**Nutrient Content and Organoleptic Qualities of “*Brukina*” Prepared with Corn Agglomerates and “*Brukina*” Prepared with Millet Agglomerates**

**ABSTRACT**

**Background:** Brukina is a traditional fermented milk beverage in Ghana that is frequently drunk for its flavour and alleged nutritional advantages. There is, however, little scientific research comparing the nutritional value of various cereal preparations. Fermented milk with millet agglomerates, locally referred to as “Brukina” or “Burkina,” is a minimally processed beverage often consumed by most Ghanaians as a snack. It has a high nutritional value, consisting of proteins, essential vitamins, dietary fibre, carbohydrates, fats, and minerals.

**Aim:** Fermented milk with cereal agglomerates locally known as ‘*Brukina*’ is a widely consumed beverage in Ghana. This study aimed to develop, evaluate and compare the nutrient content and organoleptic qualities of ‘*Brukina*’ made with millet agglomerates and that made from corn agglomerates.

**Methodology:** Proximate analysis was determined using standard AOAC methods, whereas mineral nutrient content was determined using Flame Atomic Absorption Spectroscopy (FAAS). The fatty acid content was determined using Gas Chromatography-Mass Spectrometry (GC-MS), while the pH was measured using a pH meter. A consumer sensory test was performed using a 9-point hedonic scale to assess consumer likability. The products were relatively rich in carbohydrates (38.34% - 57.79%) but recorded relatively low ash content (0.53% - 0.88%) and low protein content (2.06% - 3.46%). Moisture content ranged between 23.42% and 34.55%. ‘*Brukina*’ from corn (BPC) recorded the highest crude fat content of 14.14%, while the lowest crude fat content was recorded by ‘*Brukina*’ from millet (BPM) (3.39%).

**Results:** The crude fibre results also ranged between 5.06% and 11.19%, with Street-Sold ‘*Brukina*’ (SSB) recording the highest and BPC recording the lowest. Concentrations of magnesium (19.94 - 23.12 mg/100g) and potassium (15.02 - 16.5 mg/100g) were higher compared to iron and calcium concentrations of 0.56 - 6.42 mg/100g and 1.64 - 2.00 mg/100g, respectively. The concentration of sodium ranged from 7.23 to 7.55 mg/100g. The samples had pH values ranging from 3.6 to 4.47. BPC was found to be more acidic compared to SSB and BPM. All the ‘*Brukina’* samples contained both saturated and unsaturated fatty acids.

**Conclusion**: The consumer acceptability test, using a 9-point hedonic scale, recorded values between 7.06 and 8.16. The results from this study showed that ‘*Brukina*’ made with corn agglomerates also had high acceptability and could be exploited for income generation. Results from the study revealed that the “Brukina” samples were rich in nutrients and can offer consumers a significant supply of energy.

***Keywords:*** *“Brukina”,* organoleptic qualities, proximate analysis, mineral nutrients, agglomerates

**1. INTRODUCTION**

Food fermentation, as a processing technique, involves transforming raw food ingredients into various value-added products through the processes of microbial growth and their activities on different substrates (Akabanda, 2025). Fermented milk with millet agglomerates, locally referred to as “Brukina” or “Burkina,” is a minimally processed beverage often consumed by most Ghanaians as a snack. It is believed to have originated from Burkina Faso, where it is known as "Dègèr" (Appiah, 2013). According to Ghana News Agency (2013), most cities within Ghana, including Accra, “Brukina” is sold on the streets and in some supermarkets, convenience shops and serves as a source of livelihood to a good proportion of Ghanaian women. “Burkina” is a nutritious product rich in protein, carbohydrates, minerals and essential vitamins, and some studies have confirmed the probiotic nature of ‘‘Burkina’’ owing to the fermentation process. The main ingredients for the preparation of “Burkina” are fresh or powdered cow milk or a combination of both, cereals, sugar and sometimes salt for taste (Saeed, 2023; Baidoo et al., 2023). Its production and sale have become a fast-growing business, and it is amongst the leading local drinks sold on the streets of Ghana, with intense competition among vendors (Tawiah, 2015). A large number of *“Burkina”* beverages are sold on the streets of most regions in Ghana, with few individuals producing their own homemade “Burkina” to eat at gatherings or take home as snacks, starters, or refreshing beverages (Saeed, 2023).

It has a high nutritional value, consisting of proteins, essential vitamins, dietary fibre, carbohydrates, fats, and minerals (Caiquo & Mensah, 2013). Milk is one of the primary food components used in its production and significantly contributes to its nutritive value (Nyarko-Mensah, 2018). The concentration of these nutrients varies among species of animals that produce milk, with the major ones being lipids (2%–55%), proteins (1%–20%), and lactose (0%–10%) (FitzGerald & Meisel, 2003).

According to Durojaiye, Usman, and Chukwu (2016), Cereal grains are described as essential dietary components that provide substantial amounts of nutrients, including vitamins, dietary fibre, minerals, protein, and complex carbohydrates, for human and animal consumption, particularly in developing countries. They serve as an essential dietary component due to their long shelf life and affordability. Millet, a significant component of “Brukina,” is comparable to most cereals in terms of their nutritional characteristics (Tawiah, 2015). Cereals are good sources of carbohydrates, micronutrients and phytochemicals and possess nutraceutical properties. Millet is the only grain used in the production of “*Brukina*” in Ghana, leading to overexploitation of millet and a limitation in varieties of “Brukina” (Tawiah, 2015).

