (IT99K-573-2-1, IT96D-610, IT07K-292-10) used in this study were obtained from the International Institute for Tropical Agriculture (IITA), Ibadan, Nigeria. Seeds were cleaned from the dirt, foreign matter and damaged ones. All the chemicals and reagents used were of analytical grade.

Sample preparation: Cowpea seeds (500g) from each genotype were soaked in 1000mL of water for 5 min at room temperature and then dehulled manually. The resultant dehulled seeds from each genotype were divided into four portions respectively. One portion was subjected to boiling, another portion to roasting, and the third portion to autoclaving process. The fourth portion of dehulled (raw) cowpea was not further processed and served as the control.

Boiled cowpea flour: A portion (100g) of the dehulled cowpea seeds were boiled in 500mL of distilled water at 100ºC for 20 min after which they were drained and oven dried to constant weight at 60ºC for 3 h. The boiled seeds were then milled into flour using a laboratory grinder, packed in glass container and kept in freezer (-4°C) pending analysis.

Roasted cowpea flour: A portion (100g) of the dehulled cowpea seeds were roasted in aluminium frying pan using 1000W electric hot plate (Guangzhou D.G.H. Electrical Appliances Co. Limited Guangdong, China). The pan was allowed to warm to a temperature of about 60ºC to 70ºC. Cowpea sample was added and heating continued with stirring until slightly brown. The time required to roast was about 20 min. The roasted seeds were then milled into flour using a laboratory electric grinder. The cowpea flour was sifted using an 80-mesh sieve, packed in glass container and kept in freezer (-4°C) pending analysis.

Autoclaved cowpea flour: A portion (100g) of the dehulled cowpea seeds was autoclaved at a temperature of 121ºC for 10 min, after which they were drained and oven dried at 60ºC for 3 h. The autoclaved seeds were then milled into flour using a laboratory electric grinder. The cowpea flour was sifted using an 80-mesh sieve, packed in glass container and kept in freezer (-4°C) pending analysis.

Evaluation of anti-nutrient concentration: The phytate and oxalate concentrations of the flours were determined using method described by Oladele *et al.* (2009). Tannin content was determined by the method described by Mugabo *et al*. (2017).

Evaluation of functional properties: The bulk density (loose and packed) of cowpea flours was determined by the gravimetric method described by Appiah *et al*. (2011).Water and oil absorption capacities were determined using the procedures described by Sofi *et al.* (2013). Additionally, the swelling power and solubility of the cowpea samples were determined using the method reported by Wani *et al.* (2015).

Measurement of colour attributes: The surface colour trichromatic characteristics of cowpea flour was measured using a Chroma Meter CR-400 (Konica Minolta Sensing Inc., Japan) and expressed in terms of lightness (L*), red-green characteristics (a*), blue–yellow characteristics (b*). The hue angle and chroma were calculated as $h_{ab} = \tan^{-1}(b^*/a^*)$ and $C^* = [\sqrt{(a^*)^2 + (b^*)^2}]$, respectively. Colour traits were based on triplicate determinations.

Statistical Analysis: Data analysis was performed using the SPSS software for window release 16.00; SPSS Inc., Chicago IL, USA. Each sample was analyzed in triplicate, and the results were expressed as mean ± standard deviation (SD). Duncan test was used to determine the differences between the means within groups. The statistically significant difference was defined as $p \leq 0.05$.

RESULTS AND DISCUSSION

Anti-nutrients composition of cowpea genotypes: The concentration of anti-nutrients of raw and processed cowpea genotypes is presented in Table 1. The concentration of tannin was 121.80 g/kg, 80.28 g/kg and 117.51 g/kg for raw (IT99K-573-2-1), (IT96D-610) and (IT07K-292-10), respectively. Tannin was the most affected anti-nutrient with boiling causing reduction range of 33.2% for IT99K-573-2-1 genotype to 38.80 % for IT96D-610 genotype; roasting causing reduction range of 48.54% for IT99K-573-2-1 genotype to 60.53% for IT07K-292-10 genotype while autoclaving induced reduction range of 56.6% for IT99K-573-2-1 genotype to 61.0 % for IT96D-610 genotype, respectively. Tannin levels dropped progressively as the raw cowpea seeds were processed, producing significant differences among fractions. Despite variations in different cowpea genotypes studied; cooking, autoclaving or roasting process clearly affect tannin content in the final product. The tannin levels in the cowpea samples could have originated from the testa or from residual hulls. The reduction of tannins after cooking and autoclaving is mainly due to the fact that these compounds in addition to their predominance in seed coats are water soluble and consequently leach into the processing medium. These results agree with those of Mubarack (2005) who found out that tannin content of mung bean seeds (*Phaseolus aureus* L) reduced after autoclaving at

