Nutritional, organoleptic, and physical properties of biscuits made with cassava flour: effects of eggs substitution with kidney bean milk (*Phaseolus vulgaris* L.)

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**ABSTRACT**

Common bean forms a significant part of the diet in Africa and hence plays a critical role in human nutrition. In order to promote it, this study was designed to investigate the effects of fully substituting eggs with bean milk on the physical, nutritional and organoleptic properties of biscuits made with cassava flour. Replacement of egg by bean milk increased the biscuits’ fat, carbohydrates, crude protein, and energy content. On the other hand, there were no significant differences in mineral contents between the cassava biscuits with eggs which served as the control and cassava biscuits with bean milk following substitution by bean milk. There was no significant difference (p < 0.05) in the Saponin and Phytate contents regarding anti-nutrients contents between bean milk and cassava bean milk biscuits. In contrast, Tannin contents were significantly higher in biscuits than in bean milk. Biscuit made with eggs, was rated as “very good,” while the test biscuits were rated as “good.” Substitution of egg by bean milk in cassava biscuits increased the biscuits’ protein, the fat, and carbohydrates contents with an appreciable taste. These biscuits made with bean milk can be used as a food supplement to help fight protein malnutrition in vulnerable groups.

**Introduction**

Common bean forms a significant part of the diet in Africa and hence plays a critical role in human nutrition, providing as much as 45% or more of the total proteins consumed. It provides a critical source of protein to the diet, complementing staple carbohydrate sources. In addition to being an essential source of protein and carbohydrates, it also supplies essential vitamins and micronutrients such as Zn and Fe, an integral component to the health and well-being of women and children. The vitamins and minerals in the crop lower cholesterol levels and have preventive and curative faculties to terminal diseases such as cancer.

In Cameroon, peanuts (*Arachis hypogea*), common beans (*Phaseolus vulgaris* L.), cowpea (*Vigna unguiculata*), soybean (*Glycine max*), and voandzou (*Voandzeea subterranea*) are the main cultivated legumes. Common bean (*Phaseolus vulgaris* L.) is arguably the most important legume for human consumption, particularly for smallholder farmers across tropical regions. Cameroon is ranked the seventh in haricot bean production in Africa and first in Central Africa, with production estimated at 402,054 metric tons. According to FAO statistics, common bean is the second most frequently cultivated crop after maize in Cameroon. Most farmers who grow common beans dry them in the sun to conserve them and increase their shelf-life, making them almost permanently available in...
the markets. However, the long-term storage of these agricultural products remains limited by several factors, particularly insufficient storage capacities leading to significant post-harvest losses of more than 30% of production. Therefore, the problem of preservation remains a constraint that must be resolved in order to promote the production and use of these foodstuffs in such a way that they play their role in enhancing food and nutritional security in the region. Especially as value-added processing presents great potential to not only improve food and nutritional security but also reduce energy consumption, preserve the environment and create jobs for the youths.

Many studies have boosted interest in enhancing the consumption of common beans in different forms, thus promoting their use in some food products. Bakery products are the most important items that can fulfill the requirements of ready-to-eat processed foods with better shelf life, good taste, ease of portability, and high nutritional quality. Thus, meeting the emerging diets of especially urban dwellers. The interest in these bakery products is growing day-by-day and captivating consumers because of their nutritional properties and ease in school feeding programs and disaster situations such as earthquakes.

Among the bakery products, biscuits occupy a unique position owing to numerous features. Biscuit making has progressed from a labor-intensive craft-based industry to a well-mechanized science-based industry. Biscuits are often popular wheat-based snack foods consumed by a wide range of people to meet diverse dietary needs. For example, the substitution of fat, sugar, and eggs have been carried out by some researchers to assess if they can get a more nutritional final product. Foodstuffs with different starch sources such as rice (Oryza sativa), maize (Zea mays), potato (Solanum tuberosum), cassava (Manihot esculenta), and sorghum (Sorghum bicolor) have also been identified for partial and total replacement of wheat. Cassava tubers have been used as an alternative in the development of gluten-free (GF) biscuits. Most research on this topic involves the use of different varieties as flour except TMS 1070593, which is, biofortified with Vitamin A according to the International Institute of Tropical Agriculture (IITA) rich in vitamin A, giving it a yellow color. There is still a challenge in using cassava flour because of its low baking quality compared to wheat flour, mainly because of the lack of gluten.

With increased population, urbanization, population, health issues, and high cost of living, diets worldwide are changing. Most people prefer readily available, delicious, affordable, and healthy food and snacks with different vitamins and minerals. One approach to this phenomenon of gluten-free is developing an egg replacer product, as eggs are traditionally used in many food products. Many attempts have been made to replace eggs with different products because: it is not affordable, owing to health risks associated with its consumption and consumer preference for vegan diets. Many researchers often partially or totally replace the egg with cheaper alternatives known as egg replacers (or egg extenders). Ingredients generally selected to replace eggs carry functional properties, such as emulsification, foaming, and viscosity/structure-building abilities in a formulation. Various plant proteins such as pea protein, black gram, chia seeds, banana, soy protein, and flour have been identified as egg replacers. The common bean has high protein (20–30%), which could be used.

Enriching cereal products with legume flour has nutritional benefits, notably that of improving the amino acid balance. It also modifies their processability and functional properties. Predicting such modifications is a major issue for the industry. Replacing wheat flour with legume flour, which differs in composition, has an impact on the balance of the components in the formula because legume flours contain less starch, more protein, and more fiber than wheat flour and semolina, at an equal or higher lipid content.

