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Research Article

Effects of Cooking Conditions on the Texture Profile, Sensory and Proximate Qualities Pressure Cooked Cowpea

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Abstract

Boiling is a versatile method of cooking cowpea but it waste time and energy. Pressure cooking is a suitable alternative but requires careful management of cooking conditions to assure desire culinary quality. This study optimized cooking condition {Weight of cowpea (250 – 1000g), cooking time (15 - 60 min) and post cooking resident time (2-10 min)} for the pressure boiling on the culinary (Textural profile and sensory), and proximate qualities of boiled cowpea. The proximate and sensory qualities five out of the twenty eight optimised solutions (Desirability Index range of 86, 1% to 88.2%,) were compared with conventionally boiled cowpea samples. Data were analysed using Response surface methodology, analysis of variance, and Pearson product moment correlation. Models for hardness, springiness, chewiness, gumminess, energy to break, stringiness, sensory texture and overall acceptance with adjusted R2 of 84.58%, 67.02%, 76.34%, 79.97%, 77.52%, 81.29%, 55.13% and 46.63% respectively adequately explained the textural and sensory qualities of boiled cowpea. The range of values for moisture, fat, ash, crude protein and carbohydrate were 61.49%, 1.71%, 1.57%, 14.69% and 13.84% to 66.62%, 2.48%, 2.19%, 18.68% and 14.79% respectively Boiled cowpea produced at the verified optimisation solutions (527.62g, 82.55, 10.43 min and 591.69g, 82.96, 9.52 minutes) were adequately cooked and their proximate compositions were significantly different ($p < 0.05$) from conventionally cooked samples. In conclusion, pressure cooking of 1000g of cowpea was predicted at cooking and post cooking time of 57.14 and 10.0 min respectively but can be adequately cooked without being extremely soft in 38 minutes. It is recommended that appropriate cooking need to be adopted to produce boiled beans with suitable texture profile for different culinary end use.

Keywords: Food Production; Cowpea; Process Optimisation; Texture; Culinary Quality

Introduction

Cowpeas are leguminous seeds that are widely cultivated in Africa and in most parts of the world. Nigeria is the largest producer and consumer of cowpea grain, with about 5 million ha and over 2 Million metric tonne of production annually [1]. It is an important source of affordable protein, and B vitamins. In the foodservice subsector of the Hospitality industry, cowpea is a component of many menus. Some varieties of cowpea are also used to garnish many dishes. In Nigeria and most parts of sub-Saharan Africa, cowpea is usually prepared for consumption by combination of cooking methods. Cooking by boiling is usually the most common of these methods and depending on the menu, may be used in combination with stewing to produce dishes like bean porridge and *Gbegiri* a thickened soup. Decorticated and wet milled cowpea could be steamed to produce steamed puddings *moin-moin* and *Ekuru* while the wet milled slurry could also be fried to produce *akara.* The utilisation cowpea seed is however limited by long cooking times, prevalence of varieties with different cooking times and textural qualities. The cooking time of cowpeas ranges from 35 min to 120 min or more depending on variety and type of cooking water that is used [2]. This is a challenge in foodservice operation, not only due to the time and energy required to cook the meal but also in term of the textural characteristics of various cowpea meals. Cooking is an energy intensive activity. It accounts for about 90% of all household energy consumption in developing countries (International Energy Agency 2006). Biomass, with its attendant environmental hazards and impacts on climate change [3,4] is the predominant fuels for cooking [5]. In addition for the desire for clean energy, the exploration and adoption of suitable novel cooking technologies was meant partly to conserve energy, reduce overhead costs, optimized cooking time and quality. Such technologies were also adopted in order to ensure that meal experience of customers are well served and in relation to their expectations. Pressure cooking is one of such technologies. In Pressure cooking, food is cooked in a pressure cooker which is a sealed vessel that does not permit air or liquids to escape below a pre-set pressure. The food is cooked more quickly than the conventional method because the trapped steam in the cooker increases the internal pressure and temperature. Pressure pots are versatile, affordable and accessible to both urban and rural households and are also frequently use in foodservice operations. Texture is a primary determinant of cooked cowpea, a soft cooked texture is an important quality characteristic of most cowpea dishes. The overall texture of cooked cowpeas is a composite of the characteristics of the seed coat and the cotyledon. However, the adoption of pressure cooking for the boiling of cowpea requires the standardisation of the cooking conditions in relation to the texture and other quality attributes of cooked cowpea. Also, cowpea has diverse culinary uses that require specific range of textural and sensory attributes. Accurate prediction of these attributes at various cooking times would reduce quality defects usually associated with mass production of food in the foodservice industry.

This study therefore evaluated the effects of pressure cooking on some culinary (Textural and sensory attributes) and proximate composition of boiled cowpea. Specifically, the study assessed the effect of weight (Mass) of Cowpea, cooking time, and post cooking time (Resident time) on the textural attributes of cowpea, identified texture profile attributes of pressure boiled cowpea that can be used to modelled its cooking characteristics. It also assesses the sensory and some nutritional qualities of the optimized solutions.

Materials and Methods

Materials

Cowpea seeds (Nigerian Brown Beans) were purchased from a retail market in Odeda Local Government Area, Ogun State, Nigeria.

Methods

Pressure boiling of Cowpea

A domestic pressure pot (Model PC500, 5.5 litter capacity (Black and Decker: 1910, Baltimore, Maryland, United States) was used for the experiments. The cowpea were sorted and sieved to remove shaft and other dirt. It was immersed in about 14.3% (w/w) of water, boiled under pressure for the required length of cooking time.

Design of the study

Box–Behnken design [6] was used for the experiment. The three independent variables used for the process optimisation were thickness of Mass of cowpea seeds (X1: 25 to 1000 g), cooking time (*X*2: 20 to 90 min) and post cooking resident/cooling time (*X*3: 2 to 12min). The range of values used for each of the independent variables (Table 1) was based on preliminary experiments. The design consisted of 17 generated experimental runs to which the dependent variables (Responses) were fitted after the laboratory experiments. The measured responses were textural (Hardness, springiness, Adhesiveness, Cohesiveness, Chewiness, Fracturability, Gumminess, Energy to break and Stringiness) and sensory (Colour, Taste, Texture, Aroma and Overall acceptability). Optimisation criteria were set (Table 2), the sensory and proximate qualities of optimised pressure cooked boiled seeds with five best desirability value were compared with conventionally cooked reference sample.

Processing variables	Variable	-1	0	+1
Mass (g)	(X1)	250.00	625	1000.00
Cooking time (min)	(X2)	15.00	37.5	60.00
Post cooking cooling resident time (min)	(X3)	2.00	06	10.00

Table 1: The coded values for the independent variables.

Constraints	Goal	Lower limit	Upper limit	Importance
Mass (**X_1**)	range	250	1000	3
Cooking time (**X_2**)	range	15	60	3
Holding / Post cooking time(**X_3**)	range	2	10	3
Hardness	minimize	7.88	51.15	3
springiness	minimize	0.25	0.52	3
Adhesiveness	range	-0.02	2.28	3
Cohessiveness	range	0.15	0.38	3
Chewiness	range	0.37	10.66	3
Fracturability	range			
Gumminess	minimize	1.51	17.68	3
Energy to break	range	0.01	0.06	3
Stringiness	minimize	1.95	3.05	3
Colour	maximize	6.07	7.37	3
Taste	maximize	4.97	7.23	3
Texture	maximize	4.63	7.17	5
Overall acceptability	maximize	5.4	7.07	3

Table 2: Constraints to optimization of process variables.