121°C for 35 min. Moreso, the decrease noted in roasted cowpea could also be related to the fact that these compounds are heat labile and degrade upon heat treatment. Tannins had been reported to affect protein digestibility, adversely influencing the bio-availability of non-heme iron leading to poor iron and calcium absorption, also carbohydrate is affected leading to reduced energy value of a diet (Massey *et al*., 2001). They are also known to interact with other food components. Fish and Thompson (1991) reported the inhibitory action of tannins on amylase; likewise interaction between tannins and lectin and interaction between tannins and cyanogenic glucoside reduced the deleterious effect of the later (Goldstein and Spencers, 1985). It is however imperative to note that toxicity effects of tannins depend upon their chemical structure and dosage (Bello *et al*., 2008). Therefore, the toxicity effects of tannin reported in raw and processed cowpea may not be significant since the total acceptable tannic acid daily intake for a man is 560 mg/100g as reported by Bello *et al*. (2008).

The oxalate content was found to be within a range of 0.010 to 0.026g/kg. Oxalate was highly represented in raw IT99K-573-2-1genotype while the lower concentration was found in (IT96D-610) and (IT07K-292-10) cowpea genotypes. Boiling and autoclaving reduced the oxalate content to a range of 55.56-73.08% and 46.15-61.11% respectively, values that were different significantly ($p \leq 0.05$). Although the oxalate concentration was reduced by soaking and autoclaving, the percentage reduction was higher compared to the roasting process. This shows that moist heat is more effective in the reduction of oxalate content than the dry heat. The depletion in the level of oxalate as a result of processing is comparable with the finding of Obasi and Nwogu (2008).Oxalates can have a harmful effect on human nutrition and health, especially by binding with calcium and magnesium, interfering with their metabolism and subsequently causing muscular weakness and paralysis (Soetan and Oyewole, 2009). The total intake of oxalate in human diet should not exceed 50–60 mg per day as indicated by Hurrel *et al*. (1992).

Phytate content of raw cowpea genotypeIT99K-573-2-1 (48.04g/kg) was higher but do not differ significantly from genotypeIT96D-610 (44.94g/kg) and genotypeIT07K-292-1 (41.15g/kg) had the lowest. The observed reduction in phytic acid content of legume seeds during heat treatment may be partly due to the heat labile nature of phytic acid. Heat processing inactivates heat sensitive phytic acid; however phytic acid is more tolerant of heat-cooking than other anti-nutritional factors (Abizari *et al*., 2012).Content variation may result from dehulling of the seeds which cause substantial changes in the phytate content due to the removal of the aleurone layers and much more is expected after processing of dehulled seeds. Phytate generally bind multivalent cations, form complexes with proteins, starch and minerals such as iron, zinc, calcium and magnesium and thus are less leached compared to oxalate and tannin that were readily soluble in water. However, the phytate concentrations of raw and processed cowpea samples might not pose any health hazard when compared to a phytate diet containing 10-60 mg/100g which if consumed over a long period of time that has been reported to decrease bioavailability of minerals (Elinge *et al*., 2012). On a positive note, there is evidence that dietary phytate at low level may have beneficial role as an antioxidant, anti-carcinogens and likely play an important role in controlling hypercholesterolemia and atherosclerosis (Adeparusi, 2001).

Generally, anti-nutrient concentration in seeds is a function of climatic conditions, irrigation, seed genotype, and soil type (Urbano *et al*., 2000). Most importantly, the variation in anti-nutrient concentrations could also be related to the colour of the seeds which was brown for IT96D-610 genotype and white for IT99K-573-2-1 and ITO7K-292-10 genotypes, thus suggesting influence of genetic origin. Coloured beans, particularly from the black and red market classes (Canadian navy bean cultivars), had significantly lower phytate content than those of white bean (Oomah *et al.*, 2008) that collaborated with the trend observed in this study.

