

Article

Exploring the Nutritional Benefits and Consumer Acceptance of Canned Bambara Beans in Ghana: Proximate, Microbial Quality and Sensory Acceptability

Gifty Selorm Bansah ^{1,*}, Grace Selorm Amatefe ², Emmanuel Tei-Mensah ³¹ Department of Family and Consumer Sciences, University for Development Studies, Tamale, Ghana² Department of Hospitality and Tourism Management, Koforidua Technical University, Koforidua, Ghana³ Department of Food and Post-Harvest Technology, Koforidua Technical University, Koforidua, Ghana

*Correspondence: Gifty Selorm Bansah (selorm5139.gifty@gmail.com)

Abstract: This study aimed to assess the proximate composition, microbial quality, and sensory acceptability of canned Bambara beans in Ghana to determine their nutritional value and consumer perceptions. The research was conducted in Tamale in the northern region of Ghana, focusing on sensory evaluation, nutritional analysis, and consumer preferences for canned Bambara beans. The study utilized canned Bambara bean varieties sourced from local markets in Ghana. It involved sensory panels, proximate analysis, and microbial testing to evaluate the quality and safety of the canned products. Data analysis included sensory scoring, proximate composition determination, and microbial count assessments. The findings indicated positive consumer attitudes towards canned Bambara beans, emphasising their convenience, nutritional richness, and sensory appeal. Nutritional analysis revealed the nutrient content of the canned beans, highlighting their potential as a nutritious food source. Conclusions emphasised the importance of sensory attributes in consumer acceptance and women's role in producing and promoting Bambara beans. It is recommended that Increase awareness among consumers, especially women and homemakers, about the nutritional benefits and culinary versatility of canned Bambara beans. Educational campaigns highlighting canned Bambara beans' health advantages and convenience can encourage their inclusion in household diets. It is also recommended that women involved in the production and processing of Bambara beans should be supported and empowered through training, capacity building, and access to resources. Recognising the pivotal role of women in the Bambara bean value chain is essential for sustainable production practices and economic empowerment.

How to cite this paper:

Selorm Bansah, Amatefe, G. S., & Tei-Mensah, E. (2024). Exploring the Nutritional Benefits and Consumer Acceptance of Canned Bambara Beans in Ghana: Proximate, Microbial Quality and Sensory Acceptability. *Universal Journal of Food Science and Technology*, 2(1), 14–28. Retrieved from <https://www.scipublications.com/journal/index.php/ujfst/article/view/956>

Keywords: Consumer, Canned, Bambara, Beans, Proximate, Microbial, Quality Sensory Acceptability

Received: February 11, 2024

Revised: April 26, 2024

Accepted: May 31, 2024

Published: July 12, 2024



Copyright: © 2024 by the authors. Submitted for possible open-access publication under the terms and conditions of the Creative Commons Attribution (CC BY) license (<http://creativecommons.org/licenses/by/4.0/>).

1. Introduction

Bambara beans, a highly nutritious and underutilised legume, hold significant potential in enhancing food security and nutrition in Ghana and beyond. With a rich nutrient profile and culinary versatility, Bambara beans offer a promising solution to address the region's food insecurity and malnutrition challenges. However, issues such as limited information on food safety, challenges in cooking times, and inadequate commercialization have hindered the widespread adoption and consumption of Bambara beans. To address these challenges, this study focuses on the evaluation of canned Bambara beans as a means to improve the quality, safety, and availability of this valuable legume. By exploring the sensory acceptability of canned Bambara beans among consumers and assessing their nutritional content, this research aims to shed light on the

potential of canned Bambara beans as a convenient and nutritious food option. Furthermore, considering the importance of women in the production and cultivation of Bambara beans in Ghana, this study also seeks to understand the role of women, particularly homemakers, in the utilization and promotion of Bambara beans in household diets. By examining the perceptions and preferences of consumers, as well as the nutritional benefits of canned Bambara beans, this research contributes to the promotion of sustainable food practices and the enhancement of food security in Ghana.

Bambara beans, also known as Bambara groundnut (BGN), are widely used, belong to the legume family, and are the third most crucial vegetable in semi-arid Africa [1]. This bean was cultivated in West and Central Africa [2, 3]. Mass production, including land preparation, planting, pesticides, herbicides, harvesting, drying, drying, threshing and tossing, was done by women, which influences gender participation [4]. This means that the plant is a "female crop". Bambara beans are considered the third most nutritious food in African countries, after peanuts (*Arachishypogea*) and cowpeas (*Vigna unguiculata*). Beans are beneficial; they contain 15.5-22.46% protein, 55.0-61.3% carbohydrates, 1-4.2% ash, 0.097% calcium, 0.007% iron, 1.25% potassium and 0.003% sodium [1]. BGN, a plant for human consumption, is a complete food as it contains sufficient amounts of protein, carbohydrates and fats. Milk prepared with BGN has a better taste than milk prepared with cowpea, pigeon pea and soybean [5]. Therefore, BGN can be an excellent plant material. The eradication of poverty and malnutrition requires using a variety of food plans that emphasize the importance of daily nutrition. Despite the diversity of agriculture in the world, people still depend on monoculture of limited crops in their daily food plans [6]. However, this does not guarantee the safety of the food and does not guarantee that the food is available or planned. Indicators such as poverty, low birth weight and adult obesity are now on the agenda [7].