Corn grain is a multipurpose crop, providing food and fuel for humans, as well as feed for animals, poultry, and livestock. Its grains have very high nutritional value and are used as raw materials for manufacturing many industrial products (Afzal, Nazir, Bashir, & Khan, 2009). Its grains are important for the production of oil, starch and glucose (Niaz & Dawar, 2009). The use of corn agglomerates in the production of "*Brukina*" may enhance nutritional value and health benefits, while also providing variety for customers to choose from. However, no research or anecdotal reports have documented or reported on the probable use of corn as an alternative in the production of this local beverage. Perhaps, researchers have not considered the nutritional value of corn agglomerates as a substitute for millet in "*Brukina*" production. Corn, as a cereal, is more prone to insect infestation during storage compared to millet; thus, its use as an alternative for the production of this beverage has positive agroeconomic implications. Corn is a popular cereal due to its excellent nutritional value and abundance of micronutrients, including the vitamin B complex, ß-carotene, and essential minerals such as magnesium, zinc, phosphorus, and copper (Bathla, Jaidka, & Kaur, 2019). Bathla et al. (2019) posit that Corn products are utilised in supplemental nutritional programmes to feed undernourished children and enhance their health. Additionally, corn is filled with B-complex vitamins, which are essential for development, healthy skin, hair, nails, brain function, heart health, digestion, and resistance to dementia. It has been observed that coeliac disease patients' health can be improved by including corn products in their daily diet (Kataria, 2014). Considering the potential health benefits of corn, the objective of this study was to develop “*Brukina*” using corn agglomerates and compare it with *‘’Brukina’’* made from millet agglomerates in terms of their proximate nutrients, mineral nutrients concentrations, fatty acid profile, pH and sensory attributes. These two products were also compared to Street-Sold *‘’Brukina’’* to determine the differences and similarities among the three different products.

**2. MATERIALS AND METHODS**

**2.1 Materials**

The ingredients used for the preparation of the *‘’Brukina’’* with corn were milk powder, starter culture (*Lactobacillus bulgaricus and Streptococcus thermophilus*), yellow corn grains, corn flour, millet flour, condensed milk, brown sugar, salt, lemon, vanilla essence and strawberry flavour. All the ingredients were purchased from a local market in Winneba, Ghana. The control sample (SSB), which is readily available, was also purchased from the same market. Distilled water was used throughout the production of the *‘’Brukina’’* with corn.

**2.2 Preparation of fermented milk (yoghurt)**

Yoghurt was prepared using protocols described (Saeed, 2023) with modifications. Table 1 shows the quantities of ingredients used in the preparation of yoghurt (fermented milk).

**Table 1. Formulation of Fermented milk (yoghurt)**

|  |  |  |
| --- | --- | --- |
| Ingredients | Quantity |  |
| Milk powder | 140 g |  |
| Inoculated milk | 100 g |  |
| Water | 4 cups |  |

One hundred and forty grams (140 g) of the purchased milk powder (Nestlé Nido) was reconstituted with 4 cups of purified water and pasteurised (72 °C for 15 s). The temperature of the milk was reduced to 45°C by taking it off the fire and covering it with a sterilised lid. The temperature was monitored using a thermometer (milk frothing thermometer). One hundred grams (100 g) of previously fermented milk (starter culture) was added to the pasteurised milk, stirred gently with a cleaned and sterilised stainless-steel whisk and poured into a sterilised flask. It was allowed to undergo fermentation for 5 h in a hygienic environment. After 5 h, the fermented product was homogenised with a sterilised whisk to obtain a fine consistency, which was subsequently bottled and refrigerated.

**2.3 Preparation of ‘*Brukina*’ with corn agglomerates and ‘*Brukina’* with millet agglomerates**

The BPC and BPM followed protocols as described (Baidoo & Parry-Hanson, 2018) with modifications. Table 2 shows quantities of ingredients used in the preparation of millet agglomerate ‘*Brukina*’ and corn agglomerate “*Brukina*.”

**Table 2. Formulation of *“Brukina*” produced with Millet and *“Brukina*” produced with Corn**

|  |  |  |  |
| --- | --- | --- | --- |
| *“Brukina*” is produced with millet (BPM)  Ingredients Quantity | | “*Brukina*” is produced with corn (BPC)  Ingredients Quantity | |
| Millet flour | 100g | Yellow corn flour | 100g |
| Salt solution | 3g of salt in 3 tablespoons of water | Corn flour | 1 tablespoon |
| Sugar | 20g | Salt solution | 16g of salt to 1 cup of water |
| Fresh yoghurt | 1cup + 2 tablespoons | Sugar | 20g |
| Condensed milk | 3 tablespoons | Fresh yoghurt | 1cup + 2 tablespoons |
| Vanilla flavor | ¼ teaspoon | Condensed milk | 3 tablespoons |
| Strawberry flavor | ¼ teaspoon | Vanilla flavor | ¼ teaspoon |
|  |  | Strawberry flavour | ¼ teaspoon |
|  |  | Lemon zest | 1 teaspoon |

Millet grains were sorted to remove stones and other unwanted materials; it was washed several times under running water and soaked in warm water for 8 h in a covered, sterilised container. After 8 h, the water was drained from the millet through a cleaned stainless-steel sieve, air dried, and the millet milled twice for 7 min, using a cleaned and sanitised disc attrition mill to achieve the desired texture. The milled millet was collected into a different sterilised container with a lid. Hundred grams (100 g) of milled millet was used for the sample preparation. The milled millet was added to a prepared brine solution and rolled into granules. The granulated millet was placed into a clean perforated metallic bowl containing a cleaned food net and covered with a tight-fitting metallic lid. It was then steamed for 15 minutes. The steamed millet was transferred into a clean bowl, covered with a cleaned food net and cooled for 30 minutes. The fermented milk, condensed milk, vanilla flavour, strawberry flavour and sugar were added and stirred to get a uniform mixture. It was bottled, labelled BPM (“*Brukina*” prepared with millet) and kept in ice for nutrients and sensory analyses.

