PROXIMATE AND MINERAL COMPOSITIONS OF NIBS AND SHELLS OF PROCESSED UNGERMINATED AND GERMINATED COCOA BEANS

E. I. Adeyeye,
Department of Chemistry, University of Ado Ekiti, P.M.B. 5363, Ado Ekiti, Nigeria
E-mail: eiadeyeye@yahoo.com
O. O. Ayejuyo,
Department of Chemistry, University of Lagos, Lagos, Nigeria.
Date Received: 4th April, 2010; Date Accepted: 5th June, 2010

Abstract

The proximate and mineral compositions of the nib and shell samples of germinated and ungerminated cocoa beans from Idanre Local Government Area of Ondo State, Nigeria, were evaluated. The dry weight of fifty-two whole cocoa beans ranged between 0.38-1.40 (0.85±0.27) g (germinated beans) and 0.89-1.30 (1.09±0.13) g (ungerminated beans). The mean moisture content of nibs was 4.38± 0.04 g/100 g (ungerminated beans) and 1.81±0.01 g/100 g (germinated beans) while shell moisture was 7.27±0.01 g/100 g (ungerminated beans) and 2.26±0.02 g/100 g (germinated beans). The protein content and ether extract for the ungerminated nibs have the following respective values in g/100 g: 18.25±0.02, 21.66±0.04, 46.82±0.03, 3.30±0.01 and 5.59±0.04 while the corresponding values in the germinated nibs were: 18.03±0.03, 8.15±0.02, 3.15±0.20 and 34.86±0.01. Na, K and P were more in the nibs and shell than Ca and Mg. The trace metals (Zn, Fe, Cu and Cr) were low in concentration in both the nibs and the shell. Significant differences occurred in the compositions of the nibs and shell of both germinated and ungerminated cocoa beans.

Keywords: Chemical composition, cocoa nibs and shell.

INTRODUCTION

Cocoa (or *Theobroma cacao* L); the tree is called cacao while the bean is called cocoa (Folayan, 1993). *Theobroma cacao* belongs to the family sterculiaceae, the same family as the kola tree (Cuatrecassa, 1964; Oyenuga, 1967). Cocoa, a low altitude crop was introduced into Nigeria in about 1894 by Squiss Ibaningo though commercial planting did not start until around 1914 (Folayan, 1993; Opeke, 1992). With particular reference to Nigeria, cocoa is the most valuable agricultural export produce obtained in exportable quantities in Ondo, Ekiti, Osun, Oyo, Edo, Delta, Cross River and Imo States (Folayan, 1993). Nigeria's current annual production was about 170,000 tonnes in 2007 and increase to 280,000 tonnes in 2008/2009. Ondo and Ekiti States account for over 60 % (that is, 102,000 tonnes) of Nigerian cocoa (Olagbaju, 1993). It was 869,000 tonnes in mid-March 2010 in the Ivory Coast. The type of cocoa grown in Nigeria is the Amelonado (melon shaped), a variety of Forastero (Wood, 1975).

The cocoa is obtained from pods which grow on cacao trees. The pods are egg-shaped, about eight inches long and contain twenty to thirty beans embedded in a soft white starchy pulp. The pods are split open and the beans, with adhering pulp, are scrapped out and allowed to ferment in a closed container for several days. A yeast fungus grows on the pulp and it liquefies owing to fermentation to alcohol. The liquid formed is allowed to drain away from the beans.During the process, change in colour occurs from the original light violet to dark brown. After drying in the sun, the beans are ready for shipment to the cocoa products manufacturers (Fox and Cameron, 1982).

The cocoa bean contains about 50 % fat that has served as a valuable source of vegetable fat-the cocoa butter. The residual cocoa powder is used in producing cakes, biscuits, beverages and in pharmaceuticals (Falade, 1993; Olagbaju, 1993; Osunkoya, 1970; Awolumate, 1986; Olaofe *et al.*, 1987).