The only eggs generally used for baking are hens’ eggs, in which egg yolk is rich in fat and lecithin, together with flavor, have made it a good and traditional bakery ingredient. Thus, eggs being too expensive for the production of most biscuits, fat and emulsifier can be obtained from other sources.

The production of bean flour is most often done with the shell, which retains the anti-nutrient elements, and the analyses do not highlight certain mineral elements. However, adequate production of bean milk can help reduce anti-nutritional factors as much as possible. In any case, the interfacial properties of bean or legume have only been used for wheat substitution because they are better
than those of wheat gluten (only ~5 m² of oil covered/g of isolate and 9 min of emulsifying stability, and foaming activity and stability indexes of 29% and 40%). The emulsifying stability and other interfacial properties of beans can also be evaluated as ingredients for biscuit-based egg substitution.

The biscuit-based cassava flour (TMS 1070593) and milk bean combination can add vitamin A which contributes to better vision, build the immune system, and improve reproduction. However, so far, minimal research has been done on the use of bean milk as an egg replacer in the production of biscuits. This study was designed to investigate the effects of fully substituting eggs with bean milk on the physical, nutritional and organoleptic properties of biscuits made with cassava flour. It also aimed to provide a biscuit high in proteins, iron, calcium, and Vitamin A to vulnerable populations at an affordable cost.

**Materials and methods**

Common beans (*Phaseolus vulgaris* L.) MAC 33, a biofortified (high in iron and zinc) red bean variety, were obtained from the Institute of Agricultural Research for Development (IRAD), Foumbot in the West Region. The cassava roots of cultivar *TMS 1070593* were purchased at the International Institute of Tropical Agriculture (IITA), Nkolbisson. The other ingredients, such as baking powder, eggs, salt, sugar, butter, and vanilla essence, were procured from the local markets in Yaoundé, Cameroon.

**Preparation of bean milk**

The common bean milk preparation process was modified from the method previously described by Calvince et al.,[7] as shown in Figure 1. Briefly, common bean (1000 g) was thoroughly cleaned, rinsed, and soaked in 3000 ml of tap water for 18 hours at room temperature (27°C). The soaked common bean seed was drained, rinsed, dehulled by hands, and ground in a commercial blender. Water was added to make a common bean slurry in a ratio of 1:3 on a weight basis. The resulting slurry was passed through 2 layers of muslin cloth to filter the water-soluble common bean milk material from other insoluble matter. The strained milk was heated in a heavy bottom pan to 100°C, and this temperature was held for 20 min, stirring frequently to prevent sticking. The heated bean milk was placed at room temperature (≈ 25°C) and left to cool for 6 hours, and after that, one part was stored until further use at 4°C. A hundred grams (100 g) of cooled bean milk were distributed on five (5) petri dishes, and the filled petri dishes were introduced into an oven (Panasonic MOV-212) set at 50°C and dehydrated for 20–25 min. This dried bean milk was stored at 20°C for chemical analysis.

**Production of cassava flour**

Edible cassava flour (TMS 1070593) was prepared from the raw roots by washing, peeling, and slicing into 0.5 cm chips, followed by oven drying (55°C during 48 hours) and powdering. The flour was sieved (30-mesh size) to obtain a fine grade sample. The flour sample was kept in sealed plastics and stored at 4°C for future use.

**Production process of biscuits**

Two types of biscuits were made. These were biscuits made with 100 % cassava with eggs which served as the control (Control), and cassava biscuits with bean milk (CBMB), with measurements presented in Table 1. The biscuits were produced following the method described by .[22] For biscuit production, butter was put in a clean bowl and creamed thoroughly with a stainless-steel spatula till it became soft and smooth. Powdered sugar was added and creamed to give a homogenous mixture. Cassava flour was mixed together with baking powder and salt. This flour-baking powder-salt mixture was added to the butter-sugar mixture and homogenized with the spatula to form a paste. Egg or bean milk and
liquid flavor were then added, and the mixture stirred to obtain the final biscuit dough. The dough was then put into the biscuit mold, and the desired biscuit shape formed on a tray lightly greased with butter. The filled trays were introduced into an oven (Panasonic MOV-212) set at 160 °C and baked for 20–25 min. The light brown baked biscuits were removed and put in a large tray to cool at room temperature before packaging. They were packaged in high-density polyethylene, labeled, and stored at ambient temperature for various analyses.
**Nutritional analysis**

Chemical analysis was done on bean-derived products and biscuit samples to measure moisture content and total fat using standard Association of Official Analytical Chemists methods.\(^{[23]}\) The total nitrogen was determined by the Kjeldahl method using 6.25 as the nitrogen conversion factor to total protein. The total carbohydrates were determined by the Anthrone method.\(^{[24]}\) The mineral content (Ca, Mg, Fe, Zn) was determined by atomic absorption spectrophotometry (Varian Vista, Victoria, Australia). The caloric value was determined by multiplying the protein and carbohydrate values by a factor of four and lipid values by a factor of nine described by Paul and Southgate.\(^{[25]}\)

**Anti-nutritional factors analysis**

Phytate content was determined by titration with iron III solutions after acid digestion\(^{[26]}\). Saponin content was determined by weight difference after extraction in solvent.\(^{[27]}\) Tannin content was evaluated following the method described by Ndhlala et al.\(^{[28]}\)

**Physical characteristics of biscuits**

The color value of different cookies was estimated using a Hunter’s Lab color analyzer (Hunter lab scan XE, Reston, VA, USA). In the Hunter colorimeter, the color of a sample is designated by the three dimensions, \(L^*\), \(a^*\), and \(b^*\). This color was measured by placing the aperture of the equipment on the sample with white paper as the reference. \(L^*\), \(a^*\), and \(b^*\) indicates lightness, redness (+)/greenness (−), yellowish (+)/blueness (−) of the sample, respectively. The color of the samples was measured after placing the samples in front of the tiniest opening.\(^{[29]}\) In order to obtain data reflecting the color of samples, different points were taken into consideration for each sample. All data were collected with three replications.