Table 1: Anti-nutritional composition of cowpea flour

Processing Variables	Cowpea genotypes	Tannin (g/kg)	Phytate (g/kg)	Oxalate (g/kg)
Raw	IT99K-573-2-1	121.80 ± 1.20^{f}	48.04 ± 0.05^{d}	0.026 ± 0.00^{c}
	IT96D-610	80.28 ± 1.25^{e}	44.94 ± 1.15^{d}	0.019 ± 0.00^{b}
	IT07K-292-10	117.51 ± 1.36^{f}	44.15 ± 1.19^{d}	0.018 ± 0.00^{b}
Boiled	IT99K-573-2-1	40.37 ± 0.67^{b}	24.50 ± 0.02^{a}	0.019 ± 0.00^{b}
	IT96D-610	31.15 ± 0.43^{a}	22.31 ± 0.12^{a}	0.012 ± 0.00^{a}
	IT07K-292-10	40.35 ± 2.25^{b}	25.65 ± 0.09^{a}	0.010 ± 0.00^{a}
Roasted	IT99K-573-2-1	59.12 ± 3.01^{c}	36.77 ± 1.13^{c}	$0.019\pm.0.00^{b}$
	IT96D-610	46.29 ± 0.31^{b}	37.98 ± 1.11^{c}	0.016 ± 0.00^{a}
	IT07K-292-10	71.13 ± 2.51^{d}	31.63 ± 0.00^{b}	0.015 ± 0.00^{a}
Autoclaved	IT99K-573-2-1	68.94 ± 4.94^{d}	38.97 ± 0.28^{c}	0.012 ± 0.00^{a}
	IT96D-610	48.59 ± 1.98^{b}	35.18 ± 0.02^{bc}	0.013 ± 0.00^{a}
	IT07K-292-10	67.33 ± 1.80^{d}	37.43 ± 0.02^{c}	0.011 ± 0.00^{a}

Each value is the mean ± SE, mean value in each column having different superscript are significantly different at p ≤0.05

Functional properties of cowpea genotypes: The functional properties of cowpea genotypes were presented in Table 2.The loose bulk density which is the lowest attainable density without compression (LBD) of raw cowpea flour ranged from 0.64 to 0.74g/mL, while the packed bulk density which is the highest attainable density with compression (PBD) ranged between 0.84 and 0.94 g/mL. There was significant difference in the loose bulk densities of raw cowpea samples. However, raw cowpea genotype (IT99K-573-2-1) showed higher packed bulk density (0.94 g/mL) than cowpea genotype IT96D-610 (0.91 g/mL) and IT07K-292-10 genotype (0.86 g/mL). The results further showed that processed cowpea flours had lower bulk density than raw flour for all cowpea genotypes. Thus making the resultant processed flours important in infant feeding where less bulk density is desirable though such flours would float on top of water and hence may not soak and mix properly in water during mixing to produce "moinmoin". In contrast, higher bulk density of raw cowpea flours gives indication that they were heavier than processed flours which in turn is desirable for greater ease of dispensability.

The water absorption capacity of the cowpea genotypes ranged between 2.12-3.07mL/g. There were significant differences ($p \leq 0.05$) in water absorption capacities among the cowpea genotypes. Raw cowpea genotype (IT07K-292-10) had the highest water absorption capacity compared to that of IT99K-573-2-1 and IT96D-610 cowpea genotypes. Appiah *et al.*(2011) in a study of three cultivars of cowpea grown in Ghana have reported water absorption capacity ranging between 1.89 and 2.15 g/g. Similar results have been reported by Chinma *et al*. (2008) with water absorption capacity varying between 1.60 and 1.94 g/g for certain cowpea cultivars. In addition, significant difference ($p \leq 0.05$) in water absorption capacity existed between processed cowpea genotypes. The water absorption capacity of processed cowpea flour was significantly higher ($p \leq 0 \cdot 05$) than that of raw sample. The low water absorption capacity of raw cowpea flour may be due to weak association of amylose and amylopectin in the samples. Malomo *et al*. (2012) reported that water absorption capacity will be low if there is loose association between amylose and amylopectin in the native granules of starch and weak associative forces maintaining the granules structure. Earlier work on comparisons between raw and toasted cowpea genotypes also showed a significant increase in water absorption capacity on toasting (Obasi *et al*., 2014). Furthermore, the moderate water absorption capacities of cowpea samples suggest that they may have useful functional ingredients in bakery products.

