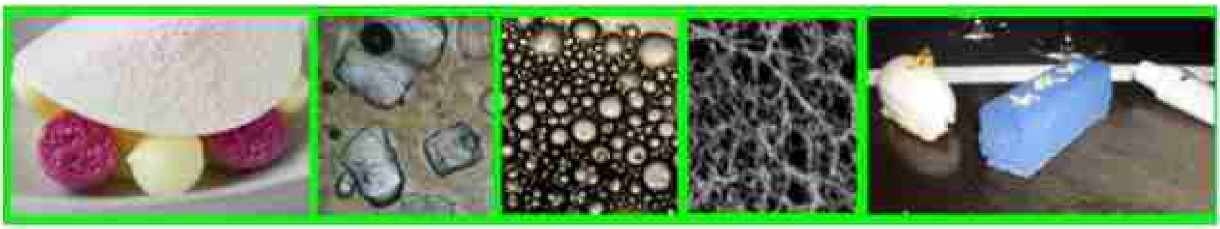

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Experimental test of culinary precisions

The impact of onion (*Allium cepa* L.) bulb addition on the softening characteristics of seeds of cowpeas (*Vigna unguiculata* L. Warp)

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Abstract

Cowpeas (*Vigna unguiculata* L. Warp) are a nutrient-rich legume widely consumed in many regions and often require prolonged cooking times. This study examines a traditional Ghanaian belief that adding onion (*Allium cepa* L.) during the cooking of cowpeas enhances their softening characteristics and impacts sensory properties. Three methods were tested: cowpeas cooked with; iodised salt, iodised salt plus baking soda, and iodised salt plus onion. Sensory evaluation using a 5-point hedonic scale was conducted by a panellists ($n = 21$) to assess odour, colour, consistency, and flavour. Results showed that incorporating baking soda samples exhibited significantly softer texture compared to the other samples. There was no significant differences between the control and samples with onions added, challenging the anecdotal belief. No significant differences were observed at $p < 0.05$ in odour, flavour, and colour among the samples, except for samples with iodised salt plus onion for which there was a darker appearance attributed to baking soda.

Keywords

onion, cowpeas, baking soda, consistency, sensory evaluation

1. Introduction

Cowpeas (*Vigna unguiculata* L. Walp.) are a legume from the Fabaceae family, and are widely consumed in Ghana (Brink *et al.*, 2006). Here it is commonly consumed as a legume, but also as a vegetable in the form of immature pods and leaves. Cowpeas are the second most important food legume in tropical Africa (Onwueme and Sinha, 1991), and their cultivation is an efficient means of maximizing protein production in most developing countries. They have been identified as a good source of protein and calories, making them important for combating malnutrition in Ghana (Affrifah *et al.*, 2022).

Cowpeas are highly valued for their rich nutritional profile, which includes high levels of protein (~ 24 %), dietary fiber (~ 11 %), and potassium (1112 mg/100 g). With lower levels of lipid (< 2 %) and sodium (16 mg/100 g), they provide an affordable and sustainable source of nutrition in areas with limited access to animal proteins (USDA, 2021). They also provide essential amino acids, including methionine, lysine, threonine, tryptophan, phenylalanine, valine, leucine, and isoleucine (Elharadallou *et al.*, 2015). These amino acids are often present as residues in proteins in a significant amount, but processes such as protein hydrolysis, germination, and fermentation can increase the proportion of free amino acids (Elharadallou *et al.*, 2015). Additionally, the starch content of the cowpeas is rich in resistant starch (9.3-12.1 %) depending on the cultivar, contributing to a low glycemic index (Ma *et al.*, 2017; Rengadu *et al.*, 2020; FAO, 2021; Affrifah *et al.*, 2022). The presence of galacto-oligosaccharides, such as α-D-galactopyranosyl -(1→6)- β- D- glucopyranosyl-(1→2)-α-D-fructofuranoside (raffinose) and α-D-galactopyranosyl - (1→6) -α-D- galactopyranosyl-(1→6)-β-D-glucopyranosyl-(1→2)-α-D-fructofuranoside(stachyose) enhances their nutritional value but can cause digestive discomfort (Nnanna and Phillip, 1988; Affrifah *et al.*, 2022). This nutritional versatility makes cowpeas a crucial food source in Ghana, supporting the diverse nutritional needs of various socio-economic groups.

"Hard-to-cook" (HTC) legumes, including cowpeas, are those that require prolonged cooking times and exhibit resistance to softening, leading to frustration among cooks who seek to prepare this legume more quickly and with less energy consumption. This phenomenon is well understood by scientists, who have identified specific factors, such as seed coat structure and antinutrients, as contributing factors to these issues (Reyes-Moreno *et al.*, 1993; Sivakanthan *et al.*, 2020).