**Sensory analysis**

The sensory test was carried out in the Food and Technology Laboratory of IRAD. A total of ten trained (10) panelists (6 women and 4 men) were invited to perform the sensory analysis. The bean biscuits were coded and presented to the panelists. The parameters were the intensity of aroma, basic taste (sweet, salty, acidic, bitter), texture (granular, melty, greasy, crumbly, crunchy), bean flavor, and overall taste quality on 6-point hedonic scales. Parameters were scored using a scale from 0 (absence) to 5 (very pronounced) for basic taste and texture and the overall acceptability from 0 (very disagreeable) to 5 (very pleasant) as given in Table 5. Drinking water was prepared for panelists, and they were asked to rinse their mouths after tasting each biscuit sample. The sensory analysis was performed three times.

| Table 5. Description of point of scale. |
|----------------------------------------|
| Scale | Perception                |
|-------|---------------------------|
| 0     | Absence or Very Bad       |
| 1     | Very Low or Bad           |
| 2     | Low or Not so Good        |
| 3     | Normal or Good            |
| 4     | High or Very Good         |
| 5     | Very High or Excellent    |
Cost evaluation of cassava-based biscuits

Cost evaluation of bean milk, control sample, and cassava biscuit fortified with bean milk was done based on direct costs (DC) (using the prices of the ingredients used for the food process of each of the products) and indirect costs (including Electricity, Miscellaneous fees (2.5 % DC) and packaging materials).

Statistical analysis

All data were subjected to one-way analysis of variance (ANOVA) on the triplicate data using XLSTAT version 2020.1.2 with a significance level of 5 %. Graphs and Radar charts were generated in Excel 2018 software (Office 365, Microsoft Corp.) from the color and sensory analysis results to determine differences in L*, a*, and b* color variables and attributes between the formulated biscuits.

Results and discussion

Nutritional analysis

The proximate composition of bean milk and cassava-based biscuits fortified with bean milk is shown in Table 2. There was a significant difference (p < .05) in the crude fat, carbohydrates, crude protein, and energy content of the biscuits. Vitamin A is a fat-soluble vitamin essential in the growth, development of epithelial tissue, reproduction, and functioning of the visual cycle. Carotenoids are important micronutrients for human health. They function as a precursor of vitamin A. For the total carotenoid content, there was no significant difference (p < .05) between cassava – egg biscuits (1.5 ± 0.05) µg/ g and cassava – bean milk biscuits (1.7 ± 0.08) µg/g. The carotenoid contents of the formulated biscuits were lower than values for biscuits prepared from pro-vitamin reported by Sogo et al., but higher than values in yellow staining roots of cassava recorded by Carvalho et al., The present study values are within the carotenoid content range (1.47 to 19.18 µg/g) of fresh weight reported by Da Silva et al.,

The moisture content plays a vital role in determining the shelf life of the product. The water content of bean milk was higher (6.16 ± 0.55) % than cassava-based biscuits fortified with bean milk (3.62 ± 0.12) % and control biscuits (2.92 ± 0.01) %. The low water content may increase the quality and stability of biscuits fortified with bean milk, as previously reported for other foods. The crude fat content of the bean milk was (2.10 ± 0.06) %, which was within the range of 1.8 to 2.7% previously reported for some common beans. The fat content of CBBM was significantly higher (25.70 ± 0.91) % than that of CEB (19.10 ± 0.56) %; this shows that the substitution of eggs with bean milk significantly changed the lipid content of those biscuits.

Carbohydrates were significantly higher (p < .05) in cassava-based biscuits fortified with bean milk (47.08 ± 0.06) % than that of bean milk and control biscuits (36.25 ± 0.96) %. This was expected as the bean is richer in carbohydrates than eggs. The protein content increased as eggs were replaced by bean milk. This could be attributed to higher protein content in bean milk relative to hens’ eggs. Other

| Material | Total carotenoids (µg/ g) | Moisture Content (%) | Crude Fat (%) | Carbohydrates (%) | Crude protein (%) | Energy (kcal/g) |
|----------|---------------------------|----------------------|---------------|-------------------|------------------|-----------------|
| BM       | ND                        | 6.16 ± 0.55a         | 2.10 ± 0.06a  | 2.92 ± 0.01a      | 23.50 ± 1.06a    | 124.58 ± 1.56a  |
| CBMB     | 1.5 ± 0.05a               | 3.62 ± 0.12b         | 25.70 ± 0.86b | 47.08 ± 0.06b     | 46.7 ± 0.06b     | 438.3 ± 4.12b   |
| CEB      | 1.7 ± 0.08a               | 2.92 ± 0.01b         | 19.10 ± 0.56c | 36.25 ± 0.96c     | 1.80 ± 0.02c     | 324.1 ± 3.50C   |

Note: BM = Bean Milk; CEB = Cassava - Egg Biscuits; CBMB = Cassava – Bean Milk Biscuits; ND = Not Determined. Values are means ± SD (standard deviation) of triplicate determinations. Different superscript letters within the same column indicate statistical significance (p < 0.05)
authors observed similar results\textsuperscript{34}, with red kidney bean flour. The results suggest that the substitution of eggs by bean milk in whole cassava biscuits may be useful as a food supplement for alleviating protein malnutrition in vulnerable groups.