Dent corn (yellow type) grains were sorted to remove stones and other unwanted materials. It was washed four times under running water. The corn was soaked in warm water for 2 h in a covered, sterilised container. The water was drained from the corn using a cleaned stainless-steel sieve and air dried for 4 h. It was milled 4 times for 15 min using a cleaned and sanitised disc attrition mill to achieve the desired texture. The milled corn was collected into a different sterilised container with a lid. Hundred grams (100 g) of milled corn was added to a prepared brine solution. One tablespoon of corn flour was added and rolled into agglomerates. The agglomerated corn was steamed for 15 min in a clean perforated metallic bowl containing a cleaned food net and covered with a tight-fitting metallic lid. The steamed corn was transferred into a clean bowl, covered with a clean food net and allowed to cool for 30 minutes. Fermented milk, condensed milk, vanilla flavour, strawberry flavour, lemon zest and sugar were added and stirred into a uniform mixture. It was bottled and labelled BPC (“*Brukina”* prepared with corn) and kept in ice for nutrients and sensory analyses.

**2.4 Proximate analysis**

Proximate nutrients (moisture, ash, crude protein, crude fat and crude fibre) were determined (AOAC, 2005). Moisture was determined by placing 5 g of the sample in a conventional oven (model number 9119-0305, Germany) for 24 h at a temperature of 105˚C. Crude protein was determined using the Kjeldahl method, and the nitrogen obtained was multiplied by 6.25. Ash content was determined by igniting 2 g of the samples in a muffle furnace at a temperature of 600˚C for 2 h. The Soxhlet method was employed in the crude fat determination. Crude fibre was analysed on 2 g fat-free samples saved after crude fat determination with the Soxhlet procedure. Carbohydrate content was calculated by difference.

**2.5 Mineral content determination**

Minerals (potassium, magnesium, sodium, calcium and iron) were determined using Flame Atomic Absorption Spectroscopy (FAAS) carried out on Analytikjena (model novAA400P atomic absorption spectrophotometer) using the single-beam optical mode. Hollow cathode lamps (HCL) for the respective elements were used as light sources for the analysis. An air (compressed air) and acetylene (N26 quality, Air Liquide, Ghana) were employed as the oxidant and the fuel gas, respectively, for the flame. Using a pneumatic nebuliser, a small volume of the sample was aspirated into a flame where the ions are reduced to elements and vaporised. The elements present in the sample then absorb light (generated from the HCL) at specific wavelengths (Ca-422.7nm, Fe-248.3nm, Mg-285.2nm, K-766.5nm, Na-589.0nm) in the visible or the ultraviolet spectrum.

**2.6 pH determination**

Determination of pH was done according to (Chinma, Abu, & Abubakar, 2010). The calibration status of the pH meter (Mettler Toledo AG pH meter) was checked before use. Standard buffer solutions of pH 4, 7 and 9 were used in the calibration. Thirty millilitres (30 mL) of each *“Brukina*” sample was measured into 50 mL beakers. The probe of the pH meter was dipped into the beaker containing the samples, and readings were recorded after a beep sound was heard. The probe was removed from the sample and rinsed thoroughly with distilled water and wiped dry. The pH meter was recalibrated after each reading to ensure precision in results.

**2.6 Fatty acids analysis**

Fatty acids were determined using GC-MS on a PerkinElmer GC Clarus 580 Gas Chromatograph interfaced to a Mass Spectrometer PerkinElmer (Clarus SQ 8 S) equipped with ZB-5HTMS (5% diphenyl/95% dimethyl polysiloxane) fused with a capillary column (30 × 0.25 μm ID × 0.25 μm DF). The oven temperature was programmed to 80˚C (isothermal for 2 min) with an increase of 15˚C/min to 150˚C, then 3˚C/min to 250˚C and holding time of 4 min at 250˚C. Oil was extracted from the sample using Soxhlet and methylated. One milligram (1 mg) of oil samples was pipetted into 15 ml Falcon tubes. One millilitre (1 mL) of 4% NaOH in methanol (NaOH-MeOH) was added to the oil samples and vortexed for 1 min. It was allowed to stand for 5 min. Hexane (1 mL) was also added to the samples after the addition of 1 mL distilled water. The resulting solution was transferred into a 1 mL Falcon tube and analysed for fatty acids.