In Ghanaian culinary tradition, there is a belief that adding parts of bulbs of onions *Allium cepa* L. ("onions") to cooking water can help soften the seeds of cowpeas ("cowpeas") and reduce cooking time (Kuokor-Neequaye, 2023). This belief, passed down through generations, suggests that certain ingredients possess special properties that influence cooking outcomes. However, the scientific basis for this claim has not been thoroughly explored, prompting the need for investigation into the potential impact of onion on cowpea cooking.

Previous studies have shown that salts like sodium hydrogen carbonate ($NaHCO_3$), sodium chloride (NaCl), and sodium carbonate (Na_2CO_3) can reduce cooking time and improve the sensory qualities of legumes (Onwuka and Opara, 2006). This study aims to explore the effects of onion (bulb) incorporation on the softening and cooking efficiency of cowpeas, specifically focusing on its impact on textural and other sensory attributes like colour, odour and flavour. Through sensory evaluation, we seek to better understand the role of onion in improving cooking outcomes and the sensory qualities of cowpeas.

2. Materials and Methods

2.1. Materials

The cowpea utilized in this experiment were sourced from a local supermarket in Dublin and specifically selected as Black Eye Beans by Heera, grown in India (growing season July,

2022) packed in the UK (August 2023). These beans typically range in size from 6 to 9 mm and are sourced dry. For the experiment, 180 g of beans were allocated, with 60 g each for the three recipes: sample 1 with an addition of salt (NaCl) with 99.5% purity; sample 2 with salt and baking soda, and sample 3 with salt and onion. The iodized table salt (NaCl) used was sourced from Saxa Salt (99.5% purity), originating from Ireland and purchased at Farm and Home Stores. A total of 2 g of salt was used across the experiments. Additionally, 1 g of sodium hydrogen carbonate ($NaHCO_3$) from Dr. Oetker with percentage purity of 99.0% was incorporated. White onions, using the bulb, weighing 20 g and procured from TU Dublin Stores, were included as an ingredient. To facilitate the cooking process, 5400 mL of water was used, with 1800 mL designated for each sample.

2.2. Equipment

- Pot, 5 L
- Electrolux burner (gas)
- Two decimal weighing scale (Cely BB-P3888)
- Bowls for weighing beans and water.
- Spoon to help in test for softness.
- Disposable plates for sensory.
- Calibrated thermometer (Doquaus Digital)

2.3. Experimental Design

Three distinct cooking recipes were tested, each incorporating different additives, with two independent trials conducted to ensure reliability and reproducibility of results. Each sample was subjected to the same controlled cooking procedure for consistency. The experimental conditions were as follows:
- Sample 1: Cowpeas cooked with iodized salt only (NaCl).
- Sample 2: Cowpeas cooked with iodized salt and baking soda ($NaHCO_3$).
- Sample 3: Cowpeas cooked with iodized salt and onion bulb.

The controlled cooking process was performed on a gas stove using identical proportions of water, cowpeas, and additives for each trial. This approach aimed to minimize variability and ensure comparability among the samples.

2.4. Cooking Procedure

Dry cowpeas were prepared for each cooking recipe following a standardized procedure. The cowpeas were weighed and then thoroughly rinsed under tap water (containing calcium ions) to remove any debris, such as dust or small particles. Each batch of cowpeas was placed in a pot with the designated cooking liquid according to the recipe (salt-only, salt and baking soda, or salt and onion). The pots were brought to a boil, reaching and maintaining a temperature of approximately 100°C, as measured by a thermometer. To ensure consistent boiling, the temperature was checked twice at 15-minute intervals throughout the 30-minute cooking duration. After cooking, the cowpeas were allowed to cool to room temperature for 30 minutes, measured at approximately 25 °C, before any sensory analysis was performed.

2.5. Sensory analysis and evaluation

A preference sensory evaluation was conducted to assess the sensory attributes of cowpea samples in two separate evaluation trials. The evaluation involved 21 trained panellists, selected based on their availability and non-allergic status to the recipe ingredients, particularly cowpeas. For panellists who participated in both sessions, measures were taken to randomize sample presentation order in each trial to minimize potential biases associated with repeated exposure. The training for panellists was conducted through an orientation session led by a sensory scientist. The session provided detailed explanations of the evaluation protocol, definitions of the attributes being assessed, and practice with mock samples to ensure panellists were familiar and consistent in their assessments. Samples were evaluated using a 5-point hedonic scale (1 = very poor, 5 = excellent) (Lawless and Heymann, 2010), assessing the following attributes:

• Colour: Evaluated for uniformity, brightness, and absence of discoloration. Poor attributes were defined as dull, uneven, or discoloured samples, while excellent attributes were bright, uniform, and visually appealing.