Energy content is a function of the total protein, fat, and carbohydrates present in the food. In this study, sample CBMB with the highest fat, carbohydrates, and protein value also recorded the highest energy value (438.3 ± 4.12 kcal/g) while the least energy value was for CEB (324.1 ± 3.50) kcal/g. The energy content of the CBMB samples was within the range (397–457) kcal/g reported by Abiodun and Ehimen \textsuperscript{35}.

Table 3 shows the variation in mineral content of cassava-based biscuits and bean milk. There were significant differences (p<.05) in the calcium, magnesium, zinc, and iron contents in bean milk compared with cassava-based biscuits CEB (control) and CBMB. This finding agrees with several studies\textsuperscript{36} which reported that kidney beans are rich in minerals essential for human development and growth. On the other hand, there were no significant differences in mineral contents between the control biscuits and cassava-based biscuits fortified with bean milk (CBMB). Calcium concentration was increased from bean milk (33.00 ± 1.61) mg/100 g to CBMB (54.00 ± 2.60) mg/100 g while magnesium, zinc and iron contents were decreased (from 146.00 ± 7.00; 3.72 ± 0.51; 12.82 ± 1.51) mg/100 g to (59.00 ± 0.19; 0.97 ± 0.09; 1.30 ± 0.01) mg/100 g respectively. Magnesium is the most abundant mineral in bean milk (146.00 ± 7.00) g/100 g, followed by calcium, iron, and zinc being the least. This result corroborates with that found for other common beans by.\textsuperscript{7} CBM biscuits contained the highest concentration of Ca (54.00 ± 2.6) mg/100 g. Calcium, the most abundant mineral in the body, makes up much of the structure of bones and teeth. The calcium recorded in biscuits produced in this study was far higher than values recorded for biscuits fortified with safou.\textsuperscript{22} This result was in the range of calcium values (41.5 ± 0.9 to 62.3 ± 4.1) mg/100 g in dry beans obtained by.\textsuperscript{7} The amounts of calcium contained in CBMB are lower than the average daily intake of calcium from foods and beverages (from 842 to 1,083 mg) independently of age and sex.\textsuperscript{37} However, they contribute to calcium intake, even though they contain small amounts of calcium because people consume them frequently. The observed higher magnesium in cassava bean milk biscuits agrees with the reports from other researchers.\textsuperscript{35,38} It is worth noting that magnesium is a cofactor in many enzyme systems that regulate diverse biochemical reactions in the body.\textsuperscript{39} Biscuits with a high iron content can be used as an alternative snack to overcome iron deficiency or anemia experienced mostly by children, the elderly, pregnant women, and nursing mothers.\textsuperscript{40} Iron concentrations in bean milk (12.82 ± 1.51) mg/100 g were comparable to those reported for different common beans in the range of 6.0 mg/100 g to 23.8 mg/100 g.\textsuperscript{7,32} The amounts of iron contained in CBMB were higher than the range (31.7 to 36.7 ppm) recorded for other biscuits.\textsuperscript{22,40} The required daily intake (RDI) is age- and sex-dependent except for infants younger than 6 months whose recommended intake is 0.27 mg/day; the recommended intake is generally between 7 and 18 mg/day.\textsuperscript{37} Zinc is found in cells and is needed during pregnancy, infancy, and childhood. The body needs zinc to grow and develop properly.\textsuperscript{41,42} The RDI is also age- and sex-dependent, 2–8 mg/day for infants and children and 11–13 mg/day for adolescents and adults.\textsuperscript{37} Although there are low levels of zinc compared to other minerals in the biscuits, consuming at least 100 g of cassava-based biscuits per day would be a good source of zinc.
Table 4. Saponins, Tannins, and Phytates content of bean milk and cassava-based biscuits fortified with bean milk.

| Material | Saponins (%) | Tannins (%) | Phytates (%) |
|----------|--------------|-------------|--------------|
| BM       | 0.80         | 0.048       | 3.25         |
| CBMB     | 0.85         | 0.092       | 3.22         |

Note: BM = Bean Milk; CEB = Cassava – Egg Biscuits; CBMB = Cassava – Bean Milk Biscuits.

Anti-nutrients

Table 4 shows the composition of anti-nutrients in bean milk and cassava-based biscuits fortified with bean milk. Legumes and some tubers contain some natural toxicants. Some of these substances can interfere with the absorption of proteins, carbohydrates, and certain minerals.\(^{43,44}\) Generally, there was no significant difference \( (p < .05) \) in the Saponin and Phytate contents between bean milk and cassava – bean milk biscuits, meaning that the only source of these elements in biscuits is bean milk. Furthermore, the phytate contents (3.25 to 3.22 %) were lower than previously reported values for common beans by \(^{45}\).