Oil absorption capacity shows significant differences between three cowpea genotypes. Oil absorption capacity was 1.78mL/g for raw cowpea genotype IT99K-573-2-1, 1.64mL/g for IT96D-610 and 1.41mL/g for IT07K-290-10. The results show that these genotypes may have different lipid or hydrophobic groups present. Appiah *et al*. (2011) had reported oil absorption capacities for the three cowpea cultivars in the range between 1.95 and 2.31 mL/g. Chinma *et al*. (2008) have also reported oil absorption capacity of the range of 0.35 to 0.54 g/g for different Nigerian cowpea cultivars. The cowpea genotype IT99K-573-2-1 could therefore be preferable to others since it has significantly higher oil absorption capacity. The oil absorption capacity makes the flours suitable in food preparations where it helps facilitating appropriate flavour and mouth feel in food preparation. There were also significant differences in oil absorption capacity between raw and processed cowpea flours. However, raw cowpea flours could also be preferable to processed flours since they have significantly higher oil absorption capacities. Similarly, Malomo *et al.* (2017) reported higher oil absorption capacity for the control (cowpea flour) than for the pre-cooked cowpea flour with 20% binder. The moderate oil absorption capacities of raw and processed genotypes of cowpea could make them useful in food systems where oil imbibition is desired; food such as sausage production. Cowpea flours were consistently more hydrophilic than lipophilic, regardless of mode of heat treatment (Padmashree *et al*., 1987) as observed in this study.

The swelling capacity was found to be significantly different for the three cowpea genotypes. Raw cowpea genotype IT96D-610 showed higher swelling power (18.42g/g) than IT07K-290-10 (17.57g/g) and IT99K-573-2-1 (17.46g/g). Immense reduction in swelling capacity noted in cowpea genotype (IT99K-573-2-1) could be attributed to the dominance of amylose–protein interaction that resulted in complex formation and hence resisted swelling in such sample. This is attributed to Pomeranz (1991) who stated that formation of protein–amylose complex in native starches and flours may be the cause of decrease in swelling power. The reason for the higher swelling power of genotype IT96D-610 at 90°C could be attributed to the lower amylose content compared to other cowpea genotypes. Starch granules become increasingly susceptible to shear disintegration as they swell and starches with lower amylose content (higher amylopectin content) swell more than those with higher amylose content (Ashogbon and Akintayo, 2012). Additionally, the white coloured cowpea genotypes (IT99K-573-2-1 and 1T07K-292-10) are firmly attached to the cotyledons; therefore, they are more difficult to dehull and have the lower swelling capacity compared to darker genotypes as earlier reported by Olapade *et al.* (2002). Moreso, swelling capacity was significantly ($p \leq 0.05$) higher in raw cowpea flour than in boiled, autoclaved and roasted flours. The swelling power of the flour is largely controlled by the strength and character of the micellar network within the starch granules (Bolade, 2009).

Starch solubility indices also varied significantly between genotypes of cowpea. Starch solubility in raw cowpea genotype (IT99K-573-2-1) was 0.16g/g and was significantly different from IT96D-610 genotype (0.41g/g) and IT07K-292-10 genotype (0.65g/g). However, processed cowpea flours had significantly higher starch solubility values than raw cowpea flour. The heating effect from boiling, roasting and autoclaving might have degraded the starch and produced more soluble molecules (Siddiq *et al*., 2010), thus increasing the starch solubility. The differences among the cowpea samples in their swelling and solubility patterns can form the basis of the functional properties that determine their suitability in product development.