Unfortunately, we would miss the United Nations Sustainable Development Goal (SDG) to eradicate poverty by 2030, based on current patterns of food production and food consumption. Problems such as automation, metropolitan sprawl, rapid growth, birth rate, pest and disease prevalence, government depression, unpredictable weather and ownership reduce the need for increased food consumption and production [8]. To achieve the United Nations' development goals by 2030, Good nutrition in development is especially important for low-income countries. The Second SDG (EAT-Lancet Compensation, 2019) requires improving agricultural nutrition and whole grains. Global food safety and security have become a major concern due to over-reliance on food crops as the primary source of nutrition and drinking consumption [9]. Therefore, more than the current production of major crops may be required to meet the population's needs [10]. Global food production is recommended to increase by 70% by 2050 to meet the needs of the worldwide population [9].

Bambara bean is an underutilized commodity yet very prospective, especially in culinary application and nutrition [11]. Bambara bean, a very nutritious bean yet tough concerning its cooking time, has seriously impacted pro consumption and commercialization. Considering the exposure of food with its consequence contamination when sold by the vendors as a result of mishandling as well as limited information on food safety, it has become necessary to process (package canned in brine) Bambara bean varieties to improve the quality, safety and availability of the beans. The nutrient profile of the other varieties is also limited in literature since the most popular variety in the market is the cream white eye Bambara beans. The basis of the selection of the varieties is to confirm which one exhibits a high level of nutritional quality. Also, there needs to be more usage and information about the Bambara bean varieties concerning the culinary application industry. This study aimed at producing ready-to-consume canned bambara bean varieties. These objectives guided the study – (1) to determine proximate and microbial quality of canned Bambara beans. (2) Conduct sensory acceptability on the canned Bambara bean.

1.1. Physical treatments (milling, roasting and canning) for Reducing the Cooking Time of Bambara Beans

Bambara beans (*Vigna subterranean* L. Verdc.), a member of the Faboidea and Fabaceae plant subfamilies, are a close relative of *Vigna* [12]. The quality of Bambara peanuts makes them challenging to grind, which is a problem for workers trying to find an excellent pick-and-grind method [13]. In hard-to-break materials, the problem may arise from the adhesion of the cotyledons to the shell due to mucus and gum at the attachment site [13, 14]. The cooking and grinding of Bambara nuts can often be influenced by the chemical composition of the mucilage. These mucilages and gums contain a cellulose microfibril network embedded in a protein and NSP matrix [14].

Bambara peanut seeds absorb 54 g of water per 100 g of seed to achieve the highest peeling yield [16]. After wet and dehusking, there was a significant difference in husk performance, loss, and cotyledon yield from dry and cold samples. When removing the shells of raw Bambara peanuts by hand, the work done by the shell is zero, but after using the grinder (using the grinder), the value is 70.5%. This value is very different (81% to 88%) compared to the dehulling effect of soaked Bambara peanut seeds. The yield and peeling of stripped cotyledons increase with increasing cold water [15]. I soaked Bambara peanuts to make aqua bean paste and found that after soaking for 20 minutes, the coating wrinkled, but the coating was still rugged enough to remove by hand, even after 10-15 hours. Although the absorption was a little slow, the seeds increased by 2% in weight after 1 hour of soaking [16]. The seed density of Bambara peanut seeds is responsible for the low water absorption. The impact of modification on the quality of Bambara peanut flour was evaluated using three different methods and a variety of Bambara peanuts [17]. Processing (grinding) is one inspection process that combines grinding and grinding and modernization (heat treatment, peeling, and grinding). For intensive processing, wash the seeds at a boil for 25 minutes, dry them in the dryer at 60 to 65 °C for 10 hours, and then grind them [17].

This study did not evaluate the efficiency of flour processing, including peeling and milling. Only the quality (i.e. chemical composition and physical strength) of Bambara peanut powder and roasted protein was evaluated [18]. However, this study did not assess the effect of temperature on the grinding and processing of Bambara nuts. Researchers evaluated the impact of milling (dry and wet milling) on Bambara peanut flour's chemical and nutritional composition. Bambara peanut seeds are coarsely ground and boiled for 10 minutes to remove the seed husk, and the cotyledons are finely ground to make powder. The seed coat has a higher fibre content compared to the dehulled cotyledon meal. In addition, raw Bambara peanut flour has a higher phytic acid content than rice flour [19].

1.2. Canning

Canning is a general term that refers to packaging food in containers and heat treating it to extend their shelf life. Canning is heating food in sealed boxes to destroy any bacteria that can spoil food. Proper canning stops this spoilage by heating the food for a certain period and killing the bacteria. As the can cools and seals, air is removed from the jar, and a vacuum is created during the canning process. Two types of cans are approved by the United States Department of Agriculture (USDA): Bath water cans are hot water cans, boiling water in a large pot. The jars filled with water were placed in water and heated at 212°C for a certain period. This method is used to process acidic foods such as fruit, fruit preparations, pickles, canned foods and tomatoes. The pressure vessel uses a large bottle to free up space in the enclosure. The ship in the vessel is heated to a temperature of 240 °C at a given pressure (in pounds) measured by a manometer or a manometer in the lid cap. Vegetables and other non-acidic foods such as meat, poultry and fish are processed at high pressure [20]. A sample of canned Bambara peanuts was

analyzed using a combination of sodium hexametaphosphate salt at boiling, soaking, and cooking scales. The seeds are bleached and soaked before closing the lid to increase water absorption and trainability. Stability, tannins and phytic acid all showed a decline. Phytate, tannin, and seed softening were all significantly reduced when the salt concentration increased during soaking ($p < 0.05$).