For GC-MS detection, an electron ionisation system was operated in electron impact mode with an ionisation energy of 70 eV. Helium gas (99.999%) was used as a carrier gas at a constant flow rate of 1.6 mL, and an injection volume of 1 μL was employed. The injector temperature was maintained at 250°C, and the ion-source temperature was 220°C. Mass spectra were taken at 70 eV, with a scan interval of 0.5 s and fragments from 45 to 4500 Da. The solvent delay was 0 to 3 min, and the total GC/MS running time was 34.5 min. The mass detector used in this analysis was Turbo-Mass, and the software adopted to handle mass spectra and chromatograms was a Turbo-Mass version 6.1.0. Interpretation of mass-spectrum GC-MS was conducted using the database of the National Institute of Standards and Technology (NIST), having more than 62,000 patterns.

**2.7 Consumer Acceptance Test**

Consumer sensory test was done using a hundred (100) untrained panellists who indicated that they were consumers of “*Brukina.*” A preference test was used to determine the degree of likeness or dislike, after which overall acceptability of each product using a 9-point hedonic scale was also assessed. Rating of each developed “*Brukina”* was done based on the appearance, aroma, taste, aftertaste, mouth feel and texture. Panellists were served with 2 tbsp of the control (SSB), BPM and BPC in a covered transparent disposable container under normal lighting conditions. The “*Brukina*” samples were coded with codes (SSB, BPM and BPC) with instructions given to the panellists to cleanse their palate with a cucumber presented in white disposable plates before and after assessing each sample.

**2.8 Statistical analysis**

The data from this study were analysed using Statistical Package for Social Sciences (SPSS) version 23. One-way analysis of variance (ANOVA) was used to compare means of sample characteristics. Differences between means were considered significant at p ≤ 0.05.

**3. RESULTS AND DISCUSSION**

**3.1 Proximate nutrients**

Table 3 presents data on the proximate nutrient composition of the ‘‘*Brukina*’’ varieties. Results from the proximate analysis of the “*Brukina*” samples revealed ash contents ranging from 0.53 ± 0.04% to 0.88 ± 0.02%. BPC recorded the highest ash content. Corn contains critical minerals like magnesium, zinc, phosphorus, copper, iron, etc (Bathla et al., 2019). The result was close to that of Tawiah (2015), who recorded ash content to be 0.42 ± 0.05% to 0.47 ± 0.04%. Ash content is considered very essential as it gives a measure of the mineral elements that can be obtained from the food sample (Bhattacharjee, Sultana, Sazzad, Islam, Ahtashom, & Asaduzzaman, 2013). Analysis of the Proximate Composition and Energy Values of Two Varieties of On) [16]. Due to their nutritional and physiological functions, minerals are essential in food. Ash content is also used to evaluate adulterations in food products. A high amount of ash implies high mineral contents.Therefore, BPC, having the highest ash content, is an indication of its rich mineral content.

Moisture was highest in BPM recording 34.55 ± 0.46%. BPC recorded 31.85 ± 0.10% moisture content while SSB recorded 23.42 ± 0.15% moisture content. BPM had a significantly higher moisture content than BPC, whose moisture content was also significantly higher than that of SSB. The results indicate that SSB may store longer compared to the two 2 other samples. Moisture content in food is significant because microorganisms require a high amount of water to aid their growth and survival (Darko, 2016). Foods with a high amount of moisture content are mainly prone to microbial attack. Related works earlier conducted recorded higher moisture content in “*Brukina*” samples (Tawiah, 2015; Nyarko-Mensah, 2018). Food preservation is aided by controlling the moisture content in food products, as microorganisms require water for their activities. The characteristics of many food products can be negatively affected by deviations from the ideal moisture content, which can impact both the product's quality and safety (Moore, 2020). Moore further stated that the amount of moisture in a product affects its shelf life because more water makes a product more susceptible to bacterial proliferation. Because producers can accurately predict a product's shelf life by maintaining a predetermined level of moisture, consumers are protected from consuming spoiled food.

Protein content ranged from 2.06±0.36% to 3.46±0.10%. The highest protein content was recorded in BPC (3.46±0.10%), followed by BPM (2.67±0.51%), with SSB (2.06±0.36%) recording the lowest. A crude protein content in the range of 3.25% to 7.91% has been reported for “*Brukina*” (Tawiah, 2015; Nyarko-Mensah, 2018). The differences in protein contents could be attributed to the differences in the ingredients used in the samples. Corn offers 9–10% protein, which, when added to other meals, helps to boost their essential amino acid content (Adigbo & Madah, 2011). Proteins play a crucial role in tissue growth and repair, as well as the formation of genes that pass traits from one generation to the next. Given that the ingredients for the products are widely available on the Ghanaian market, the high protein content of BPC could be a good alternative source of protein and may help improve protein intake in Ghana, especially among children.

For crude fat, BPC recorded 14.14±1.36% crude fat content. SSB recorded 5.00±1.43% crude fat content. BPM recorded 3.39±0.90% crude fat content. The result is contrary to earlier findings within the range of 1.4% – 4.5% (Adigbo et al., 2011). Fat content ranging from 1.04% to 4.04% has been earlier reported for “*Brukina*” (Tawiah, 2015; Caiquo et al., 2013). As a nutrient, fat supplies energy and gives flavour to food (Moore, 2020). The fat content of the samples may be a useful indicator of their flavour and may influence the processing, packaging and storage of the ‘‘*Brukina’’* products (Chinedu & Nwinyi, 2012). Higher fat content can increase the energy content of food (Lohia & Udipi, 2015). However, excessive fat intake predisposes infants to childhood obesity and subsequently cardiovascular diseases (Dietz & Robinson, 2005). Fat from plant sources is less deleterious compared to fat from animal sources.