Analyses of Culinary Attributes of Boiled Cowpea

Determination of Texture Profiles

The texture profile of the cooked cowpea were measured using Food compression test with the aid of Testometric material testing machine (Machine model No. 0500-10080, Testometric Co., United Kingdom, Lancashire, England ol11 1NR) The test distance of 0.50mm was selected after careful consideration of stickiness and adhesiveness of the product. The cooked samples were subjected to compressive force by probe up to the distance of 0.50mm for two times resulting in two curves. The condition-set up in the Texture Analyser for measuring textural properties was as follows: speed: 102 mm/min; Preload test speed: 60.000 mm/min; posttest speed: 1.0 mm/s; count: 2; Deflection (mm): 3mm (50% Strain); Preload (trigger) force 0.50 N; break sensitivity: 0.20 N; acquisition rate: 200 pps; load cell: 50 kg; Probe Diameter (mm) : 38. Every test was replicated a minimum of three times (Figure 1) and mean values for each parameter were calculated.

Texture parameters were determined from the texture profile [7-10]. Hardness was calculated as the peak force of the first compression of the product. The cohesiveness, which represents how well the product, withstands a second deformation relative to how it behaved under the first deformation. Cohesiveness was calculated as the ratio of the area under second peak to the first peak i.e. A2/A1 (Figure 1). Springiness is how well a product physically springs back after it has been deformed during the first compression. The springiness is measured at the down stroke of second compression, so the wait time between two strokes can be relatively important. Springiness is measured by the distance of the detected height of the product on the second compression divided by the original compression distance. Chewiness was measured as a product of hardness, cohesiveness, and springiness [11].

Figure 1: Typical Curve Obtained from the Texture Profile.

Proximate composition, Dry matter contents and absorbed water

Proximate composition of the samples was determined by standard procedure, Dry matter and crude fibre were determined according to AOAC [12] methods.

Sensory evaluation

Sensory appraisal of the boiled Bambara was carried out using thirty un-trained panellists consisting of staff and students of Federal University of Agriculture Abeokuta, Nigeria. The panellist rated their preference for colour, taste, texture, aroma and general Acceptance of the boiled cowpea samples using hedonic ratings (1= disliked extremely to 9 = liked extremely).

Data/Statistical Analysis

Experimental data were fitted to a second order polynomial model and regression co-efficients the various responses were obtained. The generalized second-order polynomial used in response surface analysis was. $Y = \beta_0 + \beta_1x_1 + \beta_2x_2 + \beta_3x_3 + \beta_4x_1x_2 + \beta_5x_1x_3 + \beta_6x_2x_3 + \beta_7x_1x_2x_3 + €$

Where Y is the response, β_0 is the intercept, where $\beta_{1,}$ β_2 and β_3 are linear, quadratic and interaction coefficients respectively while, x_1, x_2, x_3 are the various independent variables and € is the error. The statistical significance of the terms in the regression equations was examined by analysis of variance for each of the responses.

The Design expert software version 7.00 (Stat Ease Inc., Minneapolis, MN, USA), was used to generate response surfaces models graphs showing the relationship between the independent variable and the responses while holding a variable constant.

Optimisation goals/constraints were set (Table 2) and the responses were optimized by using the numerical method of RSM based on desirability concept to obtain range of optimised solutions. The adopted solutions were then used for the verification experiments to determine the validity of the model [13,14].

Data on the proximate and sensory qualities of pressure and conventionally cooked boiled seeds were compared using analyses of variance and means were separated using Duncan multiple range test. Statistical analysis package software, version 17 for windows was used for the analysis. Pearcon product moment correlation was used to examine the relationships between texture profile and sensory texture of boiled cowpea.

Results and Discussion

The processing of cowpea pods usually involve cooking at atmospheric pressure in which whole dry cowpeas are boiled in water in order to tenderise the cotyledons and develop a cooked texture and flavour that the increased palatability of the product (Aremu, 1991). Pressure cooking of cowpeas is a hydrothermal process that involves hydration and heating which may take place separately or concurrently [15]. Hydration capacity is a reflection of the water holding capacity of the seeds which includes water of hydration as well as capillary water. Hydration is influenced by the characteristics of the seed coat and cotyledon structure [16]. The seed coat has the first direct contact with water during soaking in the early part of the heating process and serve as conduits for water in to the cotyledon of the seed. Cooking time is one of the major criteria used to evaluate the quality of dry legume [17]. Cooking time is therefore a very important quality parameter for whole cowpeas and it is measured relative to the softening of the cotyledon texture [18]. Pressure cooking time of cowpea as used in this study excluded hydration time before the attainment of full pressure [19] after which the boiling of the seed commenced. Cooking time is discussed as the time required by the seeds to attain a softer texture rather than flavour attributes, which would include cooked aroma [17-19]. During the holding/cooling time, structural changes in the seed continues and these may have significant effects on the quality attributes of the cooked beans depending on the length of the holding/ cooling time.

The responses

Textural responses

Measurement of texture by empirical methods in which forces required to shear, penetrate, compress or cut food are used as indicators of textural characteristics [10,20] food. It is also an objective means of assessing the textural quality of food, although, this may not necessarily be regarded as an absolute indicator of texture properties of food. It has also been argued that not all the textural parameters defined in the Texture Profile Analyses (TPA) test are correct and useful [21]. Although, the use of replicated texture measurements of the same variety of cowpea with fairly consistent seed dimension and standardised test conditions (Figure 1) was done to make the results of texture measurement in this study suitable for exploration. The argument underscores the need to identify the texture parameters of the TPA that should be used as quality indicators in food production.

Hardness

The Hardness value is the peak force that occurs during the first compression of the two-cycle imitative tests (Figure 1) which attempt to simulate the conditions to which the material is subjected to in the mouth. Hardness, in this case, is an indication of the Force required to compress a food between the molars [10,22]. Most of the methods used to measure cooking time are based on hardness component of texture. The lower the hardness values the softer the kernel of the cooked cowpea. Structural changes that occurred during cooking of cowpea included the solubilisation of the middle lamella, separation of the cell walls resulting in a soft cooked texture. The mechanism involves heat-catalysed depolymerisation of the middle lamella pectin polymers which involves beta elimination of the methyl esterified polygalacturonic acid [23,24]. Other physicochemical and structural changes included the gelatinisation of starch in the cotyledon cell which also contributes to the softening of cowpea [25,26].

Hardness (Table 3) ranged from 7.88±0.46 to 50.61±6.10 N with Mass, cooking time and post cooking time of 625, 60, 10 (Run 11) and 625,15, 10 having the lowest and highest values respectively. Run 11 had significantly ($p < 0.05$) lowest value than samples from other cooking conditions. Runs 11 and 12 were not significantly ($p > 0.05$) different in this regard. Experimental runs 8, 14 and 16 which were cooked for 15 minutes were significantly ($p < 0.05$) harder than other blends. The results established that cooking time was an important determinant of softness of the beans as hardness values decreased as the cooking time was increased (Figure 2). Runs 11 (Hardness value 7.88 N) was very soft without splitting and lumping which undesirable characteristics associated with some cowpea varieties [27].

