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Processing effects on the chemical properties of components used in formulating fortified maize-bambara groundnut and maize-cowpea complementary foods

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Abstract

This study investigated the effect of degerming, malting, ashing and emulsification on the chemical properties of the respective food components used in formulating fortified maize-bambara groundnut and maize-cowpea complementary foods. The chemical properties of the processed fortifying food base components were determined by standard methods. Degerming led to 14.09%, 6.66%, 16.16% and 0.18% losses in calcium, iron, zinc and pro-vitamin A. Malting led to 7.27 and 7.94%; 9.25 and 3.38%; 2.71 and 4.08 % losses in calcium, iron and zinc contents of bambara groundnut and cowpea respectively but increased their vitamin A. Ashed *Hibiscus sabdariffa* had calcium content of 5.6967gkg^{-1}, iron (1.947 gkg^{-1}) and zinc content (7.333 gkg^{-1}). Emulsification of palm oil with *Brachystegia eurycoma* seed flour led to 57% loss in pro-vitamin a content. Processing affected the chemical properties of components used in formulating maize-bambara groundnut and maize-cowpea complementary foods hence there is need for processes modification.

Keywords: processing, components, complementary-foods, maize-bambara groundnut, maize-cowpea

1. Introduction

The nutritional quality of a complementary food depends on a number of factors including the nature of raw materials, methods of processing and fortification practices adopted. Complementary food for the 6 - 23 month infants should have a good balance of amino acids, provide 6 – 11 g of protein per 100 g, supply sufficient energy per day [202 kcal] for 6 - 8 month old infants, 307 kcal for 9 - 11 month old infants and 548 kcal for 12 - 23 month old infants [1]. It should also provide and enough micronutrients such as 225 µg iodine, 500 mg calcium, 27.5 mg iron, 12.5 mg zinc and 500 µgRE vitamin A per 100g of complementary food to meet the growing child's nutritional needs [2, 3] for adequate growth, prevent malnutrition, growth faltering and anemia.

In Nigeria and most West African countries, cereal gruel or porridge made from maize, sorghum or millet are used in formulating complementary foods. The raw materials used are usually processed by malting and fermentation as processing techniques. Such traditional plant-based complementary foods do not meet these nutritional requirements because they are particularly deficient in micronutrients such as calcium, iron, zinc and vitamin A [1]. Their high phytic acid and fiber contents impair the bioavailability of calcium, iron and zinc in the body [2, 4]. Hence the need arises to fortify these traditional plant-based complementary foods to meet the recommended daily allowance (RDA) of these nutrients in order to satisfy the growing child needs. In an attempt to solve the micronutrient problems of traditional plant based complementary foods, the modified versions of these techniques, in combination with food–to-food fortification had been used to improve the nutritional status of maize-bambara groundnut malt and maize-cowpea malt complementary foods. However, the iron and zinc content were below RDA requirement [5, 6]. Hence, this investigation was carried out to determine which processing techniques accounted for reductions in the mineral and vitamin A contents of the food components used in complementary foods and the possibility of modifying the treatments. This formed the background for this study with the specific objective of evaluating the effect of degerming, malting, ashing and emulsification on the chemical properties of the respective food components used in formulating fortified maize-bambara groundnut and maize-cowpea complementary foods.

2. Materials and Methods

Fresh leaves of Brazilian joy weed [*Alternanthera brasiliana* (L.) O. Kuntze] was obtained from a farm in the University of Nigeria Nsukka. Yellow maize [*Zea mays* (L.) var. rugosa], cowpea [*Vigna unguiculata* (L.) Walp], bambara groundnut [*Voandzeia subterranea* (L.) Thouars]**,** cattle rib bone, roselle calyce [*Hibiscus sabdariffa* (L.) Malvaceae], red palm oil, and "achi" (*Brachystegia eurycoma)* were purchased from Nsukka main market, Nigeria.

2.1 Methods

The maize, bambara groundnut and cowpea used for complementary food formulation were produced as described by Uvere *et al.* [5, 6]. Similarly, the cattle (rib) bones, *A. brasiliana* leaves, *H. sabdariffa* calyces and red palm oil were processed as described by Uvere *et al.* [5, 6].

