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Effect of Dry Heat Pre-Treatment (Toasting) on the Cooking Time of Cowpeas (*Vigna unguiculata* L. Walp)

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ABSTRACT

Four cowpea varieties (Brown beans, *Oloka* beans, *IAR48* and *IT89KD-288*) were toasted at 105°C, and used to study the effect of dry heat treatment on the cooking time and nutrient composition of cowpea seeds and also its effect on the functional properties of resultant flour of the cowpea seed varieties. Toasting reduced the cooking time for brown and *oloka* cowpea varieties from 55.00 – 31.00 and 70.67 – 51.67 min, respectively. The cooking time for IAR48 and IT89KD-288 cowpea varieties increased from 104.67 to 106.00 and 88.00 to 88.67 min, respectively. The results indicate that the cooking time of cowpea seeds can be reduced significantly on toasting, while maintaining their potential as functional agents in the food industry for nutrition and utilisation. Correlation between the amount of water imbibed by cowpea seeds and their cooking time was -0.74, but was not significant at $p \leq 0.05$, suggesting that there is no significant relationship between the amount of water imbibed by cowpea seeds and their cooking time.

Keywords: Cowpeas, toasting, cooking time, nutrient composition, functional properties.

Introduction

Cowpea *(Vigna unguiculata)* is a member of the *phaseolaea* tribe of the *leguminosae* family. In the early 1970s, cowpea was the second most important crop in Africa, after groundnut (Elegbede, 1998).

Cowpeas are sources of low-cost dietary vegetable proteins, B-vitamins and minerals when compared with animal products like meat, fish and egg (Apata and Ologhobo, 1994). They are therefore an affordable alternative protein source to the people of the poor, rural communities in Nigeria and other developing countries.

The utilization of whole seeds of cowpeas is however limited due to the issue of it having a prolonged cooking time. The cooking time of cowpea seeds ranges from 35 – 120 min or more, depending on the variety and type of cooking water used (Olapade *et al.*, 2002). This is a great challenge for both urban and rural consumers due to time and energy requirements.

Toasting is a dry heat treatment or processing technique that is used to either cook or pre-cook food materials. It involves alternate cooking and heating processes. Toasting impacts starch gelatinization in food materials (Sefa-Dedeh, 1984). Ndungu *et al.* (2012) reported that the pre-treatment of cowpea grains using dry heat – hot air roasting, reduced its cooking time by impacting a reduction in phytase activity by 40%, which in turn, improved pectin solubility, a factor in the cooking of cowpeas.

Thus, the objectives of this research are to determine the effect of dry heat pre-treatment (toasting) on

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the nutritional composition and cooking time of cowpea seeds as well as the functional properties of the resultant flour. To determine the effect of toasting on the cooking time of four cowpea seed varieties. To determine the effect of toasting on the nutritional composition of four cowpea seed varieties. To determine the effect of toasting on the functional properties of the resultant flour from four cowpea seed varieties. To determine whether a relationship exists between the cooking time and water imbibition in cowpea seeds.

Materials and Methods

Source of raw materials

Four cowpea varieties were used in this study. The *oloka (moi-moi)* and brown beans (local varieties) were bought from Umuahia main market, Umuahia North Local Government Area, Abia State, Nigeria. While the IAR48 and IT89KD-288 varieties were obtained from the International Institute of Tropical Agriculture, Ibadan, Oyo State, Nigeria.

Sample preparation

Each of the cowpea varieties was handled separately. Each sample variety was cleaned and sorted, and then divided into two equal parts. One part for each sample was toasted in a hot stainless steel pan, with continuous stirring, for 5 min at a temperature of 105^{o}C and then cooled in open air, after which they were sorted again to remove burnt seeds. Two portions (i.e., the raw and toasted portions) of each sample were then stored for 14 days, in air tight containers to check whether the heat treated samples would deteriorate during storage. Some portion of each of the samples (both raw and toasted) were also milled into flour using a hammer mill, for the nutritional and functional analysis, while the remaining whole seeds were used for analysis of cooking time and water imbibition.