Table 2: Functional properties of cowpea genotypes

Processing variable	Cowpea Genotypes	WAC* (mL/g)	OAC* (mL/g)	Swelling power(g/g)	Starch Solubility (g/g)	LBD (g/mL)	PBD (g/mL)
Raw	IT99K-573-2-1	$2.33±0.02^{b}$	$1.78±0.01^{g}$	$17.46±0.04^{e}$	$0.16±0.04^{a}$	$0.72±0.03^{b}$	$0.94±0.01^{d}$
	IT96D-610	$2.12±0.01^{a}$	$1.64±0.01^{e}$	$18.42±0.19^{f}$	$0.41±0.01^{b}$	$0.74±0.01^{b}$	$0.91±0.01^{cd}$
	IT07K-292-10	$2.51±0.02^{c}$	$1.41±0.02^{c}$	$17.57±0.08^{e}$	$0.65±0.02^{b}$	$0.73±0.01^{b}$	$0.86±0.01^{abc}$
Boiled	IT99K-573-2-1	$2.56±0.06^{cd}$	$1.73±0.10^{f}$	$12.02±0.09^{ab}$	$1.42±0.03^{g}$	$0.66±0.01^{a}$	$0.89±0.04^{bcd}$
	IT96D-610	$2.65±0.04^{e}$	$1.61±0.01^{de}$	$12.25±0.01^{b}$	$1.32±0.02^{f}$	$0.64±0.01^{a}$	$0.86±0.01^{ab}$
	IT07K-292-10	$3.07±0.02^{f}$	$1.37±0.03^{c}$	$10.79±0.37^{a}$	$1.52±0.01^{h}$	$0.67±0.01^{a}$	$0.84±0.01^{a}$
Roasted	IT99K-573-2-1	$2.34±0.02^{b}$	$1.72±0.01^{f}$	$14.12±0.07^{c}$	$0.76±0.02^{c}$	$0.71±0.01^{b}$	$0.85±0.01^{ab}$
	IT96D-610	$2.55±0.03^{cd}$	$1.57±0.01^{d}$	$11.19±0.03^{a}$	$0.72±0.01^{c}$	$0.72±0.01^{b}$	$0.89±0.01^{bcd}$
	IT07K-292-10	$2.68±0.03^{e}$	$1.22±0.01^{a}$	$12.24±0.12^{b}$	$0.73±0.02^{c}$	$0.67±0.01^{a}$	$0.86±0.01^{abc}$
Autoclaved	IT99K-573-2-1	$2.18±0.01^{a}$	$1.37±0.02^{c}$	$14.70±0.65^{cd}$	$0.91±0.01^{d}$	$0.71±0.01^{b}$	$0.85±0.01^{ab}$
	IT96D-610	$2.41±0.06^{b}$	$1.23±0.02^{a}$	$15.00±0.40^{d}$	$0.87±0.03^{d}$	$0.71±0.01^{b}$	$0.88±0.01^{bcd}$
	IT07K-292-10	$2.62±0.02^{de}$	$1.33±0.02^{b}$	$14.21±0.05^{c}$	$1.06±0.05^{e}$	$0.72±0.01^{b}$	$0.90±0.01^{bcd}$

Each value is the mean ± SE, mean value in each column having different superscript are significantly different at p ≤0.05; WAC – Water absorption capacity; OAC – Oil absorption capacity; LBD – Loose bulk density; PBD – Packed bulk density

Colour attributes of cowpea genotypes: The effect of genotype and processing on the lightness (L*), redness (a*), yellowness (b*) hue angle (h_{ab}) and chroma (C*) of cowpea flour is shown in Table 3. The measurements with the Chroma Meter system (CIELab) showed higher L* value for raw cowpea flour IT96D-610 (86.35) than IT99K-573-2-1(85.38) and IT07K-292-10 (84.81). The observation points to the fact that cowpea genotype (IT96D-610) is whiter than other two genotypes. Redness (a*) value in the range from 1.12 to 1.29 and yellowness (b*) value from 14.44 to 14.77 was observed. The processing method significantly affected the colour of the cowpea flours by decreasing the lightness (L*) of the flour. Autoclaved cowpea flours provided the lowest L* values followed by boiled cowpea flours. Roasted cowpea flours had the highest L* values compared to other processed flours. Redness (a*) and yellowness (b*) varied significantly when cowpea flours were made from the boiled, autoclaved or roasted beans. It is worth noting that the boiled, autoclaved and roasted beans showed lower L* values when compared to the raw beans. The hue angle was 85.14 for IT99K-573-2-1 genotype, 85.35 for IT96D-610 and 86.06 for ITO7K-292-10 genotype, respectively. Similarly, the chroma value was 14.81 for IT99K-573-2-1 genotype, 15.69 for IT96D-610 genotype and 14.50 for ITO7K-292-10 genotype, respectively.