In addition to flavour, physical aspects such as bean size, percentage shell and fat content influence the choice of cocoa beans by the cocoa products manufacturers (Folayan, 1993). The levels of desirable and undesirable metals in cocoa products are of great concern to both cocoa products manufacturers and consumers (Olaofe et al., 1987). Since cocoa products are used as food sources, the proximate composition is also important to consumers. At present there is little information on the chemical composition of cocoa in this part of the world. Reported in literature is the the effect of farm and industrial processing on the amino acid profile of cocoa beans by Adeyeye et al. (2010). To further enhance more information on the potential uses of cocoa; the proximate and mineral analyses of the cocoa beans (both nibs and shell) of germinated and ungerminated samples were carried out and reported here. It is hoped that the results will further enhance the uses of cocoa.

MATERIALS AND METHODS

Samples Collection and Preparation

The cocoa beans were obtained from ten different cocoa stores randomly selected in Idanre Local Government Area of Ondo State, Nigeria. (This local government is the second largest producer of cocoa in the state.) 500 g each of (germinated and ungerminated samples) were collected from each store and properly mixed together. The bulk portion of each type was then reduced to a more convenient size (20 %) by repeated quartering (Crosby, 1977). Fifty-two seeds of each type of cocoa were weighed individually as whole beans, shell removed and weighed and finally the nibs were removed mechanically. The shell and nibs were separately blended using a Kenwood food mixer. All the samples used were as collected from the cocoa stores.

Proximate Analysis

Moisture content, total ash and ether extract were determined by the methods of the Association of Official Analytical Chemists (AOAC, 2005). Crude fibre was determined by the method of Pearson et al. (1981) while the nitrogen free extract was determined by deference. Nitrogen was determined by the micro-Kjeldahl method described by Pearson (1976) and the percentage nitrogen was converted to crude protein by multiplying with a factor of 6.25.

Minerals Analysis

The minerals were analysed from solutions obtained by first dry-ashing the samples at 550 °C and dissolving the total ash in flasks using 10 % hydrochloric acid solution, 2cm^3 of 5 % lanthanum chloride and distilled and de-ionised water (Varian Techtron, 1975). Mg, Zn, Fe, Cu, Cr, Ca, Na and K were determined by means of an atomic absorption spectrophotometer (Pye Unicam Sp 9 Cambridge, U.K.) (Ajayi, 1986) while phosphorus was determined colorimetrically by using a Spectronic 20 UV/VIS Spectrophotometer using the phosphovanado molybdate method (AOAC, 2005). Before the analysis the spectrophotometer was calibrated by using the metal standard solutions. All chemicals used were of analytical grade obtained from the British Drug Houses (B.D.H.).

The data generated were analysed statistically (Chase, 1976). Using mean, standard deviation, coefficient of variation (%), correlation coefficient (C.C.), coefficient of alienation (C.A.), index of forecasting efficiency percent (I.F.E), regression coefficient (R.C.) at = 0.05.

RESULTS AND DISCUSSION

The average sizes of fifty-two dry cocoa beans of the two types analysed are shown in Table 1. The range for whole beans was 0.89-1.30 g with a mean of 1.09±0.13 g for ungerminated beans while the corresponding values in the germinated beans were 0.38-1.40 g and 0.85±0.27 g respectively. This means that the germinated cocoa bean was 0.24 g (22.02 %) less than the ungerminated beans in weight. The nibs weight in the ungerminated beans ranged between 0.78-1.17 g with a mean value of 0.96±0.12 g while the corresponding values in the germinated beans were 0.28-1.13 g and 0.73±0.25 g respectively. This means that the nibs in the germinated beans was 0.23 g (23.96 %) less than the nibs of the ungerminated cocoa. The shell weight in ungerminated cocoa beans ranged between 0.10-1.17 g with a mean of 0.13±0.02 g while the shell value in germinated cocoa beans ranged between 0.06-0.24 g with a mean of 0.12 ±0.04 g. This shows that the shell weighed 11.93 % in ungerminated cocoa but weighed 14.12 % in germinated cocoa. On comparison, the weight fractions of ungerminated and germinated cocoa beans showed high and significant correlation coefficient (0.95) at p=0.05. Also, the coefficient of alienation (0.31) was low with a corresponding high value of index of forecasting efficiency (68.78 %) showing that error of prediction of relationship between ungerminated and germinated beans could be reduced by as high as 68.78 %. The regression coefficient also showed that for every one unit increase in weight in the ungerminated