Tannin contents were significantly higher in biscuits than in bean milk, which is likely related to the additional source from cassava. The tannin contents of bean milk (0.048 %) and CBMB (0.092 %) products were very low when compared with the usual tannin content of cassava products (0.4–0.5 %).\(^ {46}\) Regarding the bean milk, its tannin contents is far lower than previously reported values for bean milk.\(^ {10}\) The products could also be considered safe regarding tannin poisoning since the levels found in this study are below the critical value of 0.7–0.9 %.\(^ {47}\)

Physical analysis of cassava-based biscuits

Color is an important sensory attribute of any food because it influences acceptability. From Figure 2, the \( a^* \) values of the cookie bars were not different between formulas. There was an increase of the brightness \( (L) \) from 41 to 45 and a decrease in yellowish \( (b^*) \) from 26 to 11 as the eggs were replaced by bean milk in biscuits. This signifies that the color of biscuits becomes a light golden color with bean milk, most likely because of the naturally milky pigmentation of bean milk. In addition, the luminosity \( (L^*) \) was influenced by non-enzymatic browning reactions.
that occurred during baking. When heated, the Maillard reaction occurs between reducing sugars and free amino acids (especially lysine) and peptides. Since CBMB had higher protein levels than control biscuits, this CEB was also expected to have more non-enzymatic browning, thus lowering luminosity values. However, the results obtained in the present work do not agree with those of, who reported that pasta with more bean flour was darker.

**Sensory evaluation of biscuits**

The sensory evaluation of the biscuits was presented in Figure 3. Biscuit made with eggs (CEB), which served as the control, had the highest rating for crunchy (2.8), crumbly (2.5), and overall acceptability (4.1) compared to Cassava – Bean Milk Biscuits which recorded the highest score for sweet (3.7), crispy (4.2), milky (4.0) and bean flavor (3.0). However, according to the panelists, there was no significant difference in the variation of color between them. The higher rating observed for the control sample may be because panel members are familiar with bakery products made with eggs, which could have influenced their rating for the control sample. The added bean milk changed the sensory properties of the biscuit, as evident in the rating recorded by the panelists. Panelists revealed that they detected the bean aroma in the final biscuits. The overall acceptability obtained for the CEB was 4.15, while CBMB obtained 3.2. Crispy is the noise and strength when the sample of biscuit breaks or cracks when chewed on the first and second. The results showed that supplementation with bean milk increased crispiness. Therefore, the substitution of egg with bean milk affected the crispiness of the biscuits. These results are not in line with those of Fieben et al., who reported that the crispiness of the biscuits decreased as haricot bean flour was added. This difference could be explained by the fact that we used bean milk instead of flour in this current study. Acidity and bitterness were not felt, recording a score of zero in both the control and CBM biscuits.

![Figure 3](image-url)

**Figure 3.** Sensory properties and acceptability of cassava-based biscuits. With CEB = Cassava – Egg Biscuits and CBMB = Cassava – Bean Milk Biscuits.
Table 6. Cost evaluation cassava-based biscuits.

| Ingredients                  | Unit Cost (FCA/g) | Quantity (CEB) (g) | Total Cost 1 (FCA) | Quantity (CBMB) (g) | Total Cost 2 (FCA) |
|------------------------------|-------------------|--------------------|--------------------|--------------------|--------------------|
| Direct costs                 |                   |                    |                    |                    |                    |
| Flour                        | 0.7               | 300                | 210                | 300                | 210                |
| Butter                       | 1.4               | 140                | 196                | 140                | 196                |
| Sugar                        | 0.8               | 100                | 80                 | 100                | 80                 |
| Eggs                         | 1.6               | 188.28             | 301.248            | 0                  | 0                  |
| Bean milk                    | 0.3               | 0                  | 0                  | 280                | 84                 |
| Baking powder                | 2.2               | 5                  | 11                 | 5                  | 11                 |
| Aroma (vanilla)              | 0.3               | 5                  | 50                 | 5                  | 50                 |
| Salt                         | 0.2               | 1                  | 0.2               | 1                  | 0.2                |
| Total direct cost of production (DC) | -          | -                  | 848.448            | -                  | 631.2              |
| Indirect cost                |                   |                    |                    |                    |                    |
| Electricity                  |                   |                    | 65                 | -                  | 65                 |
| Miscellaneous fees           | -                 | -                  | 21.2               | -                  | 15.7               |
| (2.5% DC)                    |                   |                    |                    |                    |                    |
| Package materials for 415 g | -                 | -                  | 235                | -                  | 255                |
| Total indirect cost          | -                 | -                  | 321.2              | -                  | 335.7              |
| Total cost                   | -                 | -                  | 1169.648           | -                  | 966.9              |
| Quantity of biscuits         | -                 | -                  | 89                 | -                  | 103                |
| Cost price                   | -                 | -                  | 13.14              | -                  | 9.38               |

Production cost analysis

The production cost of control and cassava-based biscuits is shown in Table 6. This table shows that replacing eggs with bean milk in the cassava biscuits can decrease production by 28.6% per biscuit produced (Cost of CEB = 13.14 FCA/Biscuit while Cost of CMBM = 9.38 FCA/Biscuit). Thus, substituting of eggs by bean milk is most economically achievable for the maximum quantity of biscuits (Table 6).