2.2 Analysis

The root length of the germinating bambara groundnut and cowpea seeds were determined on a daily basis using a metre rule [7]. Malting loss was calculated as described by Dewar *et al.* [8]. The diastatic activity of the flours were assayed by the method of Hulse *et al.* [9]. Calcium, iron and zinc were determined by the A.O.A.C [10] method using an Atomic Absorption Spectrophotometer (Laas A series 1104, Labnic

Equipment 43040, Bayland, USA). The pro-vitamin A content was determined by the A.O.A.C [10] method.

2.2.1 Statistical Analysis

All determinations were carried out in triplicates and the means were subjected to one-way analysis of variance by means of MINITAB 14 statistical software. Mean separation was carried out by Least Significant Difference (LSD) at $p<0.05$.

3. Results and Discussion

3.1 Proximate composition

The proximate composition of the unprocessed maize, degermed maize, unmalted and malted bambara groundnut, cowpea are presented in Table 1.

3.1.1 Effect of degerming on proximate composition

Degerming led to significant ($p<0.05$) losses in the crude fat, crude fibre and ash content of the maize flour. The crude protein content of the unprocessed maize was 106.4 g kg^{-1} and decreased to 103.8 g kg^{-1} in the degermed maize, which represented a 2.44 % loss due to degerming. The loss in protein due to degerming was not significant ($p<0.05$) possibly due to the fact that the protein of maize is located in the endosperm not in the germ [10]. The crude fat content of the unprocessed maize was 50.1 g kg^{-1} and decreased significantly ($p<0.05$) to 39.6 g kg^{-1} in the degermed maize. Degerming led to 20.96 % decrease in fat content. The decrease in fat could be attributed to the removal of the germ were most of the fat is located [12]. However reduction in fat content of maize based products reduces their susceptibility to oxidative rancidity hence increasing their shelf life.

The ash content of the unprocessed maize was 21.7 g kg^{-1} and decreased to 20.0 g kg^{-1} in the degermed maize which represented a 7.83 % loss due to degerming. The decrease in the ash may represent the amount of the mineral element in the germ [12, 13]. The crude fibre content of the unprocessed maize was 21.5 g kg-1 and decreased significantly ($p<0.05$) to 12.5 g kg-1 in the degermed maize, which represented a 41.86 % loss due to degerming. The decrease in the fibre content could be attributed to the removal of the germ and represents the amount of fibre in the germ [11, 12].

Table 1: Proximate composition of the processed food components used in complementary food formulation

Samples	Moisture g kg^{-1}	Crude Protein g kg^{-1}	Crude fat g kg^{-1}	Ash g kg^{-1}	Crude fibre g kg^{-1}	Carbohydrate g kg^{-1}
M_u	$80.8^a \pm 0.012$	$106.4^a \pm 0.112$	$50.1^b \pm 0.042$	21.7 ± 0.002	$21.5^b \pm 0.013$	$719.5^a \pm 0.023$
M_d	$90.3^b \pm 0.001$	$103.8^a \pm 0.021$	$39.6^a \pm 0.004$	$20.0^a \pm 0.002$	$12.4^a \pm 0.002$	$733.9^b \pm 0.013$
B_u	$110.1^a \pm 0.013$	$215.8^b \pm 0.033$	$57.5^b \pm 0.001$	$33.2^a \pm 0.002$	$38.5^b \pm 0.032$	$544.9^b \pm 0.024$
B_m	$127.6^b \pm 0.004$	$233.0^a \pm 0.012$	$49.0^a \pm 0.003$	38.7 ± 0.002	$29.1^a \pm 0.011$	$522.6^a \pm 0.011$
C_u	$103.4^a \pm 0.002$	$248.5^a \pm 0.102$	$19.4^b \pm 0.06$	$42.3^a \pm 0.000$	$22.1^b \pm 0.002$	$564.3^b \pm 0.015$
C_m	$110.5^b \pm 0.011$	$259.0^b \pm 0.007$	$10.0^a \pm 0.001$	$49.2^a \pm 0.002$	$18.7^a \pm 0.004$	$552.6^a \pm 0.021$

Results are the means of three replications. Values carrying different superscripts in the same column are significantly different ($p<0.05$) for each food component. **Key:** $M_{u\text{-}}$ unprocessed maize; Md – de-germed maize; Bu: un-malted bambara groundnut; B_m: Malted bambara groundnut; Cu: un-malted cowpea; C_m: malted cowpea

