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SUPERIORITY OF GERMINATED OVER RAW SAMPLE IN PROXIMATE COMPOSITION AND OVER BOTH RAW AND FERMENTED IN MINERALS OF *ZEA MAYS* L. DK 818

Emmanuel Ilesanmi Adeyeye[1✉], Abdul Ademola Olaleye[2], Adeolu Jonathan Adesina[1], Sulaimon Adeoye Olagboye[1], Olusegun Opeyemi Ayejuyo[3]

[1]*Department of Chemistry, Ekiti State University, Ado-Ekiti, P.M.B. 5363, Ekiti State, Nigeria*
[2]*Department of Chemistry, Federal University Dutse, P.M.B. 7156, Jigawa State, Nigeria*
[3]*Department of Chemistry, Faculty of Science, University of Lagos, Nigeria*
✉*adeyeyeilesanmi2012@gmail.com*

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ABSTRACT

This research report dealt with proximate and mineral analyses of raw (B11), germinated (B22) and fermented (B33) maize grains from the same source. Values of dry matter, organic matter and carbohydrate were high at (g/100g): 94.2-95.3, 92.9-94.6 and 74.4-75.8 respectively. Crude protein had these values (g/100g): B11 (10.9) < B22 (13.0) < B33 (13.2). Crude fat was moderate at 5.05-5.59 g/100g. On concentration levels, the following were observed in the proximate composition: B22 > B11; B22 ≡ B33; B11 > B33. The energy from Z. mays was majorly from the carbohydrate (kcal/100g): B11 (303, 77.3%); B22 (297, 74.4%) and B33 (302, 75.5%). These minerals were generally high in the samples (mg/100g): K (550-661), Mg (220-235), P (369-401) whereas values were low for Fe, Cu, Co, Mn, Zn, Se and < 0.001 in Pb. The mineral density per sample ran thus (mg/100g): B11 (1227)< B22 (1403) > B33 (1313). On the whole, B22 > B33 >B11 as follows: B22> B11, 12/12 = 100%; B22>B33, 10/12 = 83.3%; B33 > B11, 8/12 = 66.7%. In the mineral ratios determined, only Zn/Cu values of 7.80-10.7 were close to reference balance ideal of 8.00. All the calculated mineral safety index (MSI) were lower than the standard Table values. At both proximate and mineral levels, the pairs: B11/B22, B11/B33 and B22/B33 were significantly different at r=0.01. All the index of forecasting efficiency (IFE) were high making it possible for one of the pairs to carry out the other pair metabolic functions and vice versa.

1. Introduction

The word "maize" derives from the Spanish form of the indigenous Taino word for the plant *mahiz* (Maize, 2012). It is known by other names around the world. Seed of maize contains endosperm which is a food storage organ and consists primarily of starch which is digested into sugar when germination occurs and growth begins. Maize may be divided into vaious groups differing in endosperm character of the seeds. These groups or types are (Obi,1991):

-Flour corn: *Zea mays* var. *amylacea* Sturt.
-Popcorn: *Zea mays* var. *everta* Sturt.
-Dent corn: *Zea mays* var. *indentata* Sturt.
-Flint corn: *Zea mays* var. *indurate* Sturt.
-Sweet corn: *Zea mays* var. *saccharata* Sturt and *Zea mays* var. *rugosa*.
-Waxy corn: *Zea mays* var. *ceratina* Kulesh.
-Amylomaize: *Zea mays*
-Pod corn: *Zea mays* var. *tunicate* Sturt Larranaga ex A. St. Hil.
-Striped maize: *Zea mays* var. *japonica*

This is an artificial classification that is not indicative of natural relationships; however, these subspecies are sometimes classified as various subspecies related to the amount of starch each has. Dent and Flint account for the bulk of world production; pop, sweet and flour corn are used almost entirely for human consumption; pod and waxy are not important as food stuffs, however, waxy maize is used industrially in the United State of America (Obi, 1991).

1.1. Maize scientific classification

Kingdom (Plantae), *Clade* (Tracheophytes), *Clade* (Angiosperms), *Clade* (Monocots), *Clade* (Commelinids), Order (Poales), Family (Poaceae), Genus (*Zea*), Species (*Z. mays*), Binomial name (*Zea mays* L.).