Conclusion

This study was designed to investigate the effects of fully substituting eggs with bean milk on the physical, nutritional and organoleptic properties of biscuits made with cassava flour. It was found CBMB is affordable and sustainable for different entrepreneurs, making it easy to engage private sector partners to produce these nutritious products for different target groups. Good option to reduce micronutrient deficiency in the country. Is it a great market opportunity to meet the demands of vegans by providing them with an alternative to powdered cow milk. Our study provides valuable information about product attributes of processed CBMB likely to influence consumers and processors producing and buying intentions. Further studies can be undertaken for rheology and in vivo assessment purposes.

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Disclosure statement

No potential conflict of interest was reported by the author(s).
References

[1] Millicent, R. S.; Idupulapati, M. R. Chapter 12 - Common Bean. Crop Physiology Case Histories for Major Crops. Academic press, 2021; pp 384–406. doi: 10.1016/B978-0-12-819194-1.00012-8.

[2] Welch, R. M.; Graham, R. D. Breeding for Micronutrients in Staple Food Crops from a Human Nutrition Perspective. J. Exp. Bot. 2004, 55(396), 353–364. DOI: 10.1093/jxb/erh064.

[3] Hangen, L.; Bennink, M. R. Consumption of Black Beans and Navy Beans (Phaseolus vulgaris L.) Reduced Azoxymethane-induced Colon Cancer in Rats. Nutr. Cancer. 2003, 44, 60–65. DOI: 10.1207/S15327914NC441_8.

[4] IRAD (Institut de Recherche Agricole pour le Développement), 2013. C2D/Programme d’appui à la recherche agronomique PROJET 6: Légumineuses. Contribution de la recherche à l’amélioration de la production et la consommation des légumineuses alimentaires au Cameroun. 57p.

[5] FAO Statistics, 2020. http://www.fao.org/faostat/en/#compare (Accessed October 29, 2020).

[6] Ngamo, L. S. T.; Hance, T. Diversité des ravageurs des denrées et méthodes alternatives de lutte en milieu tropical. Tropiculature. 2007, 25(4), 215–220.

[7] Calvince, A.; Arnold, N. O.; Samuel, I.; Maina, J.; Onyangore, F. Chemical Composition of the Seed and ‘Milk’ of Three Common Bean (Phaseolus vulgaris L) Varieties. J. Food. Meas. Charact. 2019, 13(2), 1242–1249. DOI: 10.1007/s11694-019-00039-1.

[8] Lutomia, C. K.; Nchanji, E. B.; Induli, I.; Mutuku, T.; Gichangi, A.; Mutuli, W.; Birachi, E.; Birachi, E. Consumer Intentions to Buy Nutrient-rich Precooked Bean Snacks: Does Sensory Evaluation Matter? Afr. J. Food Agric. Nutr. Dev. 2021, 21(2), 17621–17642. DOI: 10.18697/ajfand.97.20210.

[9] Melini, F.; Melini, V.; Luziatielli, F.; Ruzzi, M. Current and Forward-Looking Approaches to Technological and Nutritional Improvements of Gluten-Free Bread with Legume Flours: A Critical Review. Compr. Rev. Food Sci. Food Saf. 2017, 1–22. DOI: 10.1111/1541-4337.12279.

[10] Nchanji, E.; Siré, B.; Ngueguim, M.; Kamdem, F.; Butare, L.; Onyang, P., and Fungo, R., 2020a. Lutter contre les carences en micronutriments au Cameroun par la biofortification du haricot commun. 8. https://hdl.handle.net/10568/111027. Accessed January 2022.

[11] Nchanji, E. B. Repositioning Women and Youths in the Bean Corridors in sub-Saharan Africa. Alliance of Bioversity International and CIAT 1p: Rome (Italy), 2021; https://hdl.handle.net/10568/113502.

[12] Tilman, J.; Schober, C. M. O.; McCarthy, D.; Anja, D.; Elke, K. A. Influence of Gluten-free Flour Mixes and Fat Powders on the Quality of Gluten-free Biscuits. Eur. Food Res. Technol. 2003, 216(5), 369–376. DOI: 10.1007/s00217-003-0693-3.

[13] Colla, K.; Costanzo, A.; Gamlath, S. Fat Replacers in Baked Food Products. DOI:10.3390/foods7120192. Foods, 2018, 7(12), 192. DOI: 10.3390/foods7120192.

[14] Sahin, A. W.; Rice, T.; Zannini, E.; Lynch, K. M.; Coffey, A.; Arendt, E. K. The Incorporation of Sourdough in Sugar-reduced Biscuits: A Promising Strategy to Improve Techno-functional and Sensory Properties. Eur. Food Res. Technol. 2019, 245(9), 1841–1854. DOI: 10.1007/s00217-019-03302-3.

[15] Ali, R.; Saeed, S. M. G.; Ali, S. A.; Sayed, S. A.; Ahmed, R.; Mobin, L. Effect of Black Gram Flour as Egg Replacer on Microstructure of Biscuit Dough and Its Impact on Edible Qualities. Food Meas. 2018, 12(3), 1641–1647. DOI: 10.1007/s11694-018-9779-3.

[16] Tavares, B. O.; Silva, E.; Silva, V. S.; Junior, M.; Ida, E.; Damiani, C. Stability of Gluten Free Sweet Biscuit Elaborated with Rice Bran, Broken Okara and Oat Kernel. Food Sci. Technology. 2016, 36(2), 296–303. DOI: 10.1590/1678-457X.0083.