Sample analyses

Cooking time

The cooking time was evaluated according to the method described by Akinyele *et al.* (1986) with slight modifications in terms of quantity of water, cooking vessel and seeds used. A 30 grams portion of each cowpea whole seeds sample (raw and toasted) were added to separate plastic bags containing 500 ml of water. Two rods were placed through holes punched in the plastic bags, enabling the bags to hang in a parallel position between the rods and remain stable (Plate 3). The plastic bags with seeds, now supported by the rods, were placed in a pot containing boiling water at a level high enough to completely submerge the bags with seeds in the water (Plate 4). Treated and untreated cowpea samples were handled separately.

Cooking time was then determined by noting the time in minutes required for soft cooking, as assessed by pressing the cooled seeds between two fingers (thumb and index fingers) until no hard material remained.

Proximate composition

The proximate composition of the cowpea samples was determined using standard methods. Each sample was handled separately and analysis was done in three replications. The specific analyses conducted include the following: moisture contents, fat contents, crude protein, crude fibre and ash contents were determined according to the method described by Ibitoye (2005). The carbohydrate contents were determined by difference.

Analysis of functional properties

These properties were analysed according to the methods described by Onwuka (2005) and by Konik *et al*. (1993). Each sample was handled separately and analysis was done in three replications. The specific analyses conducted include the following: bulk density, water absorption capacity, oil absorption capacity, foaming capacity and stability, wettability,emulsion capacity and swelling capacity.

Determination of water imbibition

Fifteen cowpea seeds were selected from each sample and weighed separately. The seeds were then placed in labelled containers containing 50 ml of distilled water at room temperature, and allowed to stand overnight for 18 h, in order to ensure uniform expansion and maximum water imbibition (Onayemi *et al*., 1986). The soak water was then drained and the cowpea samples were placed on labelled improvised blotting paper, to dry off the remaining water (Plate 5). The increase in seed weight was taken as the water imbibed and was calculated thus:

$W_2 - W_1$

Where W_1 = weight of seeds before soaking

W_2 = weight of seeds after soaking

Statistical analysis

Statistical analysis of data obtained from the cooking time, functional, nutritional and water imbibition analysis were conducted using the IBM SPSS package version 19 for personal computers (2010). Mean scores were subjected to One-way Analysis of Variance, and the significance of difference between samples was determined.

Results and Discussion

Cooking time

The effect determined by Turkey's Honest Significant Difference method (HSD). Correlation between rate of water imbibition and cooking time qualities were determined using Pearson's Correlation.

The effect of toasting on the cooking time of the cowpea samples is shown in Table 1. The cooking time means ranged between 31 min and 106 min. Cooking time for brown beans and *oloka* cowpea varieties reduced significantly on toasting. This could be as a result of the changes that occur in cell wall structure, starch composition and protein composition of the cowpea seeds when heated. No significant difference existed in the cooking time of the *IAR48* and *IT89KD-288* cowpea varieties from the IITA. This may be due to modifications made on them by the IITA.

Cell separation during cooking, tends to a soft texture. The mechanism underlying this involves the heat-catalysed depolymerisation of the middle lamella pectin polymers (Brett and Waldron, 1996).

When cowpeas are heated at 100^{o}C, the middle lamella is weakened, resulting in cell separation. Thus, the toasting treatment given to the cowpea samples at 105^{o}C could have weakened the middle lamella, resulting in cell separation in the cowpea seeds prior to more heat application during the cooking of the cowpea seeds.

The toasting treatment, causing a reduction in protein content for the brown beans and *oloka* cowpea varieties (Table 2) could have eliminated this competition between starch gelatinisation and protein denaturation during subsequent cooking, thus reducing cooking time. This is also applicable to the IAR48 and subsequent increase in cooking time, though not significant at $p \leq 0.05$.

Proximate composition

The effect of toasting on the proximate composition of the cowpea varieties is shown on Table 2.