Table 3: Colour parameters of cowpea flour

Processing Variables	Cowpea Genotypes	L*	a*	b*	C*	h_{ab}
Raw	IT99K-573-2-1	$85.38±0.22^{k}$	$1.12±0.04^{c}$	$14.77±0.05^{d}$	$14.81±0.00^{hi}$	$86.14±0.00^{h}$
	IT96D-610	$86.35±0.23^{l}$	$1.27±0.02^{d}$	$15.64±0.11^{e}$	$15.69±0.00^{j}$	$86.35±0.00^{h}$
	IT07K-292-10	$84.81±0.09^{j}$	$1.29±0.05^{d}$	$14.44±0.31^{d}$	$14.50±0.00^{h}$	$86.06±0.00^{g}$
Boiled	IT9K-573-2-1	$75.11±0.01^{f}$	$2.57±0.09^{g}$	$16.85±0.17^{g}$	$14.09±0.00^{g}$	$85.99±0.00^{ef}$
	IT96D-610	$72.67±0.35^{e}$	$1.82±0.00^{e}$	$13.32±0.07^{c}$	$13.44±0.00^{ef}$	$85.75±0.00^{e}$
	IT07K-292-10	$69.10±0.01^{c}$	$0.96±0.01^{b}$	$12.11±0.00^{b}$	$12.15±0.00^{c}$	$85.29±0.00^{c}$
Roasted	IT99K-573-2-1	$78.23±0.15^{h}$	$0.72±0.03^{a}$	$13.42±0.05^{c}$	$13.40±0.00^{ef}$	$85.77±0.00^{e}$
	IT96D-610	$76.33±0.12^{g}$	$1.79±0.02^{e}$	$16.31±0.05^{f}$	$13.42±0.00^{ef}$	$85.73±0.00^{e}$
	IT07K-292-10	$79.63±0.01^{i}$	$1.78±0.06^{f}$	$17.55±0.16^{h}$	$12.68±0.00^{d}$	$85.49±0.00^{cd}$
Autoclaved	IT99K-573-2-1	$70.29±0.32^{d}$	$3.12±0.02^{h}$	$16.80±0.05^{g}$	$13.18±0.00^{e}$	$85.66±0.00^{d}$
	IT96D-610	$60.05±0.03^{b}$	$0.78±0.01^{a}$	$9.94±0.01^{a}$	$9.97±0.00^{b}$	$84.27±0.00^{a}$
	IT07K-292-10	$54.79±0.02^{a}$	$0.79±0.00^{a}$	$9.67±0.00^{a}$	$9.70±0.00^{a}$	$84.11±0.00^{a}$

Mean ± standard deviation. Means within a column with different uppercase letters are statistically different (p< 0.05)
L= Lightness (0 = black, 100 = white), +a*= red, –a*= green, +b*= yellow, –b*= blue, Hab= Hue angle, C*= Chroma*

The multivariate tests indicated significant difference between the genotypes in terms of hue angle and chroma. Roasting had a significant effect on hue and chroma values of cowpea flour. The lower lightness and chroma values of processed cowpea flours indicate that their colours are darker and less saturated than that of the unprocessed (raw) flour. Colour of flour is important regarding its industrial application because any pigmentation would be carried to the final product in which it is to be used and its quality and thus its acceptance could be reduced (Hongbete *et al*., 2009). According to McWatters *et al*. (2007), paste properties, processing steps and quality of resultant cowpea products are affected by the use of different cowpea genotypes. The lighter bean genotypes are more appreciated in akara preparation because they produce products of similar colour (McWatters *et al*., 1993).

Conclusion: The findings of this study show that processing treatment (boiling, autoclaving or roasting) had influence on the anti-nutritional composition of dehulled cowpea genotypes. Similarly, the products exhibit good functional properties which could be exploited in food systems. Consumption of processed dehulled cowpea flour would be an important step towards relieving malnutrition in the poor countries of the world.

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