Experimental run	Mass (X1) (g)	Cooking time (X2) min	Post cooking time (x3) min	Hardness (N)	Springiness	Adhesiveness (N.S)	Cohesiveness	Chewiness (N)	Fractur-ability	Gumminess ()	Energy to break	Stringness
1.	1000	60	6	$13.11 \pm 2.30^{a b}$	0.25 ± 0.66^{a}	0.67 ± 0.86^{a}	0.2 ± 0.4^{a}	0.63 ± 0.18^{a}	Not detected	2.56 ± 0.08^{a}	0.02 ± 0.01^{a}	3.05 ± 0.11^{f}
2.	1000	38	10	$9.91 \pm 2.71^{a b}$	$0.30 \pm 0.08^{a b}$	1.73 ± 1.25^{a}	$0.25 \pm 0.01^{a b}$	0.75 ± 0.16^{a}		2.50 ± 0.60^{a}	0.01 ± 0.00^{a}	$2.86 \pm 0.03^{d e f}$
3.	625	38	6	$12.82 \pm 3.20^{a b}$	$0.30 \pm 0.15^{a b}$	0.30 ± 0.44^{a}	$0.26 \pm 0.23^{a b}$	0.66 ± 0.30^{a}		$3.33 \pm 0.77^{a b}$	0.02 ± 0.00^{a}	$2.86 \pm 0.03^{4d\ e f}$
4.	625	38	6	$19.96 \pm 6.54^{a b}$	0.37 ± 0.28^{abcd}	0.05 ± 0.05^{a}	$0.28 \pm 0.12^{a b}$	2.04 ± 0.73^{a}		$5.46 \pm 1.61^{a b c}$	0.03 ± 0.01^{a}	$2.62 \pm 0.07^{c d e}$
5.	625	60	2	$10.24 \pm 1.43^{a b}$	$0.29 \pm 0.56^{a b}$	0.52 ± 0.76^{a}	$0.26 \pm 0.06^{a b}$	0.82 ± 0.36^{a}		2.71 ± 0.91^{a}	0.02 ± 0.00^{a}	$2.84 \pm 0.17^{d e f}$
6.	625	38	6	$14.36 \pm 2.17^{a b}$	$0.36 \pm 0.12^{a b c}$	$1.01 \pm 0.80^{a b}$	0.29 ± 0.07^{ab}	1.54 ± 0.74^{a}		$4.15 \pm 0.88^{a b c}$	0.02 ± 0.01^{a}	$2.71 \pm 0.27^{c d e}$
7.	625	38	6	$16.02 \pm 3.70^{a b}$	$0.31 \pm 0.83^{a b}$	2.27 ± 1.77^{b}	$0.26 \pm 0.04^{a b}$	1.39 ± 0.86^{a}		$4.23 \pm 1.53^{a b c}$	0.02 ± 0.00^{a}	$2.84 \pm 0.22^{d e f}$
8.	625	15	2	43.14 ± 19.67^{c}	0.52 ± 0.17^{d}	0.01 ± 0.02^{a}	0.38 ± 0.16^{b}	10.66 ± 9.54^{b}		17.68 ± 13.01^{d}	0.05 ± 0.02^{b}	1.95 ± 0.46^{a}
9.	1000	15	6	23.43 ± 8.44^{b}	$0.43 \pm 0.71^{b c d}$	0.00 ± 0.00^{a}	0.15 ± 0.11^{a}	2.57 ± 1.77^{a}		$5.66 \pm 2.94^{a b c}$	0.02 ± 0.01^{a}	$2.42 \pm 0.11^{b c}$
10.	250	38	10	$12.07 \pm 4.73^{a b}$	$0.37 \pm 0.81^{a bcd}$	0.01 ± 0.15^{a}	0.28 ± 0.06^{a}	1.31 ± 0.72^{a}		$3.36 \pm 1.37^{a b}$	0.02 ± 0.01^{a}	$2.73 \pm 0.09^{c d e}$
11.	625	60	10	7.88 ± 0.46^{a}	$0.34 \pm 0.08^{a b c}$	-0.02 ± 0.18^{a}	$0.26 \pm 0.04^{a b}$	0.71 ± 0.29^{a}		2.03 ± 0.41^{a}	0.01 ± 0.00^{a}	$2.77 \pm 0.22^{c d e}$
12.	250	60	6	8.05 ± 3.34^{a}	0.25 ± 0.24^{a}	0.02 ± 0.12^{a}	0.19 ± 0.03^{a}	0.37 ± 0.12^{a}		1.51 ± 0.41^{a}	$0.01 \pm .04^{a}$	$2.98 \pm 0.03^{d e f}$
13.	1000	38	2	18.14 ± 6.44^{a}	$0.37 \pm 0.05^{a bcd}$	0.04 ± 0.05^{a}	0.20 ± 0.05^{a}	1.41 ± 0.70^{a}		$3.65 \pm 1.37^{a b c}$	0.03 ± 0.01^{a}	$2.73 \pm 0.33^{c d e}$
14.	625	15	10	51.15 ± 13.27^{c}	0.40 ± 0.15^{abcd}	$1.13 \pm 0.99^{a b}$	0.22 ± 0.12^{a}	5.24 ± 5.29^{a}		$11.23 \pm 7.79^{3c d}$	0.06 ± 0.01^{b}	$2.55 \pm 0.32^{b c d}$
15.	250	38	2	$14.32 \pm 2.99^{a b}$	$0.33 \pm 0.09^{a b}$	0.59 ± 0.92^{a}	$0.26 \pm 0.08^{a b}$	1.26 ± 0.56^{a}		$3.64 \pm 0.84^{a b c}$	0.02 ± 0.00^{a}	$2.82 \pm 0.22^{d e f}$
16.	250	15	6	50.61 ± 6.10^{c}	$0.49 \pm 0.04^{c d}$	0.00 ± 0.01^{a}	0.23 ± 0.11^{a}	5.50 ± 2.39^{a}		$10.93 \pm 3.86^{b c d}$	0.06 ± 0.01^{b}	$2.20 \pm 0.13^{a b}$
17.	625	38	6	$20.20 \pm 15.0^{a b}$	$0.33 \pm 0.07^{a b}$	0.11 ± 0.12^{a}	0.23 ± 0.08^{a}	1.58 ± 0.78^{a}		$4.60 \pm 1.43^{a b c}$	0.03 ± 0.00^{a}	$2.90 \pm 0.33^{d e f}$

Table 3: Response Surface Analysis Results for different experimental runs.

a-g= Mean in same column with the same superscripts are not significantly different (P<0.05)

Figure 2: Response Surface Plots of Change in Hardness Values at Different Experimental conditions.

Springiness

Springiness is expressed as a ratio or percentage of a product's original height. It orgonoleptically depicts how well a product physically springs back after it has been deformed during the first compression and has been allowed to wait for the target wait time between strokes. It decreased with cooking time, decreased slightly with post cooking/holding time but increased slightly with the increase in the mass of cowpea (Figure 3). The lowest (0.25) and highest (0.49) were obtained when the mass of cowpea, cooking and cooling time were 250g, 60.00 min, 6.00 min and 250 g, 16.0 min and 6.00 min respectively.

Figure 3: Response Surface Plots of Change in Springiness Values at Different Experimental conditions.

Adhesiveness

Adhesiveness is the work required to pull the mashed food away from a surface of the probe. It is an indication of the extent of stickiness of products. It could also be described as the work require to overcome the sticky forces between the sample and the probe [21]. Adhesion is measured as the negative work between the two cycles; however, in many instances the product has stuck to the probe and does not actually separate when the highest point between the two cycles is just back to the original product height. The lowest (-0.02 N.S) and highest (2.27 N.S) were obtained when the weight of the cowpea, cooking and cooling time were 625g, 60.00 min, 10.00 min and 625 g, 38.0 min and 6.00 min respectively. Higher values of adhesiveness may imply that the product may have been over cooked to the point of stickiness.