3.1.2 Effect of malting on proximate composition

In the legumes, un-malted bambara groundnut and cowpea had lower protein content (215.80 and 248.50 g kg^{-1}) than the malted bambara groundnut (233.00g kg^{-1}) and malted cowpea (262.00 g kg^{-1}). Malting significantly ($p<0.05$) increased the protein content of bambara groundnut by 8.00 % and that of cowpea by 12.56 %. The increase in protein content of the malted legumes may be attributed to mobilization of storage nitrogen of the seeds to produce high quality protein to aid the development of the young plant. This findings is in agreement with the reports of Melleshi *et al*. [14] who reported significant increases in the protein content of weaning foods from sprouted sorghum and cowpea seeds. kavitha and Parimalavalli [15] ; Genah *et.al*. [16] also reported significant increases in the protein content of malted maize. Malting led to 16.56 % and 16. 31 % increase in ash content of bambara groundnut and cowpea respectively. A similar report of increase in ash content during malting has been reported by Genah et.al. [16]. Malting resulted in significant ($p<0.05$) decreases in the crude fat content and crude fibre of bambara groundnut and cowpea. The percentage decrease due to malting were for the crude fat: 14.78 and 22.42 %, crude fibre content: 24.41 and 15.38 %, carbohydrate content: 4.09 and 2.60 % for bambara groundnut and cowpea respectively. The decrease may possibly have arisen from the action of hydrolytic enzymes present in the seeds and mobilization of soluble nutrients into roots and shoots leading to the reduction of these nutrients. Similar results occurred in reports of Genah *et.al.* [16]; kavitha and Parimalavalli [15] ; Hahm *et al*. [17].

3.2 Malting characteristics of bambara groundnut and cowpea seeds

The root length, malting loss and diastatic activity of the malted bambara groundnut and cowpea seeds are presented in Table 2.

3.2.1 Root length

The root length of the germinating bambara groundnut and cowpea seeds increased and peaked at 1.45 cm and 4.01cm respectively after 72 hours of germination. The increasing values for bambara groundnut and cowpea suggests modification of the endosperm resulting from enhanced hydrolytic enzyme secretion, translocation and activity [18, 19]. For bambara groundnut, the root length increased by 48.37 % within the first 24 hour, 41.38 % between 24 and 48 hour and

Table 2: Malting characteristics of bambara groundnut and cowpea seeds.

Time(hours)	R.L (cm)		M.L (g/kg)		D.A (^{o}L)	
	B_m	C_m	B_m	C_m	B_m	C_m
O	0	0	0	0	$19.00^{a} \pm 0.032$	$30.25^{b} \pm 0.011$
24	$0.70^{a} \pm 0.006$	$1.17^{b} \pm 0.002$	$10.10^{a} \pm 0.005$	$11.70^{b} \pm 0.011$	$25.25^{a} \pm 0.003$	$33.75^{b} \pm 0.014$
48	$1.30^{a} \pm 0.001$	$2.35^{b} \pm 0.012$	$30.00^{a} \pm 0.00^{a}$	$42.50^{b} \pm 0.002$	$32.50^{a} \pm 0.033$	$34.25^{a} \pm 0.001$
72	$1.45^{a} \pm 0.004$	$4.01^{b} \pm 0.007$	$100.00^{a} \pm 0.003$	$120.00^{b} \pm 0.010$	$32.50^{a} \pm 0.014$	$36.25^{b} \pm 0.021$

Results are the means of three replications. Values carrying different superscripts in the same row are significantly different ($p<0.05$). Key: R.L- Root length, M.L-Malting loss, D.A-Diastatic activity, B_m- malted bambara groundnut seeds, C_m-malted cowpea seeds. o-out of steep

dropped to 10.35 % between 48 and 72 hour. The reduction in growth rate with time could be as a result of reduced mobilization of nutrients for growth due to decreased moisture availability for translocation of gibberellins and nutrients. The highest increase in root length was observed within the 24 - 48 hour window, within which mobilization of nutrient for growth was probably the highest.

For cowpea: the root length increased progressively, from 29.18 % within the first 24 hours to 29.43 % between 24 and 48 hours and further to 41.39 % between 48 and 72 hour. This implies that mobilization of nutrients was highest within the last 48 hour. On each day of germination, cowpea had higher root length (1.17 - 4.01 cm) compared to bambara groundnut (0.7 – 1.45 cm) suggesting a higher free space potential for mobilization and translocation of nutrient for the growing embryo.