Moisture content means of the cowpea samples ranged between 6.58% and 19.35%. There was a significant decrease in moisture content on toasting for the comparisons between raw and toasted cowpea samples for all four cowpea varieties. This could be as a result of the drying effect of the toasting treatment. Toasting alternates between drying and cooking processes (Sefa-Dedeh, 1984).

Fat content means ranged from 0.61% to 2.46% which is within the fat content range of cowpea seeds reported by Chavan *et al*. (1989). Comparisons between raw and toasted cowpea samples for all four cowpea varieties indicated a significant difference at $p \leq 0.05$. However, while the brown and *oloka* cowpea varieties showed an increase in fat content, the IAR48 and IT89KD-288 cowpea varieties showed a decrease in fat content probably due to the modifications made on them by the IITA.

Table 1: Effect of toasting on the cooking time of four cowpea varieties

Property	HSD	Brown Beans		Oloka Beans		IAR48		IT89KD-288	
		Raw	Toasted	Raw	Toasted	Raw	Toasted	Raw	Toasted
Cooking Time (mins)	9.524	56.67^{d} ±2.89	31.00^{e} ±2.08	70.67^{c} ±2.33	51.67^{d} ±1.67	104.67^{a} ±0.88	106.00^{a} ±2.08	88.00^{b} ±2.00	88.67^{b} ±2.40

^{a,b,c,d,e,f,g,h} means with different superscripts within the same row, are significantly different ($p \leq 0.05$). HSD = Turkey's Honest Significant Difference

Table 2: Effect of toasting on the proximate composition of four cowpea varieties

Parameter (%)	HSD	Brown Beans		Oloka Beans		IAR48		IT89KD-288	
		Raw	Toasted	Raw	Toasted	Raw	Toasted	Raw	Toasted
Moisture	0.297	12.17^{b} ±0.9	8.82^{e} ±0.09	19.35^{a} ±0.02	10.23^{d}±0.02	12.47^{b} ±0.09	6.58^{f} ±0.01	11.10^{c} ±0.06	6.74^{f} ±0.01
Fat	0.000	0.62^{g} ±0.01	2.46^{a} ±0.02	0.62^{g} ±0.01	1.27^{d} ±0.01	2.13^{b} ±0.02	1.04^{e} ±0.00	1.68^{c} ±0.00	1.02^{f} ±0.01
Crude fibre	0.090	4.51^{c} ±0.05	5.70^{a} ±0.01	4.30^{d} ±0.00	5.34^{b} ±0.01	2.45^{e} ±0.00	2.13^{f} ±0.00	1.88^{g} ±0.01	1.92^{g} ±0.01
Protein	0.895	17.94^{c}±0.08	15.62^{f} ±0.06	17.04^{d} ±0.01	16.10^{e} ±0.06	23.73^{b}±0.03	25.17^{a}±0.09	23.50^{b} ±0.06	23.63^{b} ±0.03
Ash	0.090	3.36^{a} ±0.01	2.58^{d} ±0.03	2.81^{c} ±0.01	2.41^{e} ±0.01	2.60^{d} ±0.01	2.12^{f} ±0.01	3.21^{b} ±0.01	2.62^{d} ±0.04
Carbohydrate	0.657	61.58^{d}±0.29	64.82^{a} ±0.14	55.90^{g} ±0.02	64.62^{a} ±0.04	56.56^{f} ±0.12	62.96^{c} ±0.09	58.62^{e} ±0.10	64.07^{ab} ±0.04

^{a,b,c,d,e,f,g,h} means with different superscripts within the same row, are significantly different ($p \leq 0.05$). HSD = Turkey's Honest Significant Difference

Crude fibre means ranged between 1.92% and 5.70%. The composition of the crude fibre for the comparisons between raw and toasted samples of the brown and *oloka* Cowpea varieties significantly increased ($p \leq 0.05$). Ndungu *et al*. (2012) reported that pre-treatment of cowpea seeds using dry heat (hot-air toasting) reduced its cooking time, by impacting a reduction in phytase activity by 40%, which in turn, improved pectin solubility, a factor in cooking time.