1.2.1. Canning in brine

Usually, the protein is soaked in a solution of water (or other liquid, such as juice, beer, or wine), salt, and spices and left in the refrigerator for two to three hours. The advantage of desalination is that the protein is packaged in a dry salt or brine solution that preserves food, which has the highest salt concentration (called supersaturated brine) that water can hold in the body. When salt enters, water comes out, and beans with very little water do not spoil, so they are in the bag on the shelf, not in the freezer of the market food. Humidity is counterintuitive because storing beans means less moisture. Salting allows the beans to cook more by adding water to the brain before cooking the beans and allowing the brain to retain water as the beans cook. The saline surrounding the cells contains more salt than the fluid inside the cells. This causes salt ions to enter the cell by diffusion. High salt concentration immediately initiates the work of protein complexes in muscle fibres. The result is that the muscle fibres take up and retain more water by osmosis and capillary action [21].

1.2.2. Benefits of canning in brine

The brine treatment provides water to soften beans and reduces cooking time while producing beans that do not burst when cooked to achieve the desired soft, creamy texture. Surprisingly, the beans absorb some salt during the curing process. Beans soaked in salt or baking soda did better than beans in water alone. Beans cured in baking soda are better than cured in brine. This is true regardless of the type of coffee bean. Treatment will help to remove impurities and dust from legumes. It also helps to shorten the cooking time of the beans, increase the nutritional value (although there are different opinions about this), and remove up to 90% of the oligosaccharides (sugar) that are often expected to cause gas. Curing after cooking also improves the quality and texture of dried beans. The authors also found that salting the beans improved the quality and texture of the beans more than soaking them in water, helped prevent the beans from spoiling, helped them be more stable during cooking, and improved odour. This helps weaken the crust and allows the beans to cook more without breaking. It originated in West Africa but is now widely distributed in the semi-arid regions of Sub-Saharan Africa (SSA). Bambara, along with other commonly used pulses, has high nutritional value and an attractive profile reflected in small villages and niche markets [21].

1.3. Nutritional Value of Bambara Beans

Nutritional value of Bambara peanut seeds Bambara peanuts provide nearly balanced nutrition based on biochemical analysis of carbohydrate, fat and protein content [22]. Bambara peanuts contain less protein than other legumes. Bambara peanuts contain less protein than other legumes. Methionine and cysteine are limiting amino acids in most legumes [23]. However, according to FAO law, Bambara peanut seeds contain high levels of methionine (as a percentage of protein) and all other essential and non-essential amino acids [24, 25]. Also, Bambara peanut has a score of 80%, soybean (*Glycine max*) has a protein score of 74%, peanut (*Arachishypogaea*) has a protein score of 65%, and beef (*Vigna unguiculata*) has a protein score) has a protein score of 64%, indicating that Bambara peanuts are high in protein [26]. Bambara peanuts contain more fatty acids (palmitic and linoleic acids) than peanuts. Peanuts also contain vitamin A, thiamine, riboflavin, niacin, carotene, and ascorbic acid [27].

Bambara nuts contain micronutrients such as zinc and iron, calcium and potassium, but not phosphorus and magnesium [22]. Red seeds contain twice as much iron as soybeans, which is very popular in regions where iron deficiency is not a problem [28]. A study conducted in Northern Ivory Coast found that Bambara pea seeds were influential in treating diabetes. Milk, an aqueous extract made from bamboo nut powder, has been reported to be superior to cowpea and soybean in terms of soil and mineral content [29]. The reduced bioavailability of proteins and minerals in Bambara peanuts and other legumes is a negative of anti-nutritional components such as tannins, trypsin inhibitors, lectins and phytates [30].

1.4. How Canning Influence the Nutritional Value of Bambara Beans

The Protein quality of HTC beans cooked in salt solutions (0.3:1 and 8:1) ratio of monovalent ions to divalent ions was analyzed, and this ratio showed a decrease in protein quality (i.e. protein activity ratio and digestibility) [31]. Alkaline salt cooking aims to preserve nutrients and health while reducing cooking time [32]. Furthermore, high pH, prolonged heating, and the properties of diverse amino acid side chains facilitate the conversion of all amino acid liposomes to the D-isomer by racemization [33]. It has been shown that protein quality (i.e., protein efficiency ratio, net protein ratio, and relative net protein ratio) decreases when cowpea is cooked in kanwa solution [34]. When black-eyed peas are cooked with 0.5% kanwa, there is a negligible amount of amino acids and no change in lysine content [35]. It has been reported that some regions in northern Nigeria can use up to 10% by weight of cowpea when adding kanwa to food, depending on local culture and taste [34].

The chemical composition of black beans (*Phaseolus vulgaris*), including lipids and water-soluble fraction, was evaluated after cooking in kanwa solution [36]. After cooking, the content of lipids (palmitic, stearic, oleic or linoleic), protein (essential and non-essential amino acids) and intermediate sugar (galactose) decreases [36]. Kanwa produces products that are darker in colour and more abundant in foods than foods.

1.5. The Theory of Planned Behaviour (TPB)

The Theory of Planned Behaviour (TPB) can support the study on canned Bambara beans in Ghana. This theory suggests that an individual's intention to perform a behaviour is influenced by their attitude towards the behaviour, subjective norms (perceived social pressure), and perceived behavioural control. In the context of this study, the Theory of Planned Behavior can help understand consumers' attitudes towards canned Bambara beans, social influences on their consumption choices, and perceived control over incorporating this nutritious legume into their diets. By applying the TPB framework, researchers can explore factors influencing consumer acceptance of canned Bambara beans and inform strategies to promote their consumption for improved nutrition and food security in Ghana.

2. Materials and Methods

The study adopted an experimental research design. Bambara bean varieties were obtained from the Tamale main market in the Northern region of Ghana.

2.1. Pretreatment of Bambara bean varieties

The Bambara bean varieties were washed and soaked for 12 hours before production (As shown in [Figure 1](#), [Figure 2](#), [Figure 3](#), [Figure 4](#), [Figure 5](#), and [Table 1](#)).