Results from the crude fibre analysis revealed that BPM had the highest fibre content of 20.23±0.86% followed by SSB (11.19±0.09%), and the least amount of fibre (5.06±0.25%) was found in BPC. Corn has a very high fibre content but in this study, a very low fibre content was recorded for the BPC sample. Even though the same quantity of ingredients was used, the differences in fibre could be attributed to the types of cereal used (corn for BPC and millet for BPM and SSB). BPM had a very high fibre content among the samples. Fibre taken in high amounts in the diet can decrease blood cholesterol, aid weight control and slow down glucose absorption from the intestines, which helps in diabetes management (Adigbo et al., 2011). Though crude fibre does not supply nutrients to the body, it adds bulk to food and thus facilitates bowel movements (peristalsis) and prevents a host of gastrointestinal diseases in humans (Gordon, 1999). Increasing the intake of dietary fibre increases stool bulk and decreases appetite (Abeshu, Lelisa, & Geleta, 2016). In the case of carbohydrate content, SSB recorded the highest (57.79±0.10%), followed by BPC (44.60±1.61%) and BPM (38.34±1.29%). Earlier works done to determine the quantities of carbohydrates in “*Brukina*” samples recorded values below the results obtained for SSB, BPM and BPC in this study (Tawaih, 2015; Nyarko-Mensah, 2018). Carbohydrate content of 12.27% has also been reported earlier (Ampofo-Asiama, Mamudu, Oluchi, Owusu, & Quaye, 2020). The main function of carbohydrates is to supply energy for the body, especially to the brain and red blood cells [19]. Carbohydrates contribute to the taste and flavour of products and help in the development of the characteristic colour of products (Grosso, Resurreccion, Walker, & Chinnan, 2008).

**Table 3: Proximate composition (%) of SSB, BPM and BPC**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Proximate Analysis | | | | | | |
| Samples | **Ash** | **Moisture** | **Crude Protein** | **Crude**  **fat** | **Crude**  **fibre** | **Carbohydrates** |
| SSB | 0.53±0.04b | 23.42±0.15c | 2.06±0.36b | 5.00±1.43b | 11.19±0.09b | 57.79±0.10a |
| BPM | 0.83±0.02a | 34.55±0.46a | 2.67±0.51ab | 3.39±0.90b | 20.23±0.86a | 38.34±1.29c |
| BPC | 0.88±0.02a | 31.85±0.10b | 3.46±0.10a | 14.14±1.36a | 5.06±0.25c | 44.60±1.61b |

*Values are means ± standard deviation of triplicate determinations. Means in the same column with different superscript letters are significantly different at p ≤ 0.05.*

**3.2 Minerals Determination**

Table 4 presents data on the mineral nutrient concentrations of the *‘‘Brukina’’* varieties. The minerals determined include calcium, iron, potassium, magnesium and sodium.  
BPC recorded the highest calcium content of 2.00±0.02 mg/100g. This was followed by BPM (1.64±0.02 mg/100g) and SSB (1.39±0.02 mg/100g). Calcium is known to be a good mineral element in the human body for the young, adults and the aged. Milk and dairy products are well-known sources of calcium. However, there are a variety of plant-based foods such as sesame, blackstrap molasses, almonds, beans and corn, providing as much calcium as milk (Pamplona-Roger, 2001).

Iron is a mineral vital for the proper function of haemoglobin, a protein needed to transport oxygen in the blood. A low level of haemoglobin in the blood can lead to a range of serious health problems, including iron deficiency anaemia (Ware, 2018). Table 4 shows that BPC recorded the highest iron content (6.42±0.07 mg/100g), followed by BPM (0.68±0.00 mg/100g), with the least being recorded by SSB (0.56±0.01 mg/100g). Samples differed significantly from each other (p ≤ 0.05) in iron content. Higher amount of iron content, which was found in BPC, may be attributed to the fact that corn generally is a good source of iron and may have contributed to the increase in iron content in BPC than in BPM and SSB. Iron as a mineral in food promotes healthy pregnancy, increases energy, and better athletic performance. Potassium was highest in BPM (16.58±0.07 mg/100g), closely followed by BPC (16.22±0.34 mg/100g), with SSB recording 15.02±0.06 mg/100g. Potassium is one of the most important minerals in the body. A high potassium diet may help reduce blood pressure and water retention, protect against stroke and prevent osteoporosis and kidney stones (Raman, 2017). Potassium, an important component of milk, can provide health benefits such as protection against muscle wasting, osteoporosis, cardiovascular diseases and kidney stones (Antinoro, 2012). Corn is known to be a good source of potassium and confers several benefits to humans (Kumar, Jhariya, 2013). Magnesium content ranged from 19.94±0.20 mg/100g to 23.12±0.04 mg/100g. BPM recorded the highest (23.12±0.04 mg/100g), followed by BPC (22.52±0.26 mg/100g), with the least being recorded in SSB (19.94±0.20 mg/100g). Magnesium helps in the formation of bones and teeth (Pamplona-Roger, 2001). It also serves as a catalyst in energy-producing reactions within the cells. It also facilitates the transmission of nerve impulses, and it is involved in muscle relaxation, as opposed to calcium, which activates contraction.