3.2.2 Malting loss

The malting loss increased progressively during the 72 hours; for bambara groundnut it increased within the first 24 hours by 10.1 g/kg which represented a 1.1 % loss while between 24 and 48 hours it was 30.0 g/kg (3 % loss) and between 48 to 72 hours it was 100 g/kg (10 % malting loss). The increase in malting loss with germination time is due to mobilization of reserve nutrients, sprouts, loss of moisture and other volatiles. These results are in agreement with the report of Ilori and Ogundiwin [20].The total malting loss for bambara groundnut was 14.1 % for the 72 hours of malting.

For cowpea, the malting loss between 0 and 24 hours was 11.7 g/kg (1.17 %), between 24 and 48 hours, it was 42.5 g/kg (4.25 %) while for 48 and 72 hours it was 120.0 g/kg (12.0 %). The higher malting loss of the germinating cowpea seeds during the last 24 hour is indicative of the higher respiration rate and increased metabolic activity of the germinating seeds. The total malting loss for cowpea was 17.42 % for the 72 hours of malting. The highest value for malting loss of 100 g/kg and 120 g/kg in the last 24 hours of germination for bambara groundnut and cowpea respectively could be attributed to increased respiratory activities, degradation of cell wall contents, mobilization of endosperm matter and loss of dry matter as sprouts and volatiles [21].

Comparatively, cowpea had higher malting loss after 72 hour and could reflect a higher respiratory rate, loss of the longer rootlets as well as volatiles as a result of higher modification of its endosperm content. This may reflect structural differences between bambara groundnut and cowpea, with cowpea having a higher free space potential with facilitated oxygen and moisture movement during malting. The malting loss could also have contributed to the lower mineral content of the malted flours compared to the un-malted flours.

3.2.3 Diastatic activity

The diastatic activity increased progressively during the 72 hours; for bambara groundnut, the diastatic activity of out-of-steep seed flour was 19 ^{o}L, and increased by 32.90 % to 25.2 ^{o}L within the first 24 hours; between 24 and 48 hours, it increased by 28.96 % to 32.5 ^{o}L which was also the final values at 72 hours. The lack of increase between 48 and 72 hours could be attributed to the reduced growth rate due to reduced moisture content for the mobilization of gibberellins and nutrients. A similar trend was observed for cowpea in which the diastatic activity of out-of-steep seed flour was 30.25 ^{o}L and increased to 33.75 ^{o}L (11.57% increase) within the first 24hour; between 24 and 48hour it increased by 1.48 % to 34.25 ^{o}L and by 5.83% to 36.25^{o}L between 48 and 72 hours.

The highest percentage increase in diastatic activity was observed in the first 24 hours for both bambara groundnut and cowpea. This could be attributed to the high moisture content of the out-of-steep seeds [22] for adequate mobilization of gibberellins and nutrients for the growth of the embryo. Ogbonna[23] reported that enzyme activity is highest during the early stages of germination since this coincides with the movement of gibberellin.

3.3 Calcium, iron, zinc and vitamin A contents of the processed food components used in the complementary food blends.

The calcium, iron, zinc and vitamin A contents of processed maize, bambara groundnut, cowpea, cattle bone, *A. brasiliana, H. sabdariffa*, palm oil and *Brachystegia eurycoma* are presented in Table 3.

The calcium content of the unprocessed maize was 0.071g kg^{-1} and decreased significantly ($p<0.05$) to 0.061 g kg^{-1} in the degermed maize, which represented a 14.09 % loss due to degerming. Whole dry maize is low in calcium with a higher concentration in the germ compared to the endosperm [24], hence the loss in calcium may represent the amount of the mineral element in the germ [11, 13].