Figure 1. Black Bambara beans



Figure 2. Red Bambara beans



Figure 3. Cream black eye Bambara beans



Figure 4. Cream pink eye Bambara beans



Figure 5. Clean white eye Bambara beans

Table 1. Composition of various Canned Bambara beans

Ingredients	S1	S2	S3	S4	S5
Quantity of beans(g)	400	400	400	400	400
Volume of brine solution (3% w/v)	40	40	40	40	40

S1=Red Bambara beans; S2= Clean white eye Bambara beans; S3= Cream black eye Bambara beans; S4=Black Bambara beans; S5= Cream pink eye Bambara beans

2.2. Production of the Canned Bambara bean varieties

Each variant of the Bambara beans was blanched for 15 minutes and soaked at freezing temperature (5°C) for 12 hours. It was then washed and filtered to ensure that the beans were free from any form of dirt. An amount of water, thus three times the weight of the sample, was added to the samples in the pressure cooker and cooked at 120°C for approximately 30 minutes. The samples were then packaged in their respective cans and retorted (at a temperature of 115°C, a pressure of 1 bar and a time of 30 minutes), and in each case, with the addition of 3%w/v of brine solution to the samples [37] (As shown in Figures 6, 7, 8, and 9).

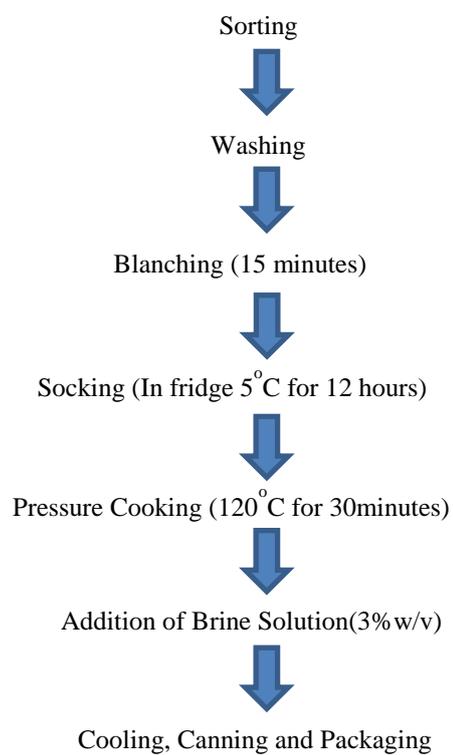


Figure 6. Flow diagram of Canned Bambara beans



Figure 7. Empty cans for packaging the varieties of Bambara beans



Figure 8. Varieties of canned Bambara beans after packaging



Figure 9. Served finished product with “kakuro”

2.3. Microbiological Analysis of the Canned Bambara Beans

2.3.1. Sample preparation

Ten grams of the samples were measured and homogenised in a sterile stomacher bag for one minute using a stomacher blender (Steward Stomacher blender 400 circulator)

in 90 0.1 % peptone water to suspend the microorganisms. The stock preparation was serially diluted from 10^{-1} to 10^{-9} and the appropriate Dilution was used.

2.3.2. Media preparation

All microbiological media used Plate count agar for total bacteria count, Simmons Citrate agar for *Clostridium botulinum*, and Violet Red Bile Glucose Agar for Enterobacteriaceae (*E. coli*) were prepared following the instructions specified by the manufacturer. The media were sterilised in an autoclave for 15 min at 121 °C and tempered at 50°C. The plates were checked for sterility by incubating uninoculated agar plates to check for growth. Peptone water (0.1%) used as a diluent was also prepared following the manufacturer's instructions and incubated at 121 °C for 15 min.

2.4. Determination of Total Viable Count

The Colony Count technique was used to inoculate the microorganisms. An inoculum volume of 1ml from each 1:10 Dilution series was pipetted to their respective labelled Petri dishes of Plate Count Agar (Vm72974462 7023). The glass spreader (hockey stick) was sterilised using ethanol and spread over a Bunsen burner. The solution was spread evenly over the agar plate using the hockey stick while carefully rotating the Petri dishes underneath an angle of 450°. The Petri dish, now containing the agar and evenly distributed sample solution, was incubated at 37°C for 24 hours. The colonies of microbes that appeared were enumerated and recorded.

2.5. Determination of *Clostridium botulinum*

The *Clostridium botulinum* was carried out by spreading the plate method on the *botulinum* Agar Base (Cm0587). 1:10 Dilution was prepared by diluting 10 g of the sample into 90 ml of sterilized peptone water for the stock dilution. One millilitre aliquot from each of the dilutions was inoculated into Petri dishes with already prepared PAB Agar (Cm587). The inoculum was evenly spread with a sterile bent rod and allowed to dry for 15 minutes at room temperature. The *Clostridium botulinum* plates were incubated in an anaerobic jar at 37°C for 24 hours. The plates were examined, and the colonies were counted using the colony counter after the incubation period (ISO 7937:2004). The method used was a modification [38].

2.6. Determination of Enterobacteriaceae (*E. coli*)

The *E. coli* was carried out by spread plate method on Violet Red Bile Glucose Agar 1:10. Dilution was prepared by diluting 10 g of sample into 90 ml of sterilized peptone water for the stock dilution. One millilitre aliquot from each Dilutions were inoculated into Petri dishes with already prepared VRBG agar. The inoculum was evenly spread with a sterile bent rod and allowed to dry for 15 minutes at room temperature. The *E. coli* plates were incubated in an anaerobic jar at 37°C for 24 hours. The plates were examined, and the colonies were counted using the colony counter after incubation. The method used was a modification [38].