• Consistency: Assessed for perception of hardness or softness during chewing, and by pressing samples between the thumb and index fingers by the sensory panellists.

• Odour: Rated for intensity and appeal, where poor odour was weak and unappealing, and excellent odour was strong and pleasant.

• Flavour: Evaluated for overall palatability based on the intensity left in the mouth after tasting the food, with poor flavour defined as weak or unbalanced, and excellent flavour as rich, strong, and well-rounded.

Samples were served at room temperature (25 °C) in random order, each coded with a unique 3-digit identifier (Stone *et al.*, 2020). To ensure consistency, panellists received a sample questionnaire and a glass of water to cleanse their palate between samples.

2.6. Data Analysis

The sensory evaluation data were analysed for each attribute (colour, consistency, odour, and flavour) rated on a 1-5 scale. For each criterion, mean values and standard deviations were calculated to summarize the central tendency and variability of scores across samples.

Statistical analysis was conducted using JMP software (version 16.0). Principal component analysis (PCA) was employed to identify patterns and relationships in the sensory data, highlighting the main attributes contributing to variability among samples. Additionally, analysis of variance (ANOVA) was performed to determine if there were statistically significant differences among the sample means for each sensory attribute. ANOVA is appropriate in this context because it compares the means of multiple groups (samples) to evaluate the effect of the different cooking treatments (Montgomery, 2019). When significant differences were identified ($p < 0.05$), Tukey's Honest Significant Difference (HSD) test was conducted for pairwise comparisons, enabling a detailed understanding of which samples differed significantly.

This combination of PCA and ANOVA is supported by sensory analysis literature as a robust approach to understanding consumer preferences and identifying key differentiators among samples (Lawless and Heymann, 2010; Stone *et al.*, 2020).

Table 1. Mean and standard deviation values of sensory attributes for each sample. Sample 1: cowpeas cooked with only iodized salt; sample 2: cowpeas cooked with iodized salt and baking soda; sample 3: cowpeas cooked with iodized salt and diced onions.

Means	**Sample 1**	**Sample 2**	**Sample 3**
Colour	3.71 ± 0.56 a	3.10 ± 0.70 a	3.57 ± 1.12 ab
Consisten-cy	3.10 sd 1.04 a	3.86 sd 0.65 b	2.81 sd 0.93 a
Odour	2.56 sd1.73 a	2.61 sd 1.44 a	2.88 sd 1.49 a
Flavour	2.76 sd 1.04 a	2.90 sd 0.89 a	3.00 sd 1.14 a

Different alphabets within a row indicate statistically differences among samples at p < *0.05. . Attributes without significant differences share the same alphabet.*