Table 1: Dry cocoa bean weight fraction (g) [a]

Parameter	Ungerminated cocoa	Germinated cocoa
Whole bean	0.89-1.30 (1.09±0.13) [b]	0.38-1.40 (0.85±0.27)
Nib	0.78-1.17 (0.96±0.12)	0.28-1.13 (0.73±0.25)
Shell	0.10-0.17 (0.13±0.02)	0.06-0.24 (0.12±0.04)
Overall mean	0.73	0.57
Overall S.D.[c]	0.43	0.32
C. C.		0.95*
C. A.		0.31
I. F. E.		68.78 %
R. C.		1.86

P = 0.05; C. C. = Correlation coefficient; C. A. = Coefficient of alienation; I.F.E. = Index of forecasting efficiency (%); R. C. = Regression coefficient; * = significant; [a]Mean of fifty-two beans; [b]Figures in brackets are mean with standard deviations; [c]Standard deviation.

The recommended average level of shell in cocoa bean is about 12.0 % of the whole bean (Ajayi, 1986). This means the ungerminated cocoa beans was 0.07 (0.85 %) less in shell requirement while the germinated cocoa was 2.12 (17.67 %) greater in the expected level of shell. Bean size is of importance to the manufacturer because it affects shell percentages, fat content and the initial roasting process (Wood, 1975). Manufacturers want to buy beans with the lowest shell percentage consistent with adequate protection of the nib from mould and insects and with highest fat content. These two factors do not vary with bean size provided the beans do not weigh below 1.0 g (0.04 Oz) (Wood, 1975). Nigeria sells two grades of cocoa beans according to the bean size, purchases with more than 300 beans, to 11 0z being graded as `light crop', as distinct from `Main crop' for other purchases (Wood, 1975). The shell percentage of cocoa beans from Ghana and Nigeria is 11-12 % and this is generally accepted as the standard; beans from Trinidad and New Guinea have 15-16 % shell (Wood, 1975). This means manufacturers will prefer West African cocoa based on the above criterion, this is more so since the germinated cocoa bean is usually of less than 3 % production and usually not combined with the ungerminated beans.

Table 2: Proximate composition (g/100 g) of ungerminated and germinated cocoa beans (dry weight) [a]

Constituent	Ungerminated cocoa beans		Germinated cocoa beans	
	Nib	Shell	Nib	Shell
Moisture content	4.38 ± 0.04	7.27 ±0.01	1.81 ±0.01	2.26 ±0.02
Dry matter	95.62 ±0.01	92.71 ±0.03	98.19 ±0.10	97.74 ±0.20
Total ash	3.30 ±0.01	7.47 ±0.01	3.15 ±0.20	8.69 ±0.00
Crude protein	18.25 ±0.02	14.94 ±0.03	18.03 ±0.03	16.89 ±0.01
Ether extracts	21.66 ±0.04	10.95 ±0.04	8.15 ±0.02	12.89 ±0.02
Crude fibre	46.82 ±0.03	18.33 ±0.01	34.00 ±0.03	26.01 ±0.03
Nitrogen free extracts	5.59 ±0.04	41.02 ±0.03	34.86 ±0.01	38.125 ±0.02
Energy (Cals/100 g) [b]	290.30 ± 0.02	322.39 ±0.01	284.91 ±0.02	334.25 ±0.04
Overall mean	60.74	64.39	60.39	67.11
Overall S.D.	97.80	108.13	95.93	112.07
C.C.	0.98*		0.99*	
C.A.	0.20		0.14	
I.F.E.	80.00 %		86.00 %	
R.C.	1.09		1.17	

[a]Determinations were in triplicate;

[b]Calories/100 g.