Cohesiveness

Cohesiveness reflects the strength of the internal bonds binding chewed the food particles together and suggested how well the cooked cowpea withstands a second deformation relative to its resistance under the first deformation. Cohesiveness decreased with cooking time but increased with mass up to 625 g and then decreased. It also decreased with post cooking time and this suggest the need to moderate how long beings can be kept in held in the cooking medium without negatively altering the desired texture (Figure 4). The lowest (0.15) and highest (0.38) were obtained when the weight of cowpea, cooking and cooling time were 1000g, 15.00 min, 6.00 min and 625 g, 15.0 min and 2.00 min respectively. The cohesiveness of the experimental run obtained at cooking condition of 1000 g, 15.0 min and 6.00 min was not significantly different from that of runs 1, 9, 12, 13,14, 16 and 17 but both were significantly ($p < 0.05$) different from that of runs 8.

Figure 4: Response Surface Plots of Change in Cohesiveness at Different Experimental conditions.

Chewiness

Chewiness connotes the energy required to chew a solid food till it is ready for swallowing. It is sometimes estimated as the product of Hardness, Cohesiveness and Elasticity, the latter being the extent to which a compressed food returns to its original size when the load is removed (Rosenthal, 1999). Chewiness decreased with cooking time and post cooking time but increased with the mass of cowpea in the cooking medium (Figure 5). The lowest (0.37 N) and highest (10.66 N) were obtained when the weight of cowpea, cooking and cooling time were 250g, 60.00 min, 6.00 min and 625 g, 15.0 min and 2.00 (Run 8) min respectively. Run 8 was significantly ($p < 0.05$) different from other experimental run. The results suggested that the bean may not have been properly cooked when the cooking time was inadequate resulting in relatively higher hardness and chewiness values.

Gumminess

Gumminess is conceived as the energy required to disintegrate a semi-solid food to make it ready for swallowing [21]. Gumminess, for most solid product is mutually exclusive with chewiness since such product would not be both a semi-solid and a solid at the same time. However, pressure cooked cowpea boiled in excess water may become very soft when adequately cooked. Gumminess decreased with increase in cooking time, increased up to 625 g with the mass of cowpea but fairly stable with changes in post cooking time (Figure 6). The lowest (1.51 N) and highest (17.7N) were obtained when the weight of cowpea, cooking and cooling time were 250g, 60.0 min, 6.00 min and 625 g, 15.0 min and 2.00 min respectively. It is also important to note that the highest gumminess value was recorded in the experimental run with the highest hardness value (Table 3).

Figure 5: Response Surface Plots of Change in Chewiness at Different Experimental conditions.

Figure 6: Response Surface Plots of Change in Gumminess at Different Experimental conditions.

Fracturability

Fracturability is the force required to crack the cowpea seed. It also imitates the first bite force through the seed at the commencement of chewing. The absence of values for fracturability indicated that the hard to cook phenomenon may not have been so pronounced in the pressure cooked cowpea compared with what was observed in other studies (Not reported here) for maize and bamabara groundnut.

Stringiness

It is the measured of stretched distance of the samples when pulled from the area in which it rest during the test. Stringiness increased with cooking time and post cooking time but decreased with mass up to 625 g and then increased up to 1000 g thus suggesting that quantity of beans may have significant impact on stringiness at certain level (Figure 7). The lowest (1.95) and highest (3.05) were obtained when the weight of cowpea, cooking and cooling time were 625g, 15.00 min, 2.00 min and 1000 g, 60.0 min and 6.00 min respectively.

Figure 7: Response Surface Plots of Change in Stringiness at Different Experimental conditions.

Sensory Responses

The range of values for Colour, taste, texture, appearance and overall acceptability were 6.07 to 7.37, 4.97 to 7.23, 4.63 to 7.17, 5.70 to 6.77 and 5.40 to 7.07 respectively (Table 4). The samples were significantly different ($p < 0.05$) from each other even at the replicated points. The lowest texture score was recorded in 625 g of the samples cooked 15 minutes and held for 2 minutes while cooling (run 8). The highest texture score were recorded in 625 g of the samples cooked 60 minutes and held for 10 minutes while cooling (run 11). The results also indicated that cowpea needs to be cooked for at least 37.5 minutes and held for not less than 2 minutes to soften the cowpea for reasonably high texture scores. Most of the samples were generally acceptable to the panellists.

Experimental runs	Mass (X1) (g)	Cooking time (X2 min	Post cooking time (X3) min	Colour	Taste	Texture	Appearance	Overall Acceptance
	1000	60	6	6.53 ± 0.31^{abcd}	6.83 ± 0.16^{abc}	6.47 ± 0.27^{abcd}	6.60 ± 0.25^{ab}	6.93 ± 0.18^{a}
	1000	37.5	10	7.00 ± 0.26^{abc}	7.07 ± 0.22^{ab}	6.77 ± 0.29^{abc}	6.47 ± 0.35^{ab}	6.90 ± 0.27^{a}
	625	37.5	6	7.00 ± 0.22^{abc}	6.53 ± 0.18^{abc}	6.43 ± 0.21^{abcd}	6.47 ± 0.30^{ab}	6.77 ± 0.20^{ab}
	625	37.5	6	6.57 ± 0.26^{abcd}	6.37 ± 0.17^{bc}	6.20 ± 0.27^{bcde}	6.33 ± 0.27^{ab}	6.53 ± 0.27^{abc}
	625	60	2	6.37 ± 0.27^{cd}	6.30 ± 0.25^{bc}	6.10 ± 0.33^{cde}	6.40 ± 0.23^{ab}	6.47 ± 0.21^{abc}
	625	37.5	6	6.47 ± 0.21^{bcd}	6.13 ± 0.22^{c}	6.20 ± 0.31^{bcde}	6.50 ± 0.24^{ab}	6.40 ± 0.22^{abc}
	625	37.5	6	6.07 ± 0.23^{d}	6.13 ± 0.24^{c}	5.70 ± 0.25^{def}	5.90 ± 0.25^{ab}	6.27 ± 0.20^{abc}
	625	15	2	6.27 ± 0.34^{cd}	5.03 ± 0.34^{d}	4.63 ± 0.32^{g}	5.70 ± 0.32^{b}	5.40 ± 0.28^{d}
	1000	15	6	6.33 ± 0.34^{cd}	4.97 ± 0.30^{d}	4.87 ± 0.32^{fg}	6.30 ± 0.32^{ab}	5.83 ± 0.28^{cd}
	250	37.5	10	6.70 ± 0.22^{abcd}	6.37 ± 0.24^{bc}	6.40 ± 0.23^{abcd}	6.50 ± 0.25^{ab}	6.67 ± 0.23^{ab}
	625	60	10	7.37 ± 0.1^{6}a	7.20 ± 0.22^{a}	7.17 ± 0.25^{a}	6.80 ± 0.26^{a}	7.03 ± 0.26^{a}
	250	60	6	6.57 ± 0.23^{abcd}	6.17 ± 0.31^{c}	6.77 ± 0.30^{abc}	6.13 ± 0.31^{ab}	6.53 ± 0.27^{abc}
	1000	37.5	2	6.90 ± 0.27^{abcd}	7.23 ± 0.22^{a}	7.03 ± 0.23^{ab}	6.50 ± 0.35^{ab}	7.07 ± 0.29^{a}
	625	15	10	6.70 ± 0.19^{abcd}	6.33 ± 0.29^{bc}	5.40 ± 0.30^{efg}	6.67 ± 0.22^{a}	6.30 ± 0.22^{abc}
	250	37.5	2	6.70 ± 0.25^{abcd}	6.50 ± 0.26^{abc}	6.33 ± 0.30^{abcd}	6.50 ± 0.27^{ab}	6.63 ± 0.28^{ab}
	250	15	6	6.57 ± 0.27^{abcd}	6.03 ± 0.26^{c}	5.17 ± 0.30^{fg}	5.93 ± 0.31^{ab}	5.97 ± 0.30^{bcd}
17	625	37.5	6	7.23 ± 0.18^{ab}	6.35 ± 0.23^{abc}	6.60 ± 0.18^{abcd}	6.77 ± 0.21^{a}	6.83 ± 0.24^{a}

Table 4: Response Surface Analysis Results for Different Experimental Runs on Sensory attributes of Pressure cooked Cowpea.
a-g =. Mean in same column with the same superscripts are not significantly different (P<0.05).