However, a significant decrease in crude fibre composition was observed in the comparison between raw and toasted cowpea samples of the IAR48 cowpea variety. As a result of the modifications done on the variety, it could be that the phytase activity was encouraged by the treatment, hereby decreasing the pectin solubility.

Protein content means ranged between 15.62% and 25.17% which is within the cowpea protein content range reported by Chavan *et al*. (1989). A significant decrease in protein content for comparisons between raw and toasted cowpea samples for the brown beans and *oloka* cowpea varieties was observed at $p \leq 0.05$. This could be as a result of protein denaturation that occurred on toasting the cowpea seeds at 105^{o}C.

An increase in protein content for comparisons between raw and toasted cowpea samples for the IAR48 and IT89KD-288 cowpea varieties was observed. This increase in protein content was significant for the IAR48 cowpea variety but not for the IT89KD-288 variety. This may be due to modifications done on the cowpea seeds by the IITA.

Ash composition means ranged between 2.12% and 3.36% which is within the cowpea ash composition range reported by Chavan *et al*. (1989). The comparisons between raw and toasted cowpea samples for all four cowpea varieties indicated a significant reduction in ash composition at $p \leq 0.05$. This could be due to the fact that almost all minerals are heat labile and may have been lost during toasting at 105^{o}C.

Carbohydrate composition means ranged between 55.90% and 64.07%. The comparisons between raw and toasted cowpea samples for all four cowpea varieties indicated a significant increase in carbohydrate composition at p ≤ 0.05.

Since toasting increases starch gelatinisation, it can be deduced that this increase in starch gelatinisation is as a result of inherent increase in amylase content. It could also be deduced that, increase in carbohydrate composition implies an increase in cowpea oligosaccharide content, and so toasting of cowpea seeds may still cause flatulence when cooked and consumed.

Functional properties

The effect of toasting on the functional properties of the cowpea varieties is shown on Table 3. Bulk density means ranged between 0.41 and 0.72. The bulk density for the comparisons between raw and toasted cowpea samples of the brown beans and *oloka* cowpea varieties indicated that there was a significant decrease at p ≤ 0.05. Since the bulk densities for all the cowpea samples were low, it then suggests that the cowpea seeds (both raw and toasted) would be easily incorporated into other food flours to obtain a composite, and the toasted cowpea samples would be better incorporated, as they have lower bulk densities.

Water absorption capacity means ranged between 0.00 and 6.00 g/ml. Comparisons between raw and toasted cowpea samples for all cowpea varieties, with the exception of the *IAR48* variety showed a significant increase in water absorption capacity on toasting. The comparison for *IAR48* Cowpea variety indicated a decrease in this property, though not significant at p ≤ 0.05.

Components of cowpea seeds responsible for water absorption are: protein, starch and cell wall material generally composed of cellulose, pectins (soluble fibre in cowpea seeds) and hemicelluloses, which form a matrix structure where capillary water is held, contributing towards water absorption capacity of the flour (Kethireddipalli *et al.,* 2002).

Thus, increase in water absorption capacity could be linked to changes in crude fibre contents (Table 2), where there was an increase in the crude fibre composition of the brown beans, *oloka* and *IT89KD-288* Cowpea varieties on toasting, and a reduction in crude fibre composition of the IAR48 cowpea variety on toasting.

Oil absorption capacity means ranged between 0.00 and 2.17 g/ml. For the comparisons between the raw and toasted cowpea samples of brown beans and *oloka* beans cowpea varieties, a significant increase in the oil absorption capacity was observed at p ≤ 0.05. This could be as a result of protein denaturation of samples on toasting, which caused unfolding of protein layers. Prinyawiwatkul *et al*. (1997) reported that thermal treatment slightly increased the oil absorption capacity of cowpea flour, possibly due to increased surface hydrophobicity of proteins which has been associated with the unfolding of proteins when exposed to heat.