The proximate composition of the ungerminated cocoa beans is shown in Table 2. Both the proximate values in the nibs and shell are shown. The average value for the moisture content was 4.38 ±0.04 g/100 g in the nibs and 7.27 ±0.01 g/100 g in the shell. The moisture content was lower than the critical moisture content (8.0 g/100 g) (Olaofe *et al.*, 1987; Scott, 1928) for mould growth in cocoa. This means that the shelf life of the cocoa beans will be reasonably long. The moisture contents of cocoa beans previously reported were: Rawnsley (1959), 6.0-7.0 g/100 g; Lee (1972), 6-8 g/100 g; Oyenuga (1968), 4.3 g/100 g; Ockerman (1978), 4.39 g/100 g and Olaofe *et al.* (1987), 2.0-3.2 g/100 g. The differences between the present results and those in the literature could be due to the relative equilibrium moisture contents in different environments and lengths of time of sun drying. The dry matter was high because moisture content was low.

The total ash content with mean values of 3.30 ±0.01 g/100 g (nibs) and 7.47 ±0.01 g/100 g (shell) is an indication of the total quantity of inorganic material in the samples. The pattern of ash distribution between the nibs and the shell is consistent with the report of Oyenuga (1968) who reported higher ash content for shell than the nibs. The total ash reported for the current work is more than what Opeke (1992) reported (2.74 %) for nibs but the current work fell within the range reported by Olaofe *et al.* (1987). The variation between the current report and literature values could be as a result of factors such as soil pH, soil nutrients and/or level of fertilizer applied (Olaofe *et al.*, 1987).

The protein content of the ungerminated cocoa beans was 18.25 ±0.02 g/100 g (nibs) and 14.94 ±0.03 g/100 g (shell). Both values were greater than the values reported by Opeke (1992) which was 13.50 % (nibs) while nibs and shell values were 14.28 % and 14.50 % respectively as reported by Oyenuga (1968). The reasons for the variation in the protein values in literature and the current report are consistent with those given for the variation in the ash from different sample locations. Cocoa bean protein is of fairly good quality since it contains most of the amino acids essential for growth. It is high in lysine, it is therefore a useful source of protein for supplementing foods with low lysine but high methionine content (Oyenuga, 1968).

The ether extract was 21.66 ±0.04 g/100 g in the nibs and 10.95 ±0.04 g/100 g in the shell. The ether extract of the nibs was lower than the value reported by Opeke (1992), 54.68 %; Oyenuga (1968), 42.84 % and Osunkoya (1970), 49.0 % but the ether extract of the shell was higher than the 3.10 g/100 g reported by Oyenuga (1968). Bean size, shell and fat percentage are all said to be influenced by the distribution of rainfall during the period of development of the crop (Toxopeus and Wessel, 1970). A close correlation between rainfall and bean weight has been established by a detailed study carried out in Nigeria (Toxopeus and Wessel, 1970). Beans harvested in June normally start their development in the dry season and are smaller, have a higher shell percentage and a lower butter fat than the main crop beans harvested from September onwards, which develop during the rainy season (Wood, 1975). The collection of our samples was around May; hence, the development of our samples must have been during the dry season with consequent lowering of the fat content.

The crude fibre was high in the nibs (46.82 ±0.03 g/100 g) but low in the shell (18.33 ±0.01 g/100 g). The value of crude fibre in the shell as reported by Oyenuga (1968) is close (18.30 %) with the current value of 18.33 % whereas our value fibre in the nibs is higher than the value of 8.96 % reported by Oyenuga (1968). Environmental conditions could have been responsible for the variation in the literature and the current report. The nitrogen free extract was low (5.59 ±0.04 g/100 g) in the nibs but high (41.02 ±0.03 g/100 g) in the shell, a similar trend was reported by Oyenuga (1968).

The cocoa bean shell is an important byproduct in the chocolate industry. The shell can be hydrolysed under pressure with sulphuric acid to promote fermentable sugars (Opeke, 1992). As a result of its low fibre content, freedom from alkaloids and good ash component (Opeke, 1992) the shell is a suitable ruminant food. The shell is said to contain a substantial amount of vitamin B_2 (about 300 I. U. per gram) (Knapp and Coward, 1939). The shell has been successfully used as cattle food in compound rations in which form the theobromine (1-15 %) content is known to have a stimulating effect upon milk production (Knapp and Coward, 1939). Cocoa shell, when fed to dairy cows, increase the butter fat and vitamin B content of the milk (Knapp and Coward, 1939).