Relationships between sensory texture and the texture profile parameters

The relationships sensory texture and the texture profile parameters (Table 5) revealed negative correlation relationships between sensory texture and hardness (n=17, r = -.753 p= 0.00), springiness (n=17, r = -.731, p= 0.001), chewiness (n=17, r = -.783, p= 0.00), gumminess (n=17, r = -.806, p= 0.00 and stringiness (n=17, r = .803, p= 0.00). These implied that the sensory texture scores increased as the values for these parameters decreased.

	Sensory Texture	Hardness	Springiness	Adhesiveness	Cohesiveness	Chewiness	Gumminess	Stringiness
Sensory Texture	1#							
	0							
Hardness	-.753**	1						
	0							
Springiness	-.731**	.796**	1					
	0.001	0						
Adhesiveness	-0.111	-0.031	-0.283	1				
	0.671	0.906	0.271					
Cohesiveness	-0.168	0.092	0.313	0.074	1			
	0.519	0.724	0.222	0.778				
Chewiness	-.783**	.850**	.851**	-0.133	0.461	1		
	0	0	0	0.611	0.062			
Gumminess	-.806**	.900**	.851**	-0.081	0.425	.991**	1	
	0	0	0	0.758	0.089	0		
Stringiness	.803**	-.793**	-.967**	0.274	-0.366	-.911**	-.900**	1
	0	0	0	0.287	0.148	0	0	

Table 5: Relationships Between Texture Profile and Sensory Texture of Pressure cooked Cowpea.

Pearson Correlation,

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Model Description

Texture profile

The fitness of the model for each of the responses were tested using the sequential model sum of squares (SMSS) presented in Table 6. The SMSS indicated the contributions of the linear, two-factor interaction (2FI), quadratic and cubic polynomials terms to the totality of the model.

The SMSS suggested that the *Quadratic vs 2FI* terms made better (Prob > F was below 0.05) contributions to the model for hardness and chewiness (Table 6) while the Linear model was suggested for sensory texture and other texture profile. This was then used as basis for testing the fitness of the model. The main reason for conducting the fitness test was to identify the model that can best be used as a response predictor. The desire was for the selected model to have insignificant lack-of-fit in ordef to demonstrate that the model actually fits the data (Myers., *et al*. 2009). This was done by comparing the residual error with the "pure error" from replicated design points. An insignificant lack of fit is indicated by a low probability value ("Prob>F"), low standard deviation, high adjusted R-Squared values and a low predicted residual sum of squares (PRESS). The suggested models were therefore adopted as suggested (Figure 1-5).

Responses	Sources of Variations	Standard deviation	R-Squared	Adjusted R-Squared	PRESS	Remarks
Hardness	Linear	8.98	0.6711	0.5951	2086.76	
	2FI	8.67	0.7639	0.6222	3421.34	
	Quadratic	5.54	0.9325	0.8458	2804.43	Suggested
	Cubic	3.31	0.9862	0.9449		Aliased
p-value (Prob > F) for SMSS						0.0256 Quadratic vs 2FI
Springiness	Linear	0.044	0.732	0.6702	0.046	Suggested
	2FI	0.037	0.8528	0.7644	0.046	
	Quadratic	0.031	0.9277	0.8348	0.051	
	Cubic	0.031	0.9579	0.8317		Aliased
p-value (Prob> F) for SMSS						0.0005 Linear vs Mean
Adhesiveness	Linear	0.67	0.0237	-0.2016	8.26	
	2FI	0.68	0.2264	-0.2377	7.57	
	Quadratic	0.73	0.3633	-0.4553	9.88	
	Cubic	0.93	0.41	-1.3599		Aliased
p-value (Prob > F) for SMSS						0.9556 Linear vs Mean
Cohesiveness	Linear	0.051	0.111	-0.0942	0.069	
	2FI	0.052	0.3095	-0.1048	0.12	
	Quadratic	0.038	0.7444	0.4158	0.13	Suggested
	Cubic	0.023	0.9442	0.7767		Aliased
p-value (prob > F) for SMSS						0.0606 Quadratic vs 2FI
Chewiness	Linear	1.89	0.5758	0.478	93.47	Suggested
	Quadratic	1.28	0.8965	0.7634	167.72	Suggested
	Cubic	0.5	0.9909	0.9636		Aliased
p-value (Prob>F) for SMSS						0.0092 Linear vs mean
Gumminess	Linear	2.81	0.6374	0.5538	209.14	Suggested
	2FI	2.90	0.7027	0.5244	407.67	
	Quadratic	1.88	0.9124	0.7997	363.24	Suggested
	Cubic	0.77	0.9916	0.9663		Aliased
p-value (Prob > F) for SMSS						0.0034 Linear vs Mean
Energy to break	Linear	0.01	0.6058	0.5149	2.78E-03	Suggested
	2FI	9.32E-03	0.7519	0.603	3.99E-03	
	Quadratic	7.01E-03	0.9017	0.7752	4.62E-03	Suggested
	Cubic	3.92E-03	0.9825	0.9298		Aliased
p-value (Prob>F) for SMSS						0.0058 Linear vs Mean
Stringiness	Linear	0.18	0.6674	0.5907	0.79	Suggested
	2FI	0.17	0.7687	0.6299	1.12	
	Quadratic	0.12	0.9181	0.8129	0.89	Suggested

	Cubic	0.12	0.9579	0.8317		Aliased
p-value (Prob> F) for SMSS						0.002 Linear vs Mean
Colour	Linear	0.34	0.2200	0.0400	2.29	Suggested
	2FI	0.37	0.2695	-0.1687	3.76	
	Quadratic	0.41	0.3815	-0.4137	6.71	
	Cubic	0.46	0.5600	-0.7599		
p-value (Prob> F) for SMSS						0.3410 Linear vs Mean
Taste	Linear	0.51	0.4424	0.3138	7.09	Suggested
	2FI	0.52	0.5688	0.3100	13.19	
	Quadratic	0.43	0.7871	0.5134	19.32	
	Cubic	0.17	0.9809	0.9235		
p-value (Prob> F) for SMSS						0.0489 Linear vs Mean
Texture	Linear	0.50	0.6354	0.5513	6.18	Suggested
	2FI	0.56	0.6411	0.4258	14.09	
	Quadratic	0.43	0.8485	0.6538	14.54	
	Cubic	0.34	0.9474	0.7896		
p-value (Prob> F) for SMSS						0.0036 Linear vs Mean
Appearance	Linear	0.27	0.3513	0.2016	1.65	Suggested
	2FI	0.30	0.4072	0.0515	2.94	
	Quadratic	0.33	0.4941	-0.1562	6.29	
	Cubic	0.32	0.7293	-0.0827		
p-value (Prob> F) for SMSS						0.1203 Linear vs Mean
Overall acceptance	Linear	0.33	0.5663	0.4663	2.69	Suggested
	2FI	0.36	0.6013	0.3621	5.62	
	Quadratic	0.28	0.8241	0.5979	5.79	
	Cubic	0.24	0.9294	0.7176		
p-value (Prob> F) for SMSS						0.0105 Linear vs Mean

Table 6: Sequential Sum of Squares and fit Summary of model Statistics for Texture Parameters.