Results on sodium content in Table 4 indicate that sodium content was higher in BPM (7.55±0.01 mg/100g) and was closely followed by BPC (7.37±0.04 mg/100g) and the least sodium content was recorded in SSB (7.23±0.04 mg/100g). The variations in the quantities of the minerals determined can be attributed to several factors, such as the ingredients used and possibly the preparation process. Excess sodium in the body may lead to arterial hypertension, fluid retention and calcium loss through urine. Animal-based and processed foods contain more sodium than potassium, and their regular consumption alters the essential balance between sodium and potassium, leading to hypertension and other diseases (Pamplona-Roger, 2001; Karppanen & Mervaala, 2006).

Minerals are important in food for their nutritional and physiological roles. However, they can be a disadvantage as they can cause off flavours and colours when there is poor handling or storage (Blitz, Grosch, & Shieberle, 2009). They help in building strong teeth and bones, the functioning of muscles and nerves, blood clotting, boosting the body’s immune system and promoting proper functioning of organs of the body.

**Table 4: Mineral composition of SSB, BPM and BPC**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Mineral Composition | | | | | |
| **Samples** | **Calcium**  **mg/100g** | **Iron**  **mg/100g** | **Potassium**  **mg/100g** | **Magnesium**  **mg/100g** | **Sodium**  **mg/100g** |
| **SSB** | 1.39±0.02c | 0.56±0.01c | 15.02±0.06b | 19.94±0.20c | 7.23±0.04c |
| **BPM** | 1.64±0.02b | 0.68±0.00b | 16.58±0.07a | 23.12±0.04a | 7.55±0.01a |
| **BPC** | 2.00±0.02a | 6.42±0.07a | 16.22±0.34a | 22.52±0.26b | 7.37±0.04b |

*Values are means ± standard deviation of triplicate determinations. Means in the same column with different superscript letters are significantly different at p ≤ 0.05.*

**3.3 pH Determination**

Table 5 shows data on the pH of the *‘‘Brukina’’* varieties. Results on pH generally were within acidic ranges, with SSB being the most acidic (3.6±0.04), followed by BPM (4.11±0.05) and the least being BPC (4.47±0.06). Most microorganisms thrive well at a pH near neutral (7.0) (Darko, 2016). The findings confirm earlier studies that also reported the pH of “*Brukina*” samples to be acidic (Tawiah, 2016; Nyarko-Mensah, 2018). Since all the products are acidic, it may reduce the risk of microorganism proliferation, thus prolonging the shelf life of the products. The pH of food is very important in food applications, food preservation, food packaging and storage (Egbebi & Bademosi, 2011; Fekria, Isam, Suha, & Elfadil, 2012). Microorganisms such as moulds, yeasts and bacteria are sensitive to the pH of foods (McGlynn, 2011). The pH of food products also influences sensory parameters such as taste, colour, texture, and flavour (Andrés-Bello, Barreto-Palacios, García-Segovia, Mir-Bel, & Martínez-Monzó, 2013). The degree of sourness and the aftertaste of a product are known to be influenced by the pH of the product (Andrés-Bello et al., 2013). An earlier study reported that panellists enjoyed the sourness of “*Brukina*” samples [6]. During food processing, pH affects many processes such as coagulation, enzymatic activities, mortality of microorganisms, and chemical reactions such as fermentation. Thus, the knowledge of pH and its effects during processing is important for product safety and quality (Andrés-Bello et al., 2013).

**Table 5: pH of SSB, BPM and BPC**

|  |  |  |  |
| --- | --- | --- | --- |
| **Sample pH** | |  |  |
| **SSB** | 3.60±0.04 c |  |  |
| **BPM** | 4.11±0.05 b |  |  |
| **BPC** | 4.47±0.06 a |  |  |

*Values are averages, means ± standard deviation of triplicate determinations. Means in the same column with different superscript letters are significantly different at p ≤ 0.05.*

**3.4 Fatty Acid Determination**

The fatty acid profile of the “*Brukina*” varieties is represented in Table 6. The results revealed that BPC contained the highest proportion (52.39%) of saturated fatty acids, followed by BPM (30.73%), and SSB recorded the least (28.70%). BPC recorded the highest proportion of monounsaturated fatty acids (Oleic acid, 11-Octadecenoic acid, Myristoleic acid, 9-Hexadecenoic acid and cis-11-Eicosenoic acid). SSB contained Oleic acid, 11-Octadecenoic acid and Gadoleic acid, and Oleic acid, Myristoleic acid and cis-11-Eicosenoic acid were found in BPM. Linoleic acid was the highest by proportion (13.46%) in SSB. The proportion of Linoleic acid was 6.21% in BPM and 2.27% in BPC. The results from all samples indicated that in terms of heart health, all samples (SSB, BPM and BPC) may be ideal.

The trends of results found were similar to those reported by (Dufour, Lamouche, Detalle, Gauthier & Sammut, 2004). Milk contains saturated fat, which can raise the levels of cholesterol. A one-cup serving of whole milk contains 9 grams of total fat, which includes 6 grams of saturated fat (Micinski, Zwierzchowski, Kowalski, Szarek, Pierozynski, & Raistenskis, 2012). Skimmed milk contains about half the amount of total and saturated fat in whole milk. The fats dropped to 2.4 grams for total fat and 2 grams for saturated fat in 1% fat milk. The unsaturated fatty acids (polyunsaturated and monounsaturated) found in the samples are beneficial to the human body.