In the legumes, un-malted bambara groundnut and cowpea had higher calcium content (0.055 and 0.063 g kg^{-1}) than the malted bambara groundnut (0.051 g kg^{-1}) and malted cowpea (0.058 g kg^{-1}). Malting resulted in 7.27 % decrease in calcium for bambara groundnut and 7.94 % decrease in cowpea which may possibly have arisen from leaching. The higher percentage loss in cowpea may

Table 3: Calcium, iron, zinc and vitamin A content of processed food components used in complementary food formulation

	Calcium (g kg^{-1})	**Iron (g kg^{-1})**	**Zinc (g kg^{-1})**	**Vitamin A (µgRE/kg)**
Mu	0.071^b ±0.009	0.045^a ±0.005	0.024^b ±0.004	111.900^a ±0.002
M_d	0.061^a ±0.004	0.042^a ±0.007	0.020^a ±0.001	111.700^a ±0.023
Bu	0.055^b ±0.007	0.054^b ±0.001	0.037^a ±0.004	9.627^a ±0.011
B_m	0.051^a ±0.005	0.049^a ±0.003	0.036^a ±0.002	10.860^b ±0.041
Cu	0.063^b ±0.001	0.063^a ±0.006	0.049^b ±0.003	10.898^a ±0.065
C_m	0.058^a ±0.000	0.061^a ±0.004	0.047^a ±0.005	11.900^b ±0.013
A.b	4.786^b ±0.001	1.959^b ±0.003	0.219^b ±0.015	ND
A.b_a	4.675^a ±0.002	1.938^a ±0.006	0.213^a ±0.003	ND
H.s	5.727^b ±0.004	1.969^b ±0.007	0.746^b ±0.021	ND
H.s_a	5.696^a ±0.007	1.947^a ±0.003	0.733^a ±0.002	ND
Cb	3.910^a ±0.007	0.001^a ±0.005	0.050^a ±0.008	ND
Cb_a	4.010^b ±0.003	0.005^b ±0.002	0.051^a ±0.000	ND
Be	0.012^c ±0.000	0.05^b ±0.000	0.030^b ±0.006	15.219^a ±0.021
Pu	0.008^a ±0.006	0.001^a ±0.005	0.010^a ±0.003	1724.120^c±0.014
Pe	0.009^b ±0.001	0.009^a ±0.006	0.010^a ±0.007	615.350^b ±0.032

Results are the means of three replications. Values carrying different superscripts in the same column are significantly different ($p<0.05$) for each food component.

Key: M_u-unprocessed maize; M_d – de-germed maize; Bu: un-malted bambara groundnut; B_m: Malted bambara groundnut; Cu: un-malted cowpea; C_m: malted cowpea; Ab: *Alternanthera brasiliana,* A.b_a Ashed *Alternanthera brasiliana*,H.s: *Hibiscus sabdariffa*; H.s_a, Ashed *Hibiscus sabdariffa* Cb: Cattle bone; Cb_a Ashed Cattle bone; Be: *Brachestegia eurycoma* seed flour; Pu: unemulsified palm
oil; Pe: emulsified palm oil; ND: Not determined.

probably be due to the mealier texture of cowpea occasioned by a higher free space potential which encouraged more leaching of calcuim [13]. The calcium content of *A. brasiliana* and *H. sabdariffa* calyces decreased from 4.786 and 5.727 g kg^{-1} to 4.675 and 5.696 g kg^{-1} respectively after ashing, a loss of 2.32 and 0.54 % calcium for *A. brasiliana* and *H. sabdariffa* respectively. The higher loss in calcium for *A. brasiliana* compared to *H. sabdariffa* could be attributed to the presence of more organic matter in *A. brasiliana* than in *H. sabdariffa*. In contrast, ashing increased the calcium content of cattle bone from 3.910g kg^{-1} to 4.010g kg^{-1} (an increase of 2.55 %) which may be due to loss/decomposition of organic matter and release of mineral elements in bone. The increase in cattle bone compared to the decrease in *A. brasiliana* and *H. sabdariffa* may be due to the presence of more organic matter in *A. brasiliana* and *H. sabdariffa.* Comparatively, however, *H. sabdariffa* had the highest calcium content of 5.696 g kg^{-1} followed by *A. brasiliana* and suggests that ashed *H. sabdariffa* and *A. brasiliana* can be used in place of cattle bone in fortification for calcium.