...2FI= Two factor interaction, SMSS= Sequential Model Sum of Squares

The models were assessed for their adequacy for the experimental conditions and the significant terms in each of the models were identified. Results from the analysis of variance for each of the selected models indicated that model for all the texture parameters (Table 7) except that of cohesiveness were significant (Their probability >F were less than 0.05) while Taste, Texture and Overall acceptance were the significant models in the sensory parameters (Table 8).

Parameters	Hardness	Springiness	Adhesiveness	Cohesiveness	Chewiness	Gumminess	Energy to break	Stringiness
Model Selected p-value* (Prob > F)	Quadratic 0.0256	Linear	Mean	Quadratic 0.0606	Quadratic 0.0099	Quadratic 0.0058	Linear 0.0058	Quadratic 0.0046
Model F-values	10.25	11.84		2.27	6.74	8.1	7.13	8.72
Remark on models adequacy	Significant	Significant		Not significant	Significant	Significant	Significant	Significant
Remarks on models fitness (Lack of fit)	not significant	Not significant	Not significant	Not significant	Significant	Significant	Not significant	Not significant
Significant terms in the models	B, AB, B^2	None	**None**	A, A^2	B, B^2	B, B^2	B, AB, B^2	B, BC, B^2
		Regression	**Coefficients**					
B_o (intercept)	16.67	0.35	0.44	0.26	1.44	4.36	0.023	2.79
X_1 (A-Mass)	-2.56	-0.012		-0.019	-0.38	-0.63	-2.92E-03	0.039
X_2 (B-cooking time)	-16.13	-0.09		-7.35E-03	-2.68	-4.59	-0.016	0.31
X_3 (C- cooling time)	-0.61	-0.014		-0.012	-0.77	-1.07	-183E-03	0.072
X^2_1 (AB)	8.06			0.02	0.8	1.58	0.011	-0.037
X_2^2 (AC)	-1.49			7.92E-03	-0.18	-0.22	-2.58E-03	0.055
X^2_3 (BC)	-2.59			0.038	1.33	1.44	-1.42E-03	-0.17
X_1X_2 (A^2)	-3.68			-0.049	-1.17	-2.16	-4.58E-03	0.065
X_1X_3 (B^2)	10.81			-0.021	2	2.97	0.01	-0.19
X_2X_3 (C^2)	0.62			0.035	0.91	1.09	1.43E-03	-0.068
Mean	20.32	0.35	0.44	0.25	2.26	5.25	0.026	2.70
Std. Deviation	5.54	0.044	0.61	0.038	1.28	1.88	7.01E-03	0.12
C.V. (%)	27.27	12.35	138.75	15.24	56.37	35.9	26.9	4.51
R-Squared	0.9325	0.732	0	0.7444	0.8965	0.9124	0.9017	0.9181
Adj R-Squared	0.8458	0.6702	0	0.4158	0.7634	0.7997	0.7752	0.8129
Pred R-Squared	0.1195	0.5009	-0.1289	-2.2836	-0.525	-0.2805	-0.3201	0.2979
Adeq. Precision	11.387	9.803		5.992	10.177	10.994	9.976	10.746
PRESS	2804.43	0.406	6.68	0.13	167.72	363.24	4.62E-03	0.89

Table 7: Model Properties and Regression coefficients for different responses.

*--Obtained from ANOVA for Response Surface Type III.

Parameters	Colour	Taste	Texture	Appearance	Overall acceptability
Model Selected p-value* (Prob > F)	Linear 0.3410	Linear 0.0489	Linear 0.0036	Linear 0.1203	Linear 0.0105
Model F-values	1.22	3.44	7.55	2.35	5.66
Remarks on models adequacy	not significant	significant	Significant	not significant	Significant
Remarks on models fitness (Lack of fit)	Not significant	Significant	not significant	not significant	Not significant
Significant terms in the models	None	B	B	None	B
Bo (Intercept)	6.67	6.33	6.13	6.38	6.50
X_1 (A-Mass)	0.027	0.13	0.059	0.10	0.12
X_2 (B-cooking time)	0.12	0.52	0.80	0.17	0.43
X_3 (C-cooling time)	0.19	0.24	0.21	0.17	0.17
X^2_1 (AB)					
X^2_2 (AC)					
X^2_3 (BC)					
X_1X_2 (A^2)					
$X_1 X_3$ (B^2)					
$X_2 X_3$ (C^2)					
Mean	6.67	6.33	6.13	6.38	6.50
Std. Deviation	0.34	0.51	0.50	0.27	0.33
C.V. (%)	5.05	8.13	8.07	4.29	5.04
R-Squared	0.2200	0.4424	0.6354	0.3513	0.5663
Adj R-Squared	0.0400	0.3138	0.5513	0.2016	0.4663
Pred R-Squared	-0.2084	-0.1482	0.2924	-0.0964	0.1654
Adeq Precision	3.824	6.060	8.423	5.027	7.528
PRESS	2.29	7.09	6.18	1.65	2.69

Table 8: Model Properties and Regression coefficients for different responses of Sensory Attributes.

*-- Obtained from ANOVA for Response Surface Type III.

There were no significant terms in the model for springiness and adhesiveness. The terms in the model that were significant were B (cooking time), AB (Interaction s between mass of cowpea and cooking time), B^2 (exponential function of cooking time) for hardness, A (mass of cowpea), A^2 (exponential function of mass) for cohesiveness, B (cooking time) and B^2 (exponential function of cooking time) for chewiness, B (cooking time) and B^2 (exponential function of cooking time) for gumminess, B (cooking time), AB (Interaction s between mass and cooking time), B^2 (exponential function of cooking time) for energy to break and B(cooking time),, BC (Interactions between cooking time and cooling time), B^2 exponential function of cooking time) for stringiness (Table 7).

The regression coefficients therefore confirmed that the models for hardness, springiness, chewiness, gumminess, energy to break and stringiness were the best responses for the processing condtions with adjusted R^2 of 84.58%, 67.02%, 76.34%, 79.97%, 77,52% and 81.29% (Table 7) respectively. The graphs for the responses are indicated in Figure 2-5.

Sensory profile

The model properties for sensory profile (Table 8) indicated that the models for texture and overall acceptance were significantly adequate for exploration and had model terms that can be explored. The adjusted R^2 of 55.13% and 46.63% respectively indicated texture and overall acceptance were the most impactful sensory qualites of the pressure cooked cowpea. This is not unexpected since the attainment of suitable texture characterisristics is a pre-requisite for subsequent uses to which the cowpea might be put.

Cooking time is the significant terms in the models for most of the the texture profile and sensory attributes except colour and appearance. This reinforced the views that lenth of cooking time is one of the major limitations that make cowpea like other legumes uneconomical and unacceptable to consumers [28]. Adoption of suitable technologies that would optimise cooking time in relation to the desired textural quality of cooked cowpea would enhance the versatility of its various culinary uses [29].