Even though a high proportion of saturated fatty acids was recorded in BPC, it may not create problems when consumed. The fatty acids present by proportion ranged from as low as 0.57% to 28.61%. Palmitic acid and stearic acid are the saturated fatty acids found dominating in the product, with proportions of 28.61% and 11.79% respectively in BPC. Although palmitic acid and stearic acid recorded higher proportions, it is believed not to cause heart-related problems as compared to myristic acid, which was not present in BPC but was present in SSB and BPM. Lauric acid was present in all samples, with a proportion of 3.92% in BPC, which is very low. Under normal physiological conditions, palmitic acid accumulation is prevented by enhanced delta 9 desaturation to palmitoleic acid (16 1n-7) and /or elongation to stearic acid and further delta 9 desaturation to oleic acid (18:1n-9c) (Strable & Ntambi, 2010; Silbernagel, Kovarova, Cegan, Machann, Schick, Lehmann, Häring, Stefan, Schleicher, Fritsche, & Peter, 2012). The average intake of palmitic acid is around 20-30 g/day (Sette, Le Donne, Piccinelli, Arcella, Turrini, & Leclercq, 2011). It is suggested to limit saturated fat intake to less than 7% of total daily calories to promote general cardiovascular health (Micinski et al., 2012).

The presence of stearic acid is said not to be a problem (Strable et al., 2010). Production of oleic acid, which is a monounsaturated fatty acid, from stearic acid is important. The intake of stearic acid in amounts as high as 9% of energy results in little or no adverse effect on hemostatic risk factors. Saturated fats increase the production of cholesterol in the body, while unsaturated fats lower it. Saturated fat, however, in the body, serves as a reserve energy source. It is stored within body tissues, particularly under the skin or on artery walls and can predispose people to obesity and arteriosclerosis (Pamplona-Roger, 2001). However, relative amounts of saturated fatty acids and unsaturated fatty acids in lipids are important for good nutrition and health, and their ratios determine their effects on health.

**Table 6: Fatty acid distribution of SSB, BPM and BPC**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Fatty acids | Area% for SSB | Area% for BPM | area% for BPC | Type of fatty acid |
| Decanoic acid | 0.89 | 1.78 | 1.90 | Saturated |
| Dodecanoic acid | 1.50 | 3.40 | 3.92 | Saturated |
| Myristic acid | 3.37 | 8.51 |  | Saturated |
| Hexadecanoic acid | 11.94 | 0.57 | 28.61 | Saturated |
| Heptadecanoic acid | 0.58 | 0.99 | 1.30 | Saturated |
| Stearic acid | 9.54 | 9.49 | 11.79 | Saturated |
| Eicosanoic acid | 0.86 |  |  | Saturated |
| Pentadecanoic acid |  | 1.76 | 2.26 | Saturated |
| Octanoic acid |  | 0.61 | 0.63 | Saturated |
| Tetradecanoic acid |  | 1.69 | 1.37 | Saturated |
| Hexadecanoic acid, 14-methyl- |  | 1.89 |  | Saturated |
| 13-methyltetradecanoate |  |  | 0.57 | Saturated |
| Total | **28.70** | **30.73** | **52.39** |  |
| Oleic acid | 36.15 | 33.85 | 42.23 | Monounsaturated |
| 11 -Octadecenoic acid | 20.82 | 22.33 |  | Monounsaturated |
| Gadoleic acid | 0.85 |  |  | Monounsaturated |
| Myristoleic acid |  | 2.34 | 2.47 | Monounsaturated |
| 9-Hexadecenoic acid |  | 3.68 |  | Monounsaturated |
| cis-11-Eicosenoic acid |  | 0.80 | 0.62 | Monounsaturated |
| Total | **57.83** | **63.05** | **45.33** |  |
| Linoleic acid | 13.46 | 6.21 | 2.27 | Polyunsaturated |
| Total | **13.46** | **6.21** | **2.27** |  |

**3.5 Sensory Evaluation**

Results revealed that the sensory mean scores provided by panellists ranged from 7.06 ± 1.50 to 8.16 ± 0.93, indicating different degrees of liking. The “*Brukina*” samples had no significant differences in all sensory attributes except for aroma and overall acceptability. This could be attributed to the fact that respondents liked SSB, BPM, and BPC very much based on their appearance, taste, mouthfeel, aftertaste, and texture.

Appearance is an important characteristic considered when selecting and accepting food. The score for appearance of the samples showed that BPC had the highest score, followed by BPM and SSB. The differences in appearance among SSB, BPM and BPC in terms of their mean scores were not much, and there was no statistically significant difference (p0.05). Colour and appearance are indices of the inherent good quality of foods associated with acceptability (Singh-Ackbarali & Maharaj, 2014). ).

The tongue is the sense organ used in determining the taste of food. The taste is detected by taste buds, which are at the tip of the tongue. The mean taste value of BPM was higher than the SSB and BPC samples. This implies that panellists preferred BPM to SSB and BPC.The samples were presented randomly to the panellists; therefore, it could not be argued that BPM was probably placed at an advantageous position.