2.7. Sensory Evaluation

The composite Bambara bean samples were presented to thirty (50) panellists from the University for Development Studies who were familiar with and not familiar with Bambara bean consumption. The panel comprised both males and females who were adults. The attributes assessed were aroma, taste, texture, colour, and overall acceptability. Measures for recruiting included ensuring that panellists were frequent and non-frequent Bambara bean consumers. The panellists were served the beans with "kakro" in disposable plates that were randomly generated with three-digit codes. Panelists were asked to evaluate the samples based on the aroma, taste, texture, flavour, colour, and overall acceptability using a 5-point hedonic scale: 1-Dislike very much, 5-Like very much.

2.8. Data Analysis

Statistical Package for Social Sciences (SPSS) version 20.0 and Mini-tab software version 20 were used to perform a one-way Analysis of Variance (ANOVA) on all data received from various experiments. Means were separated using the least significant difference (LSD). Differences in means were regarded as significant at $p < 0.05$. The result obtained from the study was represented using tables.

3. Results and discussion

3.1. Microbiological Quality of canned processed Bambara bean varieties

Table 2 shows the microbiological quality of the Bambara beans variant concerning total bacteria count, *E. coli* and *Clostridium botulinum*. The TPC result, however, shows no significant difference ($p > 0.05$) between the Bambara beans varieties with S3 (Cream with black eye Bambara beans) with the highest count of 3.22 cfu/g with S5 (Cream pink eye Bambara beans) with the minor count, The values obtain however, is within the acceptable range (8 log cfu/g) [39]. Total plate count assay indicates the presence of some aerobic microorganisms in the samples, with all exhibiting significant microbial populations, though few. The absence of *E. coli* and *C. botulinum* suggests that all the canned Bambara bean varieties are safe for consumption. The results obtained conform with ISO, which states that canned bean product, concerning Total bacteria count, should be 10 cfu/g (ISO 4833-1), absent for both *E. coli* (ISO 7251) and *C. botulinum* (ISO 4833-1) respectively.

Table 2. Microbiological Quality of Canned Bambara bean varieties

Sample/Parameter	Total Bacteria Count	<i>E. coli</i>	<i>Clostridium botulinum</i>
S1	1.87±0.06 ^C	N. D	N. D
S2	1.88±0.01 ^C	N. D	N. D
S3	2.08±0.06 ^B	N. D	N. D
S4	3.22±0.06 ^A	N. D	N. D
S5	1.69±0.012 ^D	N. D	N. D

Key: Values are mean Log CFU /ML ± SD. N. D-Not detected. In Each column, means that do not share a superscript are significantly different at $p < 0.05$. S1=Red Bambara beans; S2= Clean white eye Bambara beans; S3= Cream black eye Bambara beans; S4=Black Bambara beans; S5= Cream pink eye Bambara beans

3.2. Sensory Acceptability of canned processed Bambara bean varieties

Table 3 displays the average sensory rating for the taste of the various Bambara bean samples. Taste is influenced by fragrance intensity at a healthy level [40, 41]. The result for taste ranges from 2.84 to 3.75 (S1 to S4), which means that the acceptance rate concerning taste could have been more encouraging. All samples showed a significant difference ($p > 0.05$) from each other except S4, with a mean value of 2.84. The Bambara bean variety colour is an essential sensory attribute that could improve appeal. From the results, colour ranged from 3.25 to 4.19. The control bean sample (S5) recorded the highest value, whereas the Black bean variety recorded the lowest value respectively, with a significant difference ($p < 0.05$) from each other.

Texture refers to the surface characteristics and appearance of an object based on its size, shape, and density. It is those properties of a food that are sensed by touch in the mouth and with the hands (Alemu 2023). The texture of food materials plays a crucial role in consumer acceptance and market value. The samples analyzed show a significant ($p < 0.05$) difference in texture. The score for texture ranged from 3.21 to 4.03 for S4 and S5, respectively.

Food aroma is a crucial aspect since it stimulates the taste receptors and gets the body ready to receive the product. Food that smells bad may be rejected entirely before it is ever

tasted. Based on the sensory evaluation of the five products under investigation, the statistical analysis revealed that their respective colour had a significant impact ($p < 0.05$) on consumer preferences. The result for aroma ranges from 3.25 to 3.84. All samples showed a significant difference ($p < 0.05$) from each other except sample treatment one and sample treatment 5, which show no significant difference.

Flavour is also a sensory quality factor that is mainly considered during sensory evaluation. The results from these results show a significant ($p < 0.05$) difference between the various sample treatments ranging from 3.09 to 3.84, with S5 with the highest mean score and S1 with the lowest mean score value. The descriptive statistics were assessed to assess the panellists' overall satisfaction with all the products.

The overall acceptability of the samples ranged from 3.41 to 4.31. The maximum score value of overall acceptability from the five-point hedonic scale was 4.31, recorded by S5 (Cream pink eye Bambara beans), while the minimum score value was 3.41 concerning S1 (Red Bambara bean). Significant disparities in the general acceptability of all the items were observed. The overall acceptability of samples was significantly different ($p < 0.05$). In general, all the samples were generally acceptable except sample treatment one and sample treatment 4, thus the red and black variety of the Bambara beans, respectively. The results are in line with findings from Atoyebi *et al.* (2017), who researched the Sensory Evaluation of Bambara Groundnut (*Vigna subterranean* (L.) Verdc.) Food Products.