Targets for numerical optimization

Appropriate targets that were set for numerical optimisation (Table 2) were based the outcome of focus group discussion involving foodservice personnel, consumers of cowpea foods. Some texture attributes were deliberately set in range in give room for flexibility of responses. A reasonable understanding of the importance of each of the responses to the textural quality of cowpea was necessary for the elimination of irrelevant constraints in the optimisation process and for the setting optimisation goals. In view of this, the optimisation goal for each of the responses was set as presented in Table 2. This was considered necessary so that the experimental conditions would be able to capture the different culinary uses for boiled cowpea.

In Nigeria, cooking by boiling is an intermediate processing activity in the preparation of most African dishes. Many of these dishes have specific range of functional and organoleptic culinary attributes. Cowpea is consumed mostly in boiled form or as porridge, attainment of suitable textural characteristics during the boiling stage usually serve as basis for final end use.

Twenty eight possible optimisation solutions (Table 9) were identified from the models each with desirability index ranging from 0.861 to 0.882, five of which were selected for the comparison of their sensory and proximate qualities with the control samples prepared using conventional method of cooking.

Solutions Number	Mass (g)	Cooking time (min)	Post cooking time (min)	Hard-ness	springi-ness	Adhe-siveness	Cohe-siveness	Chewi-ness	Gum-miness	Energy to break	String-iness	Colour	Taste	Tex-ture	Appear-ance	Overall accept-ability	Desir-ability
1*	1000	57.14	10.0	7.88	0.25	0.44	0.25	0.89	2.26	0.014	2.90	6.67	6.33	7.09	6.38	7.16	0.98
2+	264.89	60.0	10.0	1.53	0.26	0.44	0.24	0.93	1.51	0.006	2.75	6.67	6.33	7.09	6.38	6.99	0.977
3+	258.2	60.0	10.0	1.33	0.26	0.44	0.24	0.89	1.42	0.006	2.76	6.67	6.33	7.09	6.38	6.99	0.977
4+	284.7	60.0	9.62	2.17	0.26	0.44	0.24	0.82	1.51	0.006	2.78	6.67	6.33	7.07	6.38	6.98	0.975
5+	333.95	59.94	10.0	3.45	0.26	0.44	0.26	1.34	2.33	0.008	2.74	6.67	6.33	7.09	6.38	7.01	0.974
6#	265.7	60.00															

Table 9: Selected Numerical Optimisation Solutions.

--- *Adequately cooked, * Conventional method, Not adequately cooked +Over cooked

Proximate Composition of Boiled Cowpea

The proximate composition of cooked cowpea boiled by conventional and pressure cooked methods (Table 10) indicated that The moisture, fat, ash, crude protein and carbohydrate contents of the samples ranged from 61.49%, 1.71%, 1.57%, 14.69% and 13.84% to 66.62%, 2.48%, 2.19%, 18.68% and 14.79% respectively. The results also revealed that the proximate contents of the conventionally cooked sample were significant different ($p < 0.05$) from the pressure cooked samples. The relatively higher moisture content of the conventionally cooked samples suggested that more water may have been imbibed by the beans during the cooking process and this had implications on other proximate parameters.

Solutions Number	Mass	CT (min)	PCT (min)	DI	Moisture (%)	Dry Matter (%)	Fat (%)	Ask (%)	Crude Protein (%)	Carbohydrate (%)
1*	1000	57.14	10.0	0.98	61.49 ± 0.5^{a}	38.28 ± 0.2	2.48 ± 0.0^{d}	2.19 ± 0.0^{e}	18.68 ± 0.4^{e}	14.79 ± 0.4^{b}
2+	264.89	60.0	10.0	0.977	66.62 ± 0.1^{c}	33.38 ± 0.1^{b}	1.78 ± 0.0^{b}	1.62 ± 0.0^{a}	15.23 ± 0.1^{b}	14.76 ± 0.0^{b}
3+	258.2	60.0	10.0	0.977	66.44 ± 0.0^{c}	33.57 ± 0.0^{b}	1.86 ± 0.0^{c}	1.74 ± 0.0^{b}	15.61 ± 0.0^{bc}	14.36 ± 0.0^{ab}
4+	284.7	60.0	9.62	0.975	66.33 ± 0.1^{c}	33.68 ± 0.1^{b}	1.90 ± 0.0^{c}	1.88 ± 0.0^{c}	15.97 ± 0.0^{c}	13.95 ± 0.1^{a}
5+	333.95	59.94	10.0	0.974	64.09 ± 0.3^{b}	35.91 ± 0.3^{c}	2.13 ± 0.0^{d}	1.98 ± 0.0^{d}	16.96 ± 0.2^{d}	14.79 ± 0.1^{b}
6#	265.7	60.00			68.20 ± 0.4^{d}	31.80 ± 0.5^{a}	1.71 ± 0.0^{a}	1.57 ± 0.0^{a}	14.69 ± 0.2^{a}	13.84 ± 0.1^{a}

Table 10: Proximate Composition of Samples From Optimisation Solutions and Conventional Methods.

a-g =. Mean in same column with the same superscripts are not significantly different (P<0.05). CT = Cooking time, PT = Post cooking time, DI = Desirability Index.

--- *Adequately cooked, * Conventional method, Not adequately cooked +Over cooked

Sensory Properties Boiled Cowpea

Sensory properties of the boiled samples (Table 11) indicated that there was no significant different ($p > 0.05$) in colour, texture, appearance and general acceptance although, conventionally cooked samples had relatively low values than the pressure cooked optimized samples.

Solutions Number	Mass	Cooking time	Post cooking time	Desirability Index	Colour	Taste	Texture	Appearance	General Acceptance
1*	1000	57.14	10.0	0.98	6.26± 1.4 a	6.10± 1.4 ab	6.03± 1.1a	5.93±1.2a	6.37± 1.3a
2*	264.89	60.0	10.0	0.977	6.23± 1.3 a	5.60± 1.7 a	5.83± 1.3 a	6.10±1.3 a	6.20± 1.1 a
3*	258.2	60.0	10.0	0.977	6.33± 1.2 a	6.60± 1.5b	6.23± 1.4 a	6.20±1.3 a	6.60± 1.3 a
4*	284.7	60.0	9.62	0.975	6.00± 1.4 a	6.23± 1.8 ab	6.03± 1.6 a	5.80±1.5 a	6.33± 1.4 a
5*	333.95	59.94	10.0	0.974	6.17± 1.1 a	6.33± 1.2 ab	6.20± 1.5 a	6.13±1.4 a	6.23± 1.3 a
Conventional Methods#	265.7	60.00			6.53± 1.5 a	6.07± 1.3 ab	5.86±1.59 a	5.83±1.4 a	6.23± 1.4 a
Samples from Conventional Methods									

Table 11: Sensory Properties of Cooked Samples From Optimisation Solutions and Conventional Methods.

a-g =. Mean in same column with the same superscripts are not significantly different ($P<0.05$). CT = Cooking time, PT = Post cooking time, DI = Desirability Index.

--- *Adequately cooked, * Conventional method, Not adequately cooked +Over cooked

Conclusion

The study confirmed that cooking time played important role in the texture profile of boiled cowpea as samples (Run 11 and 12) 60 minutes had significantly ($p < 0.05$) lowest hardness values than samples from other cooking conditions. It takes more than 15 minutes to pressure cook cowpea to appropriate softness as samples (runs 8, 14 and 16) cooked within 15 minutes were significantly ($p < 0.05$) harder than other blends. This suggested that adequate cooking time was achieved within 38 minutes. Samples cooked beyond 38 minutes may have high adhesive values and may become sticky. The hard to cook phenomenon usually associated with dried cereal grains and legumes is not pronounced in the pressure cooked cowpea as no fracturability value was recorded in this study. This implied that little or no force is needed to bite through the pressure cooked seed at the commencement of chewing, even at the lowest cooking time. Sample with the highest gumminess value also had the highest hardness value implying that inadequately cooked beans are more likely to be gummy.