Comparisons between the raw and toasted cowpea samples for the *IAR48* and *IT89KD-288* cowpea varieties indicated a decrease in oil absorption capacity, although this decrease was not significant at p ≤ 0.05. This maybe as a result of the increase in protein content of the varieties on toasting (Table 2).

Wettability means ranged between 52.33 and 155.33 seconds. The comparisons between the raw and toasted cowpea samples for all four cowpea varieties showed no significant difference at p ≤ 0.05, except for the comparison for the *IAR48* cowpea variety which showed a significant decrease on toasting.

Emulsion capacity means ranged between 42.33 and 58.67%. Emulsion capacity for comparisons between raw and toasted cowpeas samples for all cowpea varieties with the exception of that for brown beans variety, indicated a significant decrease in emulsion capacity on toasting at p ≤ 0.05. The comparison for the brown beans cowpea variety also decreased on toasting, but not significantly.

Decrease in emulsion capacity may be due to the fact that emulsion capacity is a protein-dependent property, and so is affected by protein content of the flour. Soluble proteins are inherently surface active due to their amphiphilic (having both hydrophobic and hydrophilic regions) nature and the tendency to adsorb at oil-water interfaces (Silvestre and Decker, 1999).

Foaming capacity means ranged between 2.00 and 9.33%. Foaming capacity of cowpea paste is desirable for the development of textural properties and mouth-feel of foam-type products like akara (Plahar *et al*., 2006).

Swelling capacity means ranged between 4.57 and 6.63 g/g. There was a significant decrease ($p \leq 0.05$) in swelling capacity of the brown beans cowpea variety on toasting. This may be due to the formation of protein-amylase complex, which might have taken place when protein denaturation and starch gelatinisation of cowpea seeds occurred on toasting. According to Pomeranz (1991), formation of protein-amylase complex in native starches and flour may be the cause of a decrease in swelling power.

The comparisons between raw and toasted samples of all other cowpea varieties also showed a decrease in swelling capacity, but the decrease in the comparisons, on toasting were not significant at $p \leq 0.05$.

Relationship between water imbibition and cooking time of cowpea seeds

The Pearson's correlation between water imbibition and cooking time of cowpea seeds is shown in Table 4. The Pearson's correlation coefficient (r) for the relationship between the amount of water imbibed by cowpea seeds on soaking and the cooking time of cowpea seeds was -0.74, suggesting that the relationship between the parameters is a strong, negative, linear relationship. However, this relationship was not significant at $p \leq 0.05$.

Table 3: Effect of toasting on the functional properties of resultant flour from four cowpea varieties

Parameter (%)	HSD	Brown Beans		Oloka Beans		IAR48		IT89KD-288	
		Raw	Toasted	Raw	Toasted	Raw	Toasted	Raw	Toasted
B/D	0.000	0.66^{b} ±0.01	0.58^{d} ±0.01	0.72^{a} ±0.01	0.64^{c}±0.01	0.44^{e} ±0.00	0.44^{e} ±0.00	0.43^{e} ±0.00	0.41^{ef} ±0.00
WAC (g/ml)	0.704	0.00^{f} ±0.00	1.00^{c} ±0.00	1.00^{e} ±0.00	2.00^{d} ±0.00	4.53^{b} ±0.24	4.20^{bc} ±0.31	5.00^{b} ±0.12	6.00^{a} ±0.00
OAC (g/ml)	0.410	0.00^{d} ±0.00	0.44^{c} ±0.00	0.44^{c} ±0.00	1.76^{b} ±0.00	1.82^{b} ±0.06	1.64^{b} ±0.06	2.17^{a} ±0.21	2.00^{a} ±0.57
Wet. (Sec)	43.086	84.67^{b}±1.45	52.33^{bc} ±2.03	86.67^{b} ±1.76	54.67^{b} ±2.73	155.33^{a}±7.69	101.67^{b}±12.86	101.67^{b} ±7.45	84.33^{b} ±17.94
E/C (%)	2.237	48.33^{c} ±0.34	47.34^{c} ±0.33	49.00^{c} ±0.00	42.33^{e} ±0.33	54.67^{b} ±0.67	45.33^{cd} ±0.67	58.67^{a} ±0.67	54.00^{b} ±0.00
F/S (%)	2.311	3.00^{bc}±0.00	2.00^{c} ±0.00	4.00^{b} ±0.00	3.00^{bc} ±0.00	9.33^{a} ±1.33	6.00^{b} ±0.00	2.00^{c} ±0.00	6.00^{b} ±0.00
F/S (%)	3.003	98.50±0.00^{a}	99.00^{a} ±0.00	98.10^{a} ±0.00	97.10^{a} ±0.00	94.57^{b} ±1.73	96.00^{ab} ±0.00	98.00^{a} ±0.00	96.00^{a} ±0.00
S/C (g/g)	1.132	6.63^{a}±0.07	4.63^{b} ±0.07	5.37^{b} ±0.09	4.73^{b} ±0.07	4.97^{b} ±0.33	4.57^{b} ±0.37	5.20^{b} ±0.40	4.80^{b} ±0.00