Table 3. Sensory Analysis of the composite of Canned Bambara beans varieties

Sample/Parameters	Mean± SD				
	S1	S2	S3	S4	S5
Colour	3.44±1.05 ^A	3.84±0.67 ^B	3.88±0.70 ^B	3.25±1.16 ^{AB}	4.19±0.89 ^C
Taste	3.28±1.37 ^A	3.31±1.12 ^A	3.69±0.82 ^A	2.84±1.05 ^C	3.75±1.19 ^A
Flavour	3.09±1.22 ^A	3.53±1.05 ^B	3.63±0.91 ^B	3.19±1.06 ^A	3.84±1.08 ^C
Aroma	3.25±1.11 ^A	3.84±0.72 ^B	3.53±0.88 ^C	3.31±1.03 ^A	3.59±1.10 ^C
Texture	3.43±1.29 ^A	3.69±1.18 ^B	3.72±0.89 ^B	3.21±1.07 ^D	4.03±0.97 ^C
Overall Acceptability	3.53±1.22 ^A	4.06±0.72 ^B	4.00±0.84 ^B	3.41±1.04 ^A	4.31±1.06 ^C

***In each column, means that do not share a superscript are significantly different at $p < 0.05$; S1=Red Bambara beans; S2= Clean white eye Bambara beans; S3= Cream black eye Bambara beans; S4=Black Bambara beans; S5= Cream pink eye Bambara beans; Scale: 5-point.

The moisture content increased in the canned products compared to the raw products. A slight increase in the protein contents in both varieties observed after canning compared to those of the raw samples may be attributed to the loss of soluble solids during processing, which increased their concentrations in cooked beans. The processed samples also had significantly reduced fat for the canned Bambara bean varieties. The study also revealed an increase in the fibre content of the canned Bambara bean varieties compared to the raw varieties; there was also a decrease in the mineral (ash) content of the canned product compared to the raw Bambara bean varieties. The raw and processed beans displayed high energy levels due to their high protein and carbohydrate contents.

The Total Plate count result, however, shows no significant difference between the Bambara bean varieties. The values obtained, however, are within the acceptable range of the Total plate count assay. The absence of *E. coli* and *C. botulinum* indicates that all the canned Bambara bean varieties are safe for consumption. The results obtained conform with ISO, which states that canned bean product, concerning Total bacteria count, should be 10cfu/g (ISO 4833-1), absent for both *E. coli* (ISO 7251) and *C. botulinum* (ISO 4833-1) respectively. The overall acceptability of samples was significantly different. In general, all the samples were generally acceptable except the red and black varieties of the Bambara beans, respectively, which recorded lower acceptability scores.

In the context of the Theory of Planned Behaviour (TPB), the findings of the study on canned Bambara beans in Ghana revealed that “consumers exhibited a positive attitude towards canned Bambara beans, particularly in terms of convenience, nutritional value, and sensory acceptability. Participants perceived canned Bambara beans as a convenient and nutritious food option, aligning with their positive attitudes towards incorporating this legume into their diets”. The subjective norms component of the TPB considers the influence of perceived social pressure on individuals' behaviour. In the study, participants' acceptance of canned Bambara beans may have been influenced by social factors such as family preferences, cultural norms, and recommendations from peers or health professionals. Positive feedback from social circles and perceived social approval likely contributed to consumers' favourable reception of canned Bambara beans. The study also indicated that participants' perceived control over consuming canned Bambara beans may have been influenced by factors such as accessibility, affordability, and ease of preparation. The findings indicated that the sensory acceptability and nutritional quality of canned Bambara beans positively influenced participants' perceived control over including this legume in their diets. Applying the Theory of Planned Behaviour to the study findings, it becomes evident that consumers' attitudes, subjective norms, and perceived behavioural control play crucial roles in shaping their acceptance and intention to consume canned Bambara beans. Understanding these factors can inform targeted interventions and promotional strategies to encourage the adoption of canned Bambara beans as a nutritious and convenient food option, thereby promoting food security and improved nutrition in Ghana.

4. Conclusions

The sensory evaluation indicated that factors such as taste, colour, texture, and aroma significantly influenced consumers' acceptance of canned Bambara beans. Varieties with favourable sensory attributes, such as appealing colour and texture, were preferred among participants, emphasizing the importance of sensory characteristics in consumer choices. It is also revealed that the nutritional analysis of canned Bambara beans showcased their potential as a nutritious food source, rich in essential nutrients and bioactive compounds. Participants recognized the dietary benefits of canned Bambara beans, indicating a positive perception of their health-promoting properties. The study also concluded that Women, particularly homemakers, play a significant role in the production, utilization, and promotion of Bambara beans in Ghana. Understanding the preferences and perceptions of women consumers is crucial for promoting the consumption of canned Bambara beans and enhancing food security in the region.

5. Recommendations

It is recommended that Increase awareness among consumers, especially women and homemakers, about the nutritional benefits and culinary versatility of canned Bambara beans. Educational campaigns highlighting the health advantages and convenience of canned Bambara beans can encourage their inclusion in household diets. It is also recommended that opportunities for product diversification and innovation in canned Bambara beans to cater to diverse consumer preferences. Developing new flavours, textures, and packaging formats can enhance the appeal of canned Bambara beans and attract a broader consumer base. The study recommends expanding the market reach of canned Bambara beans through strategic partnerships with retailers, supermarkets, and food outlets, which will increase the availability and accessibility of canned Bambara beans in urban and rural areas and can boost consumer adoption and contribute to food security initiatives. It is also recommended that women involved in the production and processing of Bambara beans should be supported and empowered through training,

capacity building, and access to resources. Recognizing the pivotal role of women in the Bambara bean value chain is essential for sustainable production practices and economic empowerment.