Although, most of the experimental samples were generally acceptable to the panelists, the results also indicated that the cowpea needs to be cooked for at least 37.5 minutes and held for not less than 2 minutes to soften the cowpea for reasonably high sensory texture scores. Results revealed that sensory texture scores increased as the values for some of the texture parameters decreased as negative correlation relationships was observed between sensory texture and hardness ($n=17$, $r = -.753$ $p= 0.00$), springiness ($n=17$, $r = -.731$, $p= 0.001$), chewiness ($n=17$, $r = -.783$, $p= 0.00$), gumminess ($n=17$, $r = -.806$, $p= 0.00$ and stringiness ($n=17$, $r =.803$, $p= 0.00$).

Model characteristics showed that all the texture profile parameters except that of cohesiveness were significant for exploration while taste, texture and overall acceptance models were the significant sensory parameters. In all the models, cooking time, its exponential function and/or its Interaction with other independent variables were the significant terms. However, there were no significant terms in the model for springiness and adhesiveness. The regression coefficients therefore confirmed that the models for hardness, springiness, chewiness, gumminess, energy to break and stringiness were the best texture profiles responses for the processing conditions with adjusted R^2 of 84.58%, 67.02%, 76.34%, 79.97%, 77,52% and 81.29% respectively. Texture and overall acceptance were the significantly models for sensory attributes with adjusted R^2 of 55.13% and 46.63% respectively.

Twenty eight possible optimisation solutions were identified with desirability index ranging from 86, 1% to 88.2%, five of which were selected for the comparison of their sensory and proximate qualities with the control samples prepared using conventional method of cooking. Verification experiment showed that all the suggested optimized solutions were adequately cooked while the samples from the conventional method were not adequately cooked even cooked for 60 minutes. The proximate compositions of samples from the optimized solution were significantly different ($p < 0.05$) from that of the conventionally conventional samples. The panelists were unable to detect a significant different ($p > 0.05$) in the colour, texture, appearance and general acceptance of the both the pressure cooked optimized solutions and the samples from the conventional method. Pressure cooking of cowpea therefore reduced substantially the cooking time required to cook cowpeas but appropriate cooking time need to be adopted to produce boiled beans with suitable texture profile for different culinary end use.

Bibliography

1. Singh A., *et al*. "Effect of milling method on selected physical and functional properties of cowpea (Vigna unguiculata) paste". *International Journal of Food Science and Technology* 40.5 (2005): 525–536.
2. Olapade A., *et al*. "Characterization of common Nigerian cowpea (Vigna unguiculata L. Walp) varieties". *Journal of Food Engineering* 55.2 (2002): 101-105.
3. De D K., Shawhatsu ., *et al*. "Energy-efficient cooking methods". Energy-efficient cooking methods 5.1 (2012): 3-15.
4. NASA 2009 "Ends warmest decade on record. NASA Earth observatory—image of the day". 22 (2010).
5. Federal Ministry for Economic Corporation and Development gtzHERA–Household Energy (2010).
6. Box G E P and Behnken D W. "Some new three level designs for the study of quantitative variables". *Technometrics* 2 (1960): 455–462.
7. Wani I A., *et al*. "Physical and cooking characteristics of black gram (Phaseolus mungoo L.) cultivars grown in India". *International Journal of Food Science and Technology* 48.2 (2013): 2557–2563.
8. Bourne MC. "Texture profile analysis". *Food Technology* 32 (1978): 62–66.
9. Bourne M C., *et al*. "Computer assisted readout of data from texture profile analysis curves". *Journal of Texture Studies* 9 (1978): 481–494.
10. Rosenthal A J. "Relation between instrumental and sensory measures of food texture". In: A.J. Rosenthal (ed.) Food Texture. *Aspen Publishers Gaithersburg* (1999): 1–17.
11. Gupta K K., *et al*. "Instrumental Texture Profile Analysis (TPA) of Shelled Sunflower Seed Caramel Snack Using Response Surface Methodology". *Food Science and Technology International* 13.7 (2007): 455–460.
12. AOAC, Official Methods of Analysis, 16th ed. TheAssociation of Official Analytical Chemists, Virginia, (2005): 1588.
13. Bakare HA., *et al*. "Optimization of Lye peeling of Breadfruit (Artocarpus comminis Frost) Using Response Surface Methodology. Journal of Natural". *Science Engineering and Technology* 8.2 (2009): 86-95.
14. Bakare H A O., *et al*. "Optimisation of the Processing Conditions on the Culinary Qualities of Pressure-Cooked Boiled Yam". *Journal of Culinary Science and Technology* (2016).
15. Sefa-Dedeh S., *et al*. "Effects of soaking time and cooking conditions on texture and microstructure of cowpeas (Vigna unguiculata)". *Journal of Food Science* 43.6 (1978): 1832-1838.
16. Lush W M. and Evans LT. "The seed coats of cowpeas and other grain legumes: structure in relation to function". *Field Crops research* 3 (1980): 267-286.
17. Proctor J R. and WattS B M. "Development of a modified Mattson Bean Cooker procedure based on sensory panel cookability evaluation". *Canadian Institute of Food Science and Technology Journal* 20.1 (1987): 9-14.
18. Phadi M M. "Physico–chemical effects of micronization on cowpeas (Vigna unguiculata L. Walp)". *MInst Agrar Dessertation, University of Pretoria* 14 (2004): 44- 56.
19. Deol J K and Bains K "Effect of household cooking methods on nutritional and anti nutritional factors in green cowpea (Vigna unguiculata) pods". *Journal of Food Science and Technology* 47.5 (2010): 579–581.

20. Lawless HT and Heymann H. "Sensory Evaluation of Food Principles and Practices Second Edition Springer New York Dordrecht Heidelberg London (2010).

21. Trinh K T and Glasgow S. "On the texture profile analysis test". *Conference paper* (2012).

22. Scott-Blair G. "Rheology in food research". *Advances in Food Research* 8 (1958): 1-61.

23. Liu K., *et al*. "Mechanism of pectin changes during soaking and heating as related to hard-to-cook defect in cowpeas". *Journal of Agriculture and Food Chemistry* 41.9 (1993): 1476-1480.

24. Brett CT and Waldron KW. "Physiology and biochemistry of plant cell walls. In: Black M, Charlwood B, editors. 1. Topics in plant functional biology". London, U.K.: Chapman and Hall. (1996): 230.

25. Afoakwa E O., *et al*. "Response surface methodology for optimizing the pre-processing conditions during canning of a newly developed and promising cowpea (Vigna unguiculata) variety". *Journal of Food Engineering* 73.4 (2006): 346-357.

26. FAO Energy supply and demand: trends and prospects. (2012). ftp://ftp.fao.org/docrep/fao/010/i0139e/i0139e03.pdf.

27. Hamid S., *et al*. "Physical and cooking characteristics of two cowpea cultivars grown in temperate Indian climate". *Journal of the Saudi Society of Agricultural Sciences* (2016): 127-134.

28. Sefa-Dedeh S and Stanley D W. "Textural implications of the microstructure of legumes". *Food Technology* 10 (1979): 77-83.

29. Sefa-Dedeh S., *et al*. "Effect of storage time and conditions on the hard to cook defect in cowpeas (Vigna unguiculata)". *Journal of Food Science* 44.3 (1979): 790-796.

Volume 3 Issue 5 May 2019