The iron content of the unprocessed maize decreased from 0.045 to 0.042 g kg^{-1} in the degermed maize which represented 6.66 % loss due to degerming. However, there was no significant ($p<0.05$) difference in the iron of unprocessed maize and the degermed maize possibly because the iron content of the maize kernel is more concentrated in the endosperm than in the germ [11]. Bressani *et al*. [24] reported that the endosperm contains 76% of kernel iron while the germ contains about 18%. Hence the percentage loss due to degerming represents the amount of iron in the germ. The iron content of un-malted bambara groundnut and cowpea decreased from 0.054 and 0.063 g kg^{-1} to 0.049 and 0.061 g kg^{-1} respectively after malting. This represents a 9.25 % and 3.38 % loss in bambara groundnut and cowpea respectively and could be due to leaching during soaking and germination [13] or mobilization of minerals and other micronutrients for the growing roots which are removed after malting. The higher percentage loss (9.25 %) in bambara groundnut may be due to leaching as a result of the longer steeping time of 16 hours compared to 8 hours for cowpea. In addition, bambara groundnut may have a more porous testa and endosperm. In *A. brasiliana* leaves and *H. sabdariffa* calyces the iron content decreased from 1.959 and 1.969 g kg^{-1} to 1.938 and 1.947 g kg^{-1} respectively after ashing representing a loss of 1.07 and 1.11 % due to decomposition of organic matter. *H. sabdariffa* calyces had the highest iron content of 1.947 g kg^{-1} followed by *A. brasiliana* (1.938 g kg^{-1}). These results are lower than the 3.460 g kg^{-1} reported for *H. sabdariffa* [25] and 6.790 g kg^{-1} of iron for *A. brasiliana* [26]. Ashed cattle bone had the least iron content (0.002 g kg^{-1}) probably because there was no residual marrow or blood on it that could have contributed to the iron content, as bone is known to contain mainly calcium hydroxyapatite [27].

The zinc content of the unprocessed maize was 0.024 g kg^{-1} and significantly decreased to 0.020 g kg^{-1} in the degermed maize. Degerming resulted in 16.16 % loss in zinc content of the processed maize. The loss represents the amount of zinc in the germ where the majority of the zinc is found [24]. However, removal of germ and bran results in reduction of phytic acid which are concentrated in the germ leading to increased bioavailability of zinc [28, 11]). The zinc content of un-malted bambara groundnut and cowpea decreased from 0.037 and 0.049 g kg^{-1} to 0.036 and 0.047 g kg^{-1} after malting respectively. The percentage loss in zinc due to malting was 2.71% and 4.08 % for bambara groundnut and cowpea respectively and could be due to leaching during soaking and germination [13] or mobilization of minerals and other micronutrients for the growing roots which were removed after malting. The higher percentage loss in cowpea may be due to the porous / mealier nature of its endosperm. In *A. brasiliana* and *H. sabdariffa* calyces the zinc content decreased from 0.219 and 0.746 g kg^{-1} to 0.213 and 0.733 g kg^{-1} respectively after ashing. Ashing resulted in 2.70 and 1.75 % losses in zinc for *A. brasiliana* and *H. sabdariffa* respectively. There is however need to modify the degerming process so as to reduce loss of calcium and zinc.

The pro-vitamin A content decreased from 111.900 µgRE/kg in the unprocessed maize to 111.700 µgRE/kg in the degermed maize which represents a 0.18 % loss due to degerming. The loss due to degerming was not significant ($p > 0.05$) possibly because in the yellow maize kernel over 90 % of the carotenoids are found in the endosperm [29] while the germ contain only about 1% [11]. The pro-vitamin A content of un-malted bambara groundnut and cowpea increased from 9.627 and 10.898 µgRE/kg to 10.860 and 11.90 µgRE/kg respectively representing 12.81 % and 9.19 % increases respectively. The increase in vitamin A due to malting could be attributed to synthesis of pro-vitamin A [30] or it may be due to its concentration as a result of the associated malting loss. The pro-vitamin A content was higher in bambara groundnut compared to cowpea, possibly due to the larger size of the bambara groundnut germ.

Un-emulsified palm oil had the highest vitamin A content of 1724.12 µgRE/kg and decreased to 615.350 µgRE/kg on emulsification with *Brachystegia eurycoma.* Emulsification of palm oil with *Brachystegia eurycoma* resulted in 52.7% loss in pro-vitamin A and is possibly due to the presence of lipoxidase activity or complexation with components in *Brachystegia eurycoma*.

4. Conclusion

The study revealed that processing affected the chemical properties of components used in formulating maize-bambara groundnut and maize-cowpea complementary foods. It also pointed to the need to modify the treatments and eliminate the use of cattle bone in the formulation. However, *Alternanthera brasiliana* and *Hibiscus sabdariffa* are versatile plants which should be exploited in the formulation of nutritionally adequate complementary foods if properly processed and can replace the use of cattle bone in the formulation.

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