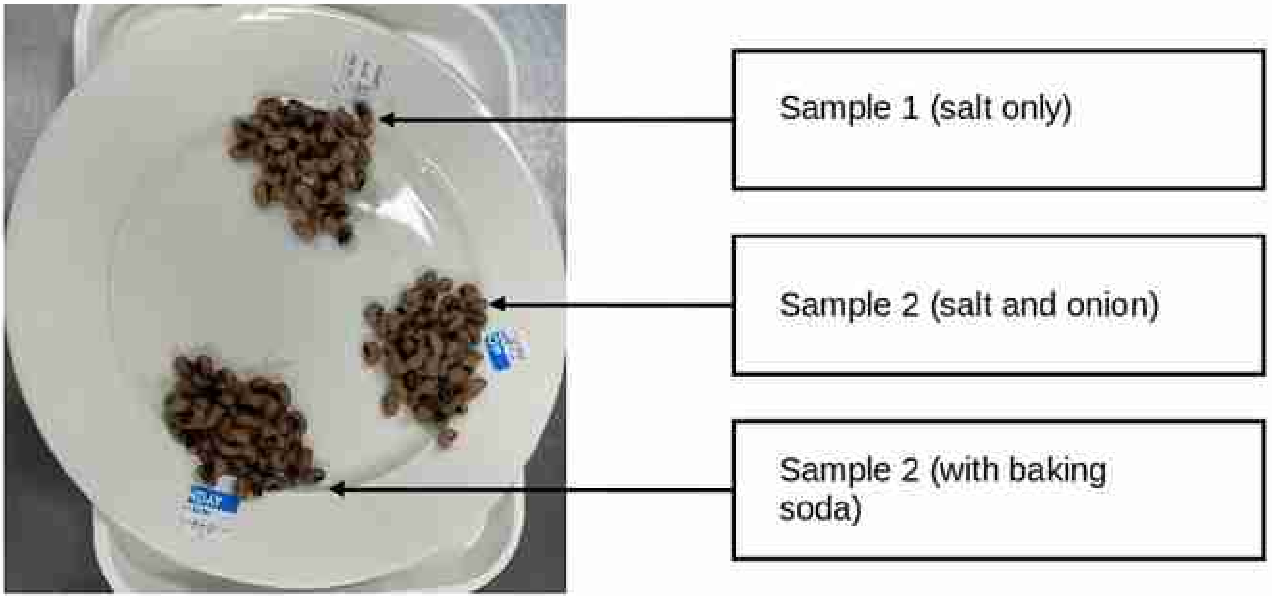

Figure 1. Visual comparison of the cowpea samples. Sample 2 with baking soda was darker compared to Samples 1 and 2.

3. Results and Discussion

Table 1 presents an analysis of sensory attributes (colour, consistency, odour, and flavour) across three samples (Sample 1, Sample 2, Sample 3) for both trials. It outlines scores and standard deviations derived from panellists' evaluations. For detailed post-hoc test results, see the Supplemental Material.

3.1. Consistency

The consistency of the samples varied significantly, as indicated by an analysis of variance (ANOVA) ($F(2, 57) = 8.68$, $p < 0.001$). *Post-hoc* analysis using Tukey-Kramer HSD revealed that Sample 2 (salt and baking soda) had a significantly softer texture (3.86 ± 0.65) compared to both Sample 1 (salt only) (3.10 ± 1.04, $p = 0.003$) and Sample 3 (salt and onion) (2.81 ± 0.93, $p < 0.001$). The enhanced softness in Sample 2 is consistent with research showing that baking soda softens legumes during cooking (Onwuka and Opara, 2006). However, no significant difference in texture was observed between Sample 1 and Sample 3 ($p > 0.05$). This finding suggests that while baking soda has a clear softening effect, the addition of onion in Sample 3 did not significantly alter the texture compared to Sample 1.

3.2. Odour and flavour

Odour and flavour were evaluated, and while Sample 3 showed marginally higher mean scores for both attributes (aroma: 2.88 ± 1.49; flavour: 3.00 ± 1.14), the differences were not statistically significant (odour: $F(2, 60) = 1.25$, $p = 0.2943$; flavour: $F(2, 60) = 0.28$, $p = 0.7535$). These findings suggest that variations in ingredient combinations did not substantially impact aroma and flavour perception.Future studies could explore alternative ingredient concentrations, cooking methods, or processing parameters to better understand how to optimize aroma and flavour in cowpea-based dishes.

3.3 Colour

The colour perception of the samples differed significantly among the three samples, as shown by ANOVA results ($F(2, 60) = 3.21$, $p = 0.0474$). Sample 2, cooked with salt and baking soda, had the lowest mean colour score (3.10 ± 0.70), likely due to the darkening effect of baking soda (Uzogara and Ofuya, 1992). In contrast, Sample 1 (salt only) and Sample 3 (salt and onion) received higher scores (3.71 ± 0.56 and 3.57 ± 1.12, respectively), with no significant difference observed between these two samples ($p > 0.05$).
These results suggest that while baking soda had a noticeable impact on darkening the colour, the addition of onion in Sample 3 did not significantly influence the perceived colour compared to Sample 1.
A visual representation of the cowpea samples on a plate highlights the differences in appearance, with Sample 2 appearing noticeably darker compared to Sample 1 and 3 (Figure 1).

4. Conclusion

The experiments reported here challenged the traditional Ghanaian belief that adding onion accelerates the softening of cowpeas. Contrary to this belief, the sample prepared with onion (Sample 3) did not achieve the desired softness, while Sample 2, cooked with salt and baking soda, demonstrated the highest softness, highlighting the effectiveness of baking soda as a softening agent.
In terms of odour and flavour, no significant differences were observed among the samples, suggesting that the addition of onion did not notably influence these sensory attributes. Similarly, while significant differences in colour were noted, the sample with onion (Sample 3) did not significantly differ in colour perception compared to the control sample (Sample 1).
Although the amount onion used in this study was not reflective of traditional practices, it was standardized to maintain experimental consistency. Future research could explore varying onion quantities, cooking methods, and additive interactions to optimize sensory outcomes in cooked cowpeas. These findings not only dispel culinary myths but also provide evidence-based insights to enhance traditional cooking practices.

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