^{a,b,c,d,e,f,g,h} means with different superscripts within the same row, are significantly different ($p \leq 0.05$).
Where: HSD = Turkey's Honest Significant Difference, B/D = Bulk Density, WAC = Water Absorption Capacity, OAC = Oil Absorption Capacity, Wet. = Wettability, E/C= Emulsion Capacity, F/C = Foaming Capacity, F/S = Foaming Stability, S/C = Swelling Capacity.

Table 4: Relationship between cooking time and water imbibition in cowpea seeds

Parameters ($p \leq 0.05$)	Cooking Time (mins)	Amount of Water Imbibed (g)
Cooking Time (mins)	1	0.74
Amount of Water Imbibed(g)	-0.74	1

It is a general theory that the amount of water absorbed before cooking of cowpea seeds is negatively correlated with cooking time (Liu *et al.,* 2005). Variations in water absorption however, have contrasted with the theory. This could be the reason behind the relationship between the amount of water imbibed and the cooking time of the cowpea seeds not being significant ($p \leq 0.05$). The cowpea samples had variations in their water absorption capacities (Table 3).

Conclusion

This study has shown that the toasting of cowpea seeds, through its effects on the cell structure, and modification of starch and protein, can be used as a pre-treatment of cowpea seeds to produce seeds with shorter cooking time and cowpea flour with modified functionality. As such, toasting could be one of the alternative processes for diversifying the utilisation of cowpea seeds.

Modifications made on cowpea seeds should take into consideration, its effects on all other characteristics that affect the utilisation of cowpea. For instance, the modifications made on the *IAR48* and *IT89KD-288* cowpea varieties by the IITA, while increasing the protein content and the resistance of the protein to heat denaturation, also significantly increased the cooking time for the seeds and also reduced the crude fibre content of the seeds on toasting.

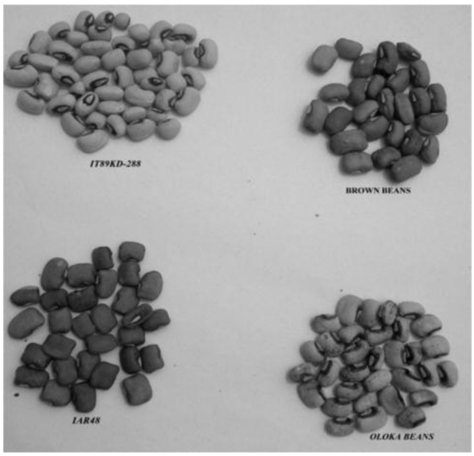

Plate 1: Raw cowpea seed samples

Plate 2: Example of toasting procedure

Plate 3: Plastic bags with seeds being supported by two rods

Plate 4: Plastic bags submerged in boiling water contained in a cooking vessel

Plate 5: Wet cowpea seeds being dried on improvised blotting paper (from top left to right with replicate samples underneath each: brown beans, oloka beans, lAR48 and IT89KD-288)

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