[17] Longoria, G. S.; Cruz-herna’ndez, M.; Flores-vera’stegui, M.; Martinez-Vázquez, M.; Martínez-Zaques, G. J.; Jiménez-Regalado, E.; Jiménez-va’ques, G. J.; Martinez-Vázquez, G. Rheological Effects of High Substitution Levels of Fats by Inulin in Whole Cassava Dough: Chemical and Physical Characterization of Produced Biscuits. J. Food Sci. Technol. 2020, 57(4), 1517–1522. DOI: 10.1007/s13197-019-04187-6.

[18] Ratnayake, W. S.; Bhimalingeswarappa, G.; Rybak, D. A. Effects of Egg and Egg Replacers on Yellow Cake Product Quality. J. Food Process. Preserv. 2012, 321–329. DOI: 10.1111/j.1745-449X.2011.00547.x.

[19] Monnet, A. F.; Laleg, K.; Michon, C.; Mical, V. Legume Enriched Cereal Products: A Generic Approach Derived from Material Science to Predict Their Structuring by the Process and Their Final Properties. Trends Food Sci. Technol. 2019, 86, 131–143. DOI: 10.1016/J.TIFS.2019.02.027.

[20] Ahmed, A. R.; Influence of Chemical Properties of Wheat-lupine Flour Blends on Cake Quality. Adv. J. Food Sci. Technol. 2014, 2(2), 67–75. DOI: 10.12691/ajfst-2-2-4.
[21] Manley, D. 28 September: 2011. Milk Products and Egg as Biscuit Ingredients. *Manley's Technology of Biscuits, Crackers and Cookies*. Fourth Manley, D. 217 (80 High Street, Sawston, Cambridge CB22 3HJ, UK: Woodhead Publishing Limited). Woodhead Publishing Series in Food Science, Technology and Nutrition. 191–199 23 June 2021. DOI: 10.1533/9780857093646.2.191

[22] Eyenga, E. F.; Tang, E. N.; Achi, M. B. L.; Boulanger, R.; Mbacham, W. F.; Ndindeng, S. A. Physical, Nutritional, and Sensory Quality of Rice-based Biscuits Fortified with Safou (Dacryodes Edulis) Fruit Powder. *Food Sci. Nutr.* 2020, 1–12. DOI: 10.1002/fsn3.1622.

[23] Association of Official Analytical Chemists (AOAC). *Official Methods of Analysis*, 18th ed.; Washington, DC, USA: Association of Official Analytical Chemists, 2007.

[24] Leyva, A.; Quintana, A.; Melly Sa´nchez, E. N.; José’ Cremaeta, R.; Sa´nchez, J. C.; Sánchez, J. C. Rapid and Sensitive Anthrone Sulfuric Acid Assay in Microplate format to Quantify Carbohydrate in Biopharmaceutical products: Method Development and Validation. *Biologicals*. 2008, 36(2), 134–141. DOI: 10.1016/j.biologicals.2007.09.001.

[25] Paul, A. A.; Southgate, D. A. T. *McCance and Widdowson’s The Composition of Foods*, 4th ed.; Her Majesty’s Stationery Office: London, 1979.

[26] Olayeye, L. D.; Owolabi, B. J.; Adesina, A. O.; Isiaka, A. A. Chemical Composition of Red and White Cocoyam (Colocasia Esculenta) Leaves. *Int. J. Sci. Res.* 2013, 11(2), 121–125.

[27] Obadoni, B. O.; Ochuko, P. O. Phytochemical Studies and Comparative Efficacy of the Extracts of Some Haemoostatic Plants in Edo and Delta States of Nigeria. *Global J Pure Appl Sci*. 2001, 8, 203–218. DOI: 10.4314/gipas.v8i2.16033.

[28] Ndhlala, A. R.; Kasiyamhuru, A.; Mupure, C.; Chitindingu, K.; Benhura, M. A.; Muchuweti, M. Phenolic Composition of Flacourtia Indica, Opuntia Megacantha and Sclerocarya Bigarea. *Food Chem.* 2007, 103(1), 82–87. DOI: 10.1016/j.foodchem.2006.06.066.

[29] Navneet, K.; Shitij, K. Development of Carrot Pomace and Wheat Flour-based Cookies. *J Pure Appl Sci Technol.* 2011, I, 4–10.

[30] Lanska, D. J.; Chapter 29: Historical Aspects of the Major Neurological Vitamin Deficiency Disorders: Overview and Fat-soluble Vitamin A. *Handbook Clin Neurol.* 2010, 95, 435–444. DOI: 10.1016/S0072-9752(08)02129-5.

[31] Sogo, J. O.; Oyeyinka, S. A.; Adetola, R. O.; Oyeyinka, A. T. Physicochemical Properties of Pro-vitamin A Cassava-wheat Composite Flour Biscuit. *Food Health Dis Sci-Prof J Nutr Diet*. 2016, 5(1), 20–26. DOI: 10.123456789/1244.

[32] Carvalho, L.; Oliveira, A.; Godoy, R.; Pacheco, S.; Nutti, M.; de Carvalho, J.; Fukuda, W.; Fukuda, W. Retention of Total Carotenoid and β-carotene in Yellow Sweet Cassava (Manihot Esculenta Crantz) after Domestic Cooking. *Food Nutr. Res.* 2012b, 56(1), 157–188. DOI: 10.3402/fnr.v56i0.15788.