The energy values were calculated using the Atwater factors (Oke and Ojofeitimi, 1984). The values were reported in kilocalories (cals/100 g). The calculated values were high because of high fat content for which it is valuable in cold countries and/or high carbohydrate content.

The proximate values of the germinated (rejects) cocoa are shown also in Table 2. The values in the various parameters determined mostly followed the trend as observed for the ungerminated cocoa beans. The moisture content was very low and this may lead to the beans being very brittle (Wood, 1975). Here, the shell contained more ether extract than the nibs; this is in reverse of our observation in the ungerminated beans. The nitrogen free extract content of the nibs in the germinated beans was higher than in the ungerminated beans.

Germinated cocoa beans are considered a defect because the hole in the shell by the emerging radicle offers an opening for moth and insects to invade the beans. Opeke (1992) gave some causes of germination of cocoa beans like: leaving pods on trees unharvested for several weeks, fermenting in hole in the ground and not turning the beans during fermentation. The effects of germinated beans include lowering of cocoa quality and reduced price. Cocoa is unsalable if too much is found (Opeke, 1992). Awolumate also attributed the following to germinated cocoa bean: has lower weight (see Table 1), wear down the processing machine, reduces the cocoa butter yield but has no effect on the taste of its products (private communication, 1986).

Table 2: shows that significant differences occurred (p=0.05) between the nibs and the shell in both the germinated and the ungerminated beans. The coefficient of alienation was low in both samples with values of 0.20 in ungerminated cocoa beans (U.C.B.) and 0.14 in germinated cocoa beans (G.C.B.), but with corresponding high values of index of forecasting efficiency of 80 % and 86 %, respectively. Regression coefficient values 1.09 (U.C.B.) and 1.17 (G.C.B.) showing that the shell would have contributed more into the proximate composition values in both the germinated and the ungerminated cocoa beans.

Table 3: Proximate composition of nib and shell of ungerminated and germinated cocoa beans compared

Constituent	Nib (U.C.B.)[a]	Nib (G.C.B.)[b]	Shell (U.C.B.)[a]	Shell (G.C.B.)[b]
Moisture content	4.38 ±0.04	1.18 ±0.01	7.27 ±0.01	2.26 ±0.02
Dry matter	95.62 ±0.01	98.19 ±0.10	92.71 ±0.03	97.74 ±0.20
Total ash	3.30 ±0.01	3.15 ±0.20	7.47 ±0.01	8.69 ±0.00
Crude protein	18.25 ±0.02	18.03 ±0.03	14.94 ±0.03	16.89 ±0.01
Ether extracts	21.66 ±0.04	8.15 ±0.02	10.95 ±0.04	12.89 ±0.02
Crude Fibre	46.82 ±0.03	34.00 ±0.03	18.33 ±0.01	26.01 ±0.03
Nitrogen free extracts	5.59 ±0.04	34.86 ±0.01	41.02 ±0.03	38.12 ±0.02
Energy (Cals/100 g)	290.30 ±0.02	284.91 ±0.02	322.39 ±0.01	334.25 ±0.04
Overall mean	60.74	60.31	64.39	67.11
Overall S.D.	97.80	95.99	108.13	112.07
C.C	0.99*		0.99*	
C. A.	0.14		0.14	
I.F.E.	86.00 %		86.00 %	
R.C.	1.17		1.17	

[a]U.C.B. = Ungerminated cocoa beans;

[b]G.C.B. = Germinated cocoa beans.

A pair wise comparison for both the nibs and the shell in the ungerminated and germinated cocoa beans are shown in Table 3. The Table shows that high difference occurred in the values of moisture with a percent coefficient of variation (C.V.) of 58.72 %, ether extract of C.V. of 64.09 % and nitrogen free extract of C.V. of 102.53 %. On the whole, high positive significant correlation coefficient occurred (p=0.05) between the nibs of both samples while the regression coefficient showed that for every unit increase in the proximate composition in the ungerminated cocoa beans, there is an increase of 1.17 units in the proximate composition of germinated cocoa beans. The proximate values of shell as depicted in the Table show that the moisture content has a wide variation among the two different samples with C.V. of 74.48 %. Other parameters determined show the C.V. values of less than 50.0 %. The correlation coefficient was high (0.99) and significant (p=0.05), the coefficient of alienation was low (0.14 or 14.0 %), the index of forecasting efficiency was high (86.0 %) and the regression coefficient was also high (1.17). The mean values obtained for moisture, total ash and crude protein are very close to the values reported by Opeke (1992) but our values for ether extract and crude fibre were higher than those reported by Opeke (1992).