Maize is widely cultivated throughout the world and a greater weight is produced each year than any other grain (International Grains Council, 2013). In 2018, total world production was 1.15 billion tonnes, led by the USA with 34.2% (392.5) of the total. China produced 22.4% (257.3) of the global total (FAOSTAT, 2020). Actual world total was 1147.6 (millions of tonnes). Nigeria was number 14 world producer (10.2 million tonnes) which is about 0.889%. Maize has a very high yield of energy more than wheat and rice. Maize of about 93% extraction has an average yield of 5.4 million calories per hectare, thus ranking wheat (85% extraction) and rice (70% extraction) which gave average yield of 3.2 and 4.3 million calories per hectare, respectively (FAO, 1968). In Africa, maize consumption accounts for about 64% of the total daily calorie intake of the rural dwellers especially during the hunger "period". In Southern Nigeria, maize has been used primarily as human food (Obi, 1991). It is eaten as whole grain when boiled or roasted and used in its prepared form as pap (*ogi*) or eko (*Agidi*) which is an extracted starch meal obtained after a prolonged soaking of maize. Maize consumption in the Western States of Nigeria varies from 2.6-2.8kg per person per week (Agboola, 1979). In Nigeria, Anasonwu-Bello (Anazonwu – Bello, 1986) published over forty recipes from maize to encourage maximum use of maize as food-crop and to give it a new outlook. Of these recipes "Ogi" (Yoruba) or "Agidi" (Igbo) and "Akamu" (Igbo) are corn diets eaten by almost all the ethnic groups of Nigeria. Obi (1991) had further elaborated the maize recipes of other countries. In Ghana, "Kenkey" is the principal corn diet of the people. In Benin Republic (corn fritters); in Cameroon (Koga); in Malawi (roasted and parched maize); in Kenya ("Posho" or Gruel", "Ugali" and "Gbenga"); in the Republic of South Africa (Mahewa or Magou, a non-alcoholic drink, is made from sorghum which is supplemented with corn); in Central and South America, "Tortilla" as "Echilada" or "Taco" or "Tamele" are corn diets of the people. From Central and South America, other food preparations of corn are "Atole", "Penolillo", "Chicheme", "Colada" and "Chicha dulee". In Nigeria, *akamu* or *ogi* has a consistency similar to that of American pudding (Kulp, 2000). *Ogi/Akamu* in Nigeria is generally accompanied with *moinmoin*, a bean pudding of *akara* which is a bean cake.

Maize grains have long been shown to be of poor quality protein and consequently of poor nutritive value due to high levels of zein. The protein fraction of maize (zein) has insignificant amounts of Lys and Trp (Jose, 1966). The deficiency of these amino acids has resulted in negative nitrogen balance and poor growth of animals and humans fed on unbalanced maize meals. The economic importance of developing a good quality protein maize is immense. It will go a long way in helping to solve human nutritional problems especially kwashiorkor among babies weaned *akamu* or *ogi* diet.

The major aim of this research was to see if processing the maize grains would improve their nutritional quality. To this end, similar grains of maize (*Zea mays* L. Dk 818) were subjected to fermentation and sprouting, dried, pulverized and analysed for proximate and mineral contents. Data results were discussed comparatively and conclusions drawn.

2. Materials and methods

2.1. Collection of samples

Samples of maize grains were collected from the Department of Crop, Soil and Wildlife, Ekiti

State University, Ado-Ekiti, Nigeria. About 1.5kg of the grains were used for the experiments. After removing stones, damaged grains, manually, the maize grains were divided into three equal parts for use as raw, steeped (fermented) and germinated (sprouted) maize samples. Raw samples were labeled as B11 and no further treatment after cleaning. It was however dried to constant weight.

2.2. Sample treatment

For steeping, 0.50kg grains were placed in a plastic container, covered with distilled water and left in the laboratory at ambient temperature (30.9^{o}C) at 0.41 Im^2/ft light intensity. After four days, grains were washed with distilled water, dried in sun to constant weight and stored in covered plastic container; this was labeled B33 (Fig-1). For germination of samples, 0.5kg were soaked in water at room temperature for 24 h; then spread on a damp fabric, protected from direct sunlight, for approximately 48 h until 5.04cm long sprouts developed. Germinated grains were dried in sun for three days until constant weight; sprouts were manually removed and desprouted grains were stored in plastic container (FAO, 1976); this was labeled sample B22 (Fig-1). Each sample was homogenized, sieved using 200 mesh size and kept in the refrigerator (2.8^{o}C). Triplicates of raw, steeped and germinated grains were used for the proximate and mineral compositions.

2.3. Proximate composition determination

Moisture content was estimated gravimetrically by drying the flours at 100^{o}C in ventilated oven to express moisture in g/100g. Crude protein (N × 6.25) of the flours was evaluated following the method of micro-Kjeldahl (Pearson, 1976). Crude fat was extracted with chloroform/methanol (2:1 v/v) mixture using Soxhlet extraction apparatus (AOAC, 2006). Carbohydrate was calculated by difference.