Author Contributions: Conceptualization GSB, DDA, GSA, EEM and ETM; methodology GSB, DDA, GSA, EEM and ETM; formal analysis; investigation GSB, DDA, GSA, EEM and ETM; Resources GSB, DDA, GSA, EEM and ETM; data curation GSB, DDA, GSA, EEM and ETM; writing-original draft preparation GSB, DDA, GSA, EEM and ETM; writing-review and editing GSB, DDA, GSA, EEM and ETM; visualization GSB, DDA, GSA, EEM and ETM; Supervision GSB, DDA, GSA, EEM and ETM; project administration GSB, DDA, GSA, EEM and ETM; Authors have read and agreed to the published version of the manuscript.

Funding: "This research received no external funding."

Data Availability Statement: Data is available on request from the corresponding author.

Acknowledgements: We acknowledge respondents for their time with us.

Conflicts of Interest: "The authors have declared no conflict of interest." "No funders had any role in the study's design; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results".

References

- [1] Oyeleke, G. O., Odedeji, J. O., Ishola, A. D., & Afolabi, O. (2014). Phytochemical screening and nutritional evaluation of African oil bean (*Pentaclethra macrophylla*) seeds. *J. Environ. Sci. Toxicol. Food Technol*, 8(2), 14-17.
- [2] Majola, N. G., Gerrano, A. S., Amelework, A., Shimelis, H., & Swanevelder, D. (2022). Genetic diversity and population structure analyses of South African Bambara groundnut (*Vigna subterranea* [L.] Verdc.) collections using SNP markers. *South African Journal of Botany*, 150, 1061-1068.
- [3] Mazahib, A. M., Nuha, M. O., Salawa, I. S., & Babiker, E. E. (2013). Some nutritional attributes of Bambara groundnut are influenced by domestic processing. *International Food Research Journal*, 20(3), 1165.
- [4] Oyugi, A. M., Kibet, J. K., & Adongo, J. O. (2021). A review of the health implications of heavy metals and pesticide residues on khat users. *Bulletin of the National Research Centre*, 45, 1-22.
- [5] Saadaoui, E., Martín, J. J., Tlili, N., & Cervantes, E. (2017). Castor bean (*Ricinus communis* L.) Diversity, seed oil and uses. *Oilseed Crops: Yield and Adaptations under Environmental Stress*, 19-33.
- [6] FAO. (2019). World Food and Agriculture—Statistical Pocketbook; FAO: Rome, Italy.
- [7] FAO. (2020). The State of Food Security (2020). and Nutrition in the World; Rome, Italy.
- [8] FAO. (2018). The Future of Food and Agriculture—Alternative Pathways to Rome. 2018. Available online: <http://www.fao.org/3/I8429EN/i8429en.pdf>
- [9] Godfray, H. C. J., Blacquiere, T., Field, L. M., Hails, R. S., Petrokofsky, G., Potts, S. G., ... & McLean, A. R. (2014). A restatement of the natural science evidence base concerning neonicotinoid insecticides and pollinators—proceedings of the Royal Society B: Biological Sciences, 281(1786), 20140558.
- [10] Khan, F., Chai, H. H., Ajmera, I., Hodgman, C., Mayes, S., & Lu, C. (2017). Transcriptomic comparison of two Bambara groundnut landraces under dehydration stress. *Genes*, 8(4), 121.
- [11] Halimi, R. A., Barkla, B. J., Mayes, S., & King, G. J. (2019). The potential of the underutilized pulse bambara groundnut (*Vigna subterranea* (L.) Verdc.) for nutritional food security. *Journal of Food Composition and Analysis*, 77, 47-59.
- [12] Gulzar, M., & Minnaar, A. (2017). Underutilized protein resources from African legumes. In *Sustainable protein sources* (pp. 197-208). Academic Press.
- [13] Ani, A. O., & Okorie, A. U. (2013). Effects of processed castor oil bean (*Ricinus communis* L) meal and supplementary dl-methionine on nutrient utilization by broiler chicks.
- [14] Brough, S. H., Azam-Ali, S. N., & Taylor, A. J. (1993). The potential of Bambara groundnut (*Vigna subterranean*) in vegetable milk production and basic protein functionality systems. *Food Chemistry*, 47(3), 277-283.
- [15] Sreerama, Y. N., Sashikala, V. B., & Pratapa, V. M. (2009). Effect of enzyme pre-dehulling treatments on dehulling and cooking properties of legumes. *Journal of Food Engineering*, 92(4), 389-395.
- [16] Enwere, N. J., & Hung, Y. C. (1996). Some chemical and physical properties of Bambara groundnut (*Voandzeia subterranean* Thouars) seed and products. *International journal of food sciences and nutrition*, 47(6), 469-475. [16] Aloba (1999)
- [17] Boateng, J., Verghese, M., Walker, L. T., & Ogutu, S. (2008). Effect of processing on antioxidant contents in selected dry beans (*Phaseolus* spp. L.). *LWT-Food Science and Technology*, 41(9), 1541-1547.
- [18] Yusuf, A. A., Ayedun, H., & Sanni, L. O. (2008). Chemical composition and functional properties of raw and roasted Nigerian benniseed (*Sesamum indicum*) and Bambara groundnut (*Vigna subterranean*). *Food Chemistry*, 111(2), 277-282.
- [19] Abiodun, A. O., & Adepeju, A. B. (2011). Effect of processing on the chemical, pasting and anti-nutritional composition of Bambara nut (*Vigna subterranean* L. Verdc) flour. *Advance Journal of Food Science and Technology*, 3(4), 224-227.