Aroma for SSB (control) was rated lowest as compared to BPM and BPC. BPM had the highest rating (7.901.03). The results for the aroma attribute of the samples as shown in Table 7 indicated that the difference between BPM and BPC’s mean scores was not much. This implies that there was not much difference in the aroma of BPM and BPC. Aroma is an important parameter to consider when evaluating the acceptability of food samples. Aroma is an integral part of taste in accepting food before it is put in the mouth (Bazaz, Baba, & Masoodi, 2016). Results on taste revealed no significant differences among the samples (Table 7). However, BPM scored the highest mean of 7.85±1.22. This could be as a result of the addition of mixed flavours to the samples which may have influenced the likability. Contrary to texture, food that has undergone slight changes may have a different mouthfeel (Karadsheh, 2020). The least score in terms of taste recorded by BPC may be due to the addition of the lemon flavour which might have given a sour taste or a bitter taste. Although BPC recorded the least value in taste, it recorded high (8.16±0.93) degree of liking in mouth feel. BPM recorded a mouth feel value of 7.58±0.13 and SSB (control) recorded the lowest (7.24±0.14). Mouthfeel literally refers to how food feels inside your mouth, and what senses are stimulated in the process.

Texture is the visual and especially tactile quality of a surface. It is a physical sensation in the mouth – soft, crisp, dry, grainy, etc. Sample BPM had a high (7.42±1.14) degree of liking in terms of texture, followed by SSB with 7.29±1.08 degree of liking, while BPC recorded 7.13±1.36 degree of liking. But there were no statistically significant differences among the samples. Texture is important to the enjoyment and acceptability of foods.

After taste is the sensory impression that lasts longest after food is swallowed. Results indicate that BPM recorded the highest value of aftertaste (7.45±1.39) among the samples. BPC recorded 7.35±1.49 and SSB recorded the least (7.06±1.50). Aftertaste is caused by the remaining chemicals sticking around the cells of the tongue and back of the throat. It is the oral or nasal sensation that occurs after the stimulus has been removed from the oral cavity (ASTM International, 2009). BPM recorded the highest degree of liking for aftertaste, and this may be attributed to the rich milky taste of the sample. However, results showed no significant differences in after aftertaste of the samples.

Overall acceptability gives an indication of the likeability of a product based on the product’s sensory characteristics. The result in Table 7 indicates that the overall acceptability score by the panellists was high for BPM (8.04±1.07), followed by BPC (7.73±1.48), and then SSB (7.56±1.35). SSB (control) had the least overall acceptability score per the results. Table 7 showed that SSB was significantly lower than BPM in terms of overall acceptability but was not different from BPC. On the other hand, there was no statistically significant difference in overall acceptability between BPM and BPC. The panellists selected BPM as the best among the samples. This could be due to the fact that consumer choices for BPM were influenced by their existing contact with millet "*Brukina*" already available on the market, without any variety to make choices. However, since there was no significant difference between BPM and BPC statistically, it implies that BPC could be an alternative to BPM and SSB for consumers.

**Table 7: Sensory analysis of “*Brukina*” prepared with corn, “*Brukina*” prepared with millet and Street sold “*Brukina*”**

|  |  |  |  |
| --- | --- | --- | --- |
| Sensory Properties | Sample | N | Mean ± Std dev |
| Appearance | SSB | 100 | 7.30±1.49a |
| BPM | 100 | 7.37±1.36a |
| BPC | 100 | 7.57±1.22a |
| Aroma | SSB | 100 | 7.14±1.28b |
| BPM | 100 | 7.90±1.03a |
| BPC | 100 | 7.83±1.19a |
| Taste | SSB | 100 | 7.48±1.50a |
| BPM | 100 | 7.85±1.22a |
| BPC | 100 | 7.46±1.53a |
| Mouth feel | SSB | 100 | 7.24±0.14a |
| BPM | 100 | 7.58±0.13a |
| BPC | 100 | 8.16±0.93a |
| After Taste | SSB | 100 | 7.06±1.50a |
| BPM | 100 | 7.45±1.39a |
| BPC | 100 | 7.35±1.49a |
| Texture | SSB | 100 | 7.29±1.08a |
| BPM | 100 | 7.42±1.14a |
| BPC | 100 | 7.13±1.36a |
| Overall Acceptability | SSB | 100 | 7.56±1.35b |
| BPM | 100 | 8.04±1.07a |
| BPC | 100 | 7.73±1.48ab |

*Values are means ± standard deviations of 100 determinations. Means with different superscript letters for each parameter indicate significant difference at p≤0.05.*

**4. CONCLUSION**

Results from the study revealed that the “*Brukina”* samples were rich in nutrients and can offer consumers a significant supply of energy. “*Brukina*” prepared with corn agglomerates had a good nutrient profile, which may offer health benefits and possibly be an alternative to ‘*Brukina’* prepared with millet agglomerates. The use of corn in this study is a groundbreaking invention and entrepreneurial creativity that may bring diversification in “*Brukina”* production in Ghana. This may also create employment for people who may not have access to millet. Top of FormThe lack of a defined and standardised procedure for “*Brukina*” preparation and low-quality ingredients, and probable adulteration are issues that need to be addressed. There is high moisture content, which may promote microbial development and shorten the product's shelf life if not stored under appropriate temperature. It is necessary that the product be kept at the proper storage temperature. Although all samples were accepted sensorially, panellists preferred the “*Brukina*” prepared with millet (BPM) more than “*Brukina*” prepared with corn (BPC) and street-sold “*Brukina*” (SSB).

**DATA AVAILABILITY STATEMENT**

Data is available on request from the corresponding author.

**DISCLAIMER (ARTIFICIAL INTELLIGENCE)**

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during the writing or editing of this manuscript.

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