Table 4: Mineral composition (mg/kg) of ungerminated and germinated cocoa beans (dry weight)*

	Ungerminated cocoa beans		Germinated cocoa beans	
Constituent	Nib	Shell	Nib	Shell
Magnesium	2.15 ±0.20	2.15 ±0.15	2.16 ±0.10	2.18 ±0.20
Zinc	2.65 ±0.12	2.68 ±0.03	2.72 ±0.15	2.62 ±0.01
Iron	3.91 ±0.04	3.26 ±0.02	1.20 ±0.05	5.65 ±0.03
Copper	0.16 ±0.04	0.10 ±0.05	0.10 ±0.01	0.05 ±0.01
Chromium	0.28 ± 0.01	0.09 ±0.02	0.66 ±0.02	0.57 ±0.03
Calcium	4.35 ±0.02	2.39 ±0.01	1.09 ±0.10	1.52 ±0.12
Sodium	330.00 ±0.01	495.00 ±0.01	340.00 ±0.02	320.00 ±0.03
Potassium	145.00 ±0.01	110.00 ±0.01	35.00 ±0.02	70.00 ±0.03
Phosphorus	149.83 ± 0.01	50.25 ±0.02	666.68 ±0.23	126.00 ±0.20
Overall mean	70.93	73.99	116.62	58.73
Overall S. D.	115.73	162.18	234.23	107.34
C.C.	0.93*		0.66*	
C.A.	0.37		0.75	
I.F.E.	63.00 %		25.00 %	
R.C.	1.30		0.30	

*Determinations were in triplicate.

The mineral values of the ungerminated cocoa beans in both the nibs and the shell are shown in Table 4. The values of Na, K and P were 330.0 ±0.02 mg/kg, 145.0±0.02 mg/kg and 149.83±0.01 mg/kg in the nibs respectively. These results therefore suggest that cocoa beans can provide appreciable amounts of these minerals in cocoa-based products (Fleck, 1976). The shell also contains appreciable levels of Na, K and P. Mg, Zn Fe, Cu, Cr and Ca were low; they can however still supplement such minerals from other food sources. The distribution of the minerals between the nibs and shell is quite varied for Cr and P where coefficient of variation percent (C. V. %) were 72.62 and 70.39 respectively. There is no variation in the distribution of Mg while Zn, Fe, Cu, Ca, Na and K have C.V. (%) values less than 50.0 each. The ratio of Na: K in the nibs was 2.3: 1.0 showing that Na was more highly concentrated in the nibs than K.

The mineral elements in the germinated cocoa beans are also shown in Table 4. The results follow the trend of the result in ungerminated samples. However, Fe and P have very high C.V. (%) with values of 91.87 and 136.17 respectively. Other metals have variations less than 50.0 %. The high value of P (666.68±0.23 mg/kg) in the nibs of the germinated cocoa beans deserves special attention. The germinated cocoa beans when fermented leads to the death of the beans, the death results in a breakdown of the internal cell structure (normally enhanced by germination) which allows various enzyme reactions to take place thereby converting some of the polyphenolic compounds (Wood, 1975). This conversion might lead to the release of phosphorus from chelate complexes resulting in the higher values of the mineral. The statistical analyses results showed a high positive (0.93) and significant correlation coefficient (C.C.) (p=0.05), low (0.37) coefficient of alienation (C.A.), high (63.0 %) index of forecasting efficiency (I.F.E.) and high (1.30) regression coefficient (R.C.) in the ungerminated beans. However, in the germinated beans, C.C. was high (0.66) and significant (p=0.05), C.A. was high (0.75 or 75.0 %), I.F.E. was 25.0 % making prediction of relationship between the nibs and the shell in the germinated cocoa beans difficult, the R.C. was 0.30 which means that in the overall mineral composition (as determined here) for every unit increase in the mineral composition in the nibs there is just a corresponding increase of 0.30 in the shell minerals.