- [20] Pisoschi, A. M., Pop, A., Iordache, F., Stanca, L., Predoi, G., & Serban, A. I. (2021). Oxidative stress mitigation by antioxidants—an overview of their chemistry and influences on health status. *European Journal of Medicinal Chemistry*, 209, 112891.
- [21] Little, C., Cruz-Martínez, V., St. Fort, D. P., Pagán-Medina, C., Page, C. A., Perez-Perez, Y., ... & Pérez-Díaz, I. M. (2022). Vegetable fermentations brined with low salt for reclaiming food waste. *Journal of Food Science*, 87(5), 2121-2132.
- [22] Murevanhema, Y. Y., & Jideani, V. A. (2013). The potential of Bambara groundnut (*Vigna subterranean* (L.) Verdc) milk as a probiotic beverage—a review. *Critical reviews in food science and nutrition*, 53(9), 954-967.
- [23] Bennink, M. R., & Barrett, K. G. (2004). Total phenolic content in canned beans. *Red*, 23(92), 124.
- [24] Aykroyd, W. R., Doughty, J., & Walker, A. F. (1982). *Legumes in human nutrition* (Vol. 20). Food & Agriculture Org.
- [25] Brough, S. H., & Azam-Ali, S. N. (1992). The effect of soil moisture on the proximate composition of Bambara groundnut (*Vigna subterranea* (L.) Verdc). *Journal of the Science of Food and Agriculture*, 60(2), 197-203.
- [26] Boateng, J., Verghese, M., Walker, L. T., & Ogotu, S. (2008). Effect of processing on antioxidant contents in selected dry beans (*Phaseolus* spp. L.). *LWT-Food Science and Technology*, 41(9), 1541-1547.
- [27] Ademola, O. A., & Abioye, O. R. (2017). Proximate composition, mineral content and mineral safety index of Lablab purpureus seed flour. *Int J Sci Health Res*, 2(4), 44-50.
- [28] Kayitesi, E., Duodu, K. G., Minnaar, A., & de Kock, H. L. (2013). Effect of micronization of pre-conditioned cowpeas on cooking time and sensory properties of cooked cowpeas. *Journal of the Science of Food and Agriculture*, 93(4), 838-845.
- [29] Poulter, N. H. (1981). Properties of some protein fractions from bambara groundnut [*Voandzeia subterranea* (L.) Thouars]. *Journal of the Science of Food and Agriculture*, 32(1), 44-50.
- [30] Yagoub, A. A., & Abdalla, A. A. (2007). Effect of domestic processing methods on chemical composition, in vitro protein and starch digestibility, and functional properties of Bambara groundnut (*Voandzeia subterranean*) seed. *Research Journal of Agriculture and Biological Sciences*, 3(1), 24-34.
- [31] de León, _, Elias, L. G., & Bressani, R. (1992). Effect of salt solutions on common beans' cooking time, nutritional and sensory characteristics (*Phaseolus vulgaris*). *Food Research International*, 25(2), 131-136.
- [32] Adeleke, O. R., Adiamo, O. Q., Fawale, O. S., & Olamiti, G. (2017). Effect of processing methods on antinutrients and oligosaccharides contents and protein digestibility of the flours of two newly developed Bambara groundnut cultivars. *International Food Research Journal*, 24(5).
- [33] Friedman, M. (1999). Chemistry, biochemistry, nutrition, and microbiology of lysinoalanine, lanthionine, and histidinoalanine in food and other proteins. *Journal of Agricultural and Food Chemistry*, 47(4), 1295-1319.
- [34] Uzogara, S. G., Morton, I. D., & Daniel, J. W. (1988). Quality changes and mineral content of cowpea (*Vigna unguiculata* L. Walp) seeds processed with 'kanwa' alkaline salt. *Food Chemistry*, 30(1), 1-18.
- [35] Madodé, Y. E., Nout, M. J., Bakker, E. J., Linnemann, A. R., Hounhouigan, D. J., & van Boekel, M. A. (2013). Enhancing the digestibility of cowpea (*Vigna unguiculata*) by traditional processing and fermentation. *LWT-Food science and technology*, 54(1), 186-193. al
- [36] Minka, S. R., Mbofung, C. M., Gandon, C., & Bruneteau, M. (1999). The effect of cooking with kanwa alkaline salt on the chemical composition of black beans (*Phaseolus vulgaris*). *Food Chemistry*, 64(2), 145-148.
- [37] Suyono, S., Sanjaya, M. F., & Ardiana, A. (2023). The Effect of Various Types of Fertilizers on the Growth and Yield of Long Bean Plants (*Vigna Sinensis* L.). *Journal of Agriculture*, 2(02), 224-230.
- [38] Morello, L. G., Sartori, D., de Oliveira Martinez, A. L., Vieira, M. L. C., Taniwaki, M. H., & Fungaro, M. H. P. (2007). Detection and quantification of *Aspergillus westerdijkiae* in coffee beans based on selective amplification of β -tubulin gene by using real-time PCR. *International Journal of Food Microbiology*, 119(3), 270-276.
- [39] Amankwaah, D., Asante Nnuro, W., Awudza, J., & Afful, S. (2015). Determination of heavy metals in cocoa beans from some significant cocoa growing regions in Ghana. *Annals: Food Science & Technology*, 16(1).
- [40] Iwe, M. O., Onyeukwu, U., & Agiriga, A. N. (2016). Proximate, functional and pasting properties of FARO 44 rice, African yam bean and brown cowpea seeds composite flour. *Cogent Food & Agriculture*, 2(1), 1142409.
- [41] Beebe, S., Ramirez, J., Jarvis, A., Rao, I. M., Mosquera, G., Bueno, J. M., & Blair, M. W. (2011). Genetic improvement of common beans and the challenges of climate change. *Crop adaptation to climate change*, 356-369.