[33] Da Silva, K. N.; Vieira, E. A.; de Freitas, F. J.; Carvalho, L. J. C. B.; Silva, M. S. Potencial agronômico e teor de carotenoides em raízes de mandioca. *Ciencia Rural.* 2014, 44(8), 1348–1354. DOI: 10.1590/0103-8478/rc20130606.

[34] Ufot, E.; Inyang, E. A. D.; Bello, F. A. Production and Quality Evaluation of Functional Biscuits from Whole Wheat Flour Supplemented with Acha (Fonio) and Kidney Bean Flours. *Asian J Agric Food Sci.* 2018, 06, 193–202. DOI: 10.24203/ajafs.v6i6.5573.

[35] Abiodun, A. A.; Ehimen, R. O. Physical, Chemical, and Sensory Properties of Biscuits Prepared from Flour Blends of Unripe Cooking Banana, Pigeon Pea, and Sweet Potato. *Food Sci. Nutr.* 2018, 6(3), 532–540. DOI: 10.1002/fsn3.590.

[36] Noah, A. A.; Banjo, O. A. Microbial, Nutrient Composition and Sensory Qualities of Cookies Fortified with Red Kidney Beans (Phaseolus Vulgaris L.) And Moringa Seeds (Moringa Oleifera). *Int J Microbiol Biotechnol* 2020, 5 (3), 152–158. DOI: 10.11648/j.ijmb2.20200503.20

[37] United States Department of Agriculture (USDA), 2020. Nutrient Lists from Standard Reference Legacy 2018. Food and Nutrition Information Center, National Agricultural Library. https://www.nal.usda.gov/fnic/nutrient-lists-standard-reference-legacy-2018 accessed on March 6, 2021.

[38] Ohizua, E. R.; Adeola, A. A.; Idowu, M. A.; Sobukola, O. P.; Afolabi, T. A.; Ishola, R.; Oyekale, T. O. Nutrient Composition, Functional and Pasting Properties of Unripe Cooking Banana, Pigeon Pea and Sweet Potato Flour Blends. *Food Sci Nutr.* 2017, 5(3), 750–762. DOI: 10.1002/fsn3.455.

[39] Wardlaw, G. M.; Kessel, M. W. *Perspective in Nutrition*, 5th edn ed.; Mcgraw-Hill, Boston, P: Boston, MA, 2002.

[40] Grail, D.; Aluminum Content of Foods, http://dietgram.com/aluminum-content-of-foods/ accessed 12 August 2021.

[41] Das, J. K.; Salam, R. A.; Kumar, R.; Bhutta, Z. A. Micronutrient Fortification of Food and Its Impact on Woman and Child Health: A Systematic Review. *Syst Rev.* 2013, 2(1), 67. DOI: 10.1186/2046-4052-2-67.

[42] Jarosz, M.; Obert, M.; Wyszogrodzka, G.; Młyńiec, K.; Librowski, T. Antioxidant and Anti-inflammatory Effects of Zinc. *Zinc dependent NF-jB Signaling*. *Inflammopharmacology*. 2017, 25, 11–24. DOI: 10.1007/s10787-017-0309-4.
MacDonald, A.; Evans, S.; Cochrane, B.; Wildgoose, J. Weaning Infants with Phenylketonuria: A Review. J. Human Nutr. Diet. 2012, 25(2), 103–110. DOI: 10.1111/j.1365-277X.2011.01199.x.

Zhang, Y. Y.; Stockmann, R.; Ajlouni, K. N. S.; Ajlouni, S. The Role of Legume Peptides Released during Different Digestion Stages in Modulating the Bioaccessibility of Exogenous Iron and Zinc: An In-vitro Study. Curr Res Food Sci. 2021, 4, 737–745. DOI: 10.1016/j.crfbs.2021.10.004.

Owolabi, S. T. O.; Prashant, S. Germination Behaviour, Techno-functional Characteristics, Anti-nutrients, Antioxidant Activity and Mineral Profile of Lucerne as Influenced by Germination Regimes. J. Food Meas. Charact. 2020, 15, 1796–1809. DOI: 10.1007/s11694-020-00777-7.

Hahn, S. K.; Cyanide and Tannin, Traditional Processing and Utilisation of Cassava in Africa; IITA: Nigeria, 1992; pp 20–25.

Delamare, G. Y. F.; Butterworth, P. J.; Ellis, P. R.; Hill, S.; Warren, F. J.; Edwards, C. H. Incorporation of a Novel Leguminous Ingredient into Savoury Biscuits Reduces Their Starch Digestibility: Implications for Lowering the Glycaemic Index of Cereal Products. Food Chemistry: X. 2020, 5. DOI: 10.1016/j.foodchem.2009.09.040.

Meilgaard, M. C.; Civille, G. V.; Carr, B. T. Sensory Evaluation Techniques. 4th; CRC Press: Boca Raton, FL, 2007; pp 201.

Fieben, K.; Welday, H.; Tilku, D.; Gesessew, L. K.; Gianfalone, E.; Marino, F.; Torella, D.; Mirici Cappa, V.; Nassa, G.; Tarallo, R. Effect of Blending Ratio of Wheat, Orange Fleshted Sweet Potato (Ipomoea Batatas L.) Powder and Haricot Bean (Phaseolus Vulgaris L.) Flour on Proximate Composition, Physical Properties and Sensory Acceptability of Biscuits. F1000Research. 2021, 10, 1–14. DOI: 10.12688/f1000research.52634.1.