The values of our results for Mg, Zn, Cu, Ca and K are lower than those reported by Olaofe *et al.* (1987) while our result for Fe falls within their own range but our result for Na is higher than their values; they did not determine P and Cr. The major differences in the mineral values in literature and the current report might be due to the level of metals in the soils in the different locations (Sutcliffe and Baker, 1974) and/or application of fertilizers. The possibility of gross variation in the mineral content of cocoa-based products can be minimized by thorough blending of raw material batches before processing (Olaofe et al., 1987). The various physiological importance of the minerals determined have been enumerated (Crosby, 1977; Rawnsley, 1959). The mineral values in this report are slightly higher than the results obtained in *Cola acuminata* (Adeyeye and Ayejuyo, 1994) which is also used as a constituent of beverages like the cocoa beans; they also belong to the same family of sterculiaceae.

Table 5 showed the pair wise comparison between the mineral elements determined in the nibs and shell of both germinated and ungerminated cocoa beans. Minerals that showed high variation in the nibs were Fe (59.38 %), Cr (57.45 %), Ca (84.92 %) and P (135.20 %) while the variations in the remaining minerals were less than 50.0 %. Although a significant difference occurred (p=0.05) between the mineral contents in the nibs, the reduction in the error of prediction (index of forecasting efficiency) was low with a value of 25.0 % making the prediction difficult. Also the regression coefficient showed that where the nib of ungerminated cocoa bean will contribute one unit to the overall composition; the germinated nib will contribute an overall 1.33. In the mineral variation in the shell values were high in Cr (102.78 %) and P (100.64 %). However, the reduction in the error of prediction of relationship in the shell of germinated and ungerminated cocoa beans was high (72.0 %) with higher significant correlation coefficient (0.96) and a higher value of regression coefficient (0.63). The results in Tables 4 and 5 shows that the mineral qualities of germinated and ungerminated cocoa beans may not warrant the total rejection of germinated cocoa beans by cocoa beans processors. The subject of byproducts and alternative uses for cocoa beans was reviewed by Greenwood-Barton (1965) and their use in the feeding of livestock has been described by Owusu-Damfeh (1972).

Table 5. Mineral composition of nib and shell of ungerminated and germinated cocoa beans compared

Constituent	Nib (U.C.B.)	Nib (G. C. B.)	Shell (U. C. B.)	Shell (G. C. B.)
Magnesium	2.15 ±0.20	2.16 ±0.10	2.15 ±0.15	2.18 ±0.20
Zinc	2.65 ±0.12	2.72 ±0.15	2.68 ±0.03	2.62 ±0.10
Iron	3.91 ±0.04	1.20 ±0.05	3.26 ±0.02	5.65 ±0.03
Copper	0.61 ±0.04	0.10 ±0.01	0.10 ±0.05	0.05 ±0.01
Chromium	0.28 ±0.01	0.66 ±0.02	0.09 ±0.02	0.52 ±0.03
Calcium	4.35 ±0.02	1.09 ±0.10	2.39 ±0.01	1.52 ±0.12
Sodium	330.00 ±0.01	340.00 ±0.02	495.00 ±0.01	320.00 ±0.03
Potassium	145.00 ±0.02	35.00 ±0.02	110.00 ±0.01	70.00 ±0.02
Phosphorus	149.83 ±0.01	666.68 ±0.23	50.25 ±0.02	126.00 ±0.20
Overall mean	70.93	116.62	73.99	58.73
Overall S. D.	115.73	234.23	162.18	107.34
C. C.	0.66*		0.96*	
C. A.	0.75		0.28	
I.F.E.	25.00 %		72.00 %	
R. C.	1.33		0.63	

CONCLUSION

The findings of this study suggest that both germinated and ungerminated cocoa beans have comparable nutritionally valuable minerals with the exception of K and P. The proteins, crude fibre and energy were high; the high crude fibre concentration could be advantageous, if it possesses hypocholesterolemic properties (Selvendran *et al.*, 1979); the low moisture assists a long shelf-life. The results here will further enhance information on cocoa beans in the food composition tables.

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