Carbohydrates (g/100g) = [Protein (g/100g) + Lipids (g/100g) + Fibre (g/100g) +Ash (g/100g) + Moisture (g/100g)] (1)

Gross energy (kcal/kJ/100g) was calculated using Atwater factors (Muller and Tobin, 1980).

Gross energy (kcal/100g) = (Protein × 4) + (Lipid × 9) + (Carbohydrate × 4) (2)

Gross energy (kJ/100g) = (Protein × 17) + (Lipid × 37) + (Carbohydrate × 17 (3)

Utilizable energy due to protein (%): UEDP % = %protein energy in gross energy × 60% (4)

Energy requirement for infants per day: calculation = 100/Total energy value × 740 kcal (5)

Water required for complete protein metabolism for each sample: X × 3 = y; 3.5 × X = Z; Z-Y = water required (6)

where 3 = 1 calorie of protein requires 3.0ml of water for excretion of the urea and sulphate formed from it; X = protein energy in kcal/100g; 3.5 = water deficit (350/100 = 3.5).

Conversion of lipid to total fatty acid (TFA): Crude fat × 0.72 = TFA (Greenfield H. & Southgate, 2003) (7)

2.4. Mineral analysis

Minerals were determined using the solutions obtained by ashing the samples at 550^{o}C and dissolving it in 10% HCl and (25ml) and 5% lanthanum chloride (2ml), boiling, filtering and making up to standard volume with deionized water. Phosphorus was evaluated colorimetrically using a Spectronic 20 (GallenKamp, London, UK) instrument with KH_2PO_4 as the standard (AOAC, 2006). Na and K were determined by flame photometry, Model 405 (Corning, Halstead Essex, UK) using NaCl and KCl to prepare standards. All other elements (Ca, Mg, Fe, Zn, Ni, Co, CU, Pb and Se) were determined by atomic absorption spectrophotometry, Model 403 (perkin-Elmer, Norwalk, Connecticut, USA). All chemicals used were of analytical grade, and were products obtained from British Drug House (BDH, London, UK). Detection limits for the metals in aqueous solution had been determined just before the mineral analyses using the methods of Varian Techtron (Varian, 1975) giving the following values in µg/ml: Fe (0.01), Cu (0.002), Na (0.002), K (0.005), Ca (0.04), Pb (0.08), Mg (0.002), Zn (0.005), Mn (0.01), Co (0.05), Mn (0.01) and Se (0.15). The optimal analytical range was 0.1-0.5 absorbance units with coefficients of variation from 0.9-2.2%. From the mineral elements determined, further calculations were made.

2.5. Mineral ratios

Ratios of Ca/Mg, Ca/K, Zn/Cu, Ca/P, Fe/Cu, Ca/Pb, Fe/Pb, Fe/Co, Na/Mg, K/Co, K/[(Ca + Mg)], Na/K and Zn/Pb (Hatcock, 1985; Watts, 2010; ARL, 2012) were calculated.

Mineral safety index (MSI)

The mineral safety index (MSI) (Hatcock, 1985) of Fe, Ca, P, Mg, Zn, Na and Se were calculated using the formula:

MSI = MSIs/RAI × Research data result (8)

where MSI = mineral safety index of Table (standard); RAI = recommended adult intake.

2.6. Statistical analyses

Both descriptive and inferential statistics were used to discuss the analytical results. The descriptive statistics used were mean, standard deviation (SD) and coefficient of variation percent (CV%). For the inferential statiatics, Pearson's moment correlation coefficient (r_{xy}) mode was used (Oloto, 2001). Further to the r_{xy} calculation were the determination of variance (r_{xy}^2), regression coefficient (R_{xy}). Also determined were the coefficient of alienation (C_A) and index of forecasting efficiency (IFE) (Chase, 1976). The level of significance of r_{xy} was determined at a critical level of $r_{=0.01}$.

$$C_A = \sqrt{1-(r_{xy})^2} \quad (9)$$

$$IFE = (1 - C_A)100 \quad (10)$$

2.7. PubChem CID for mineral elements

Mineral elements studied in this report were: Copper/Cu (PubChem CID: 23978); Iron/Fe (PubChem CID: 23925); Zinc/Zn (PubChem CID: 23994); Magnesium/Mg (PubChem CID: 5462224); Calcium/Ca (PubChem CID: 5460341); Cobalt/Co (PubChem CID: 104730); Manganese/Mn (PubChem CID: 23930); Sodium/Na (PubChem CID: 5360545); Potassium/K (PubChem CID: 5462222); Phosphorus/P (PubChem CID: 5462309); Selenium/Se (PubChem CID: 6326970); Lead/Pb (PubChem CID: 5352425). PbChem is a database of chemical molecules and their activities against biological assay. The system is maintained by the National Centre for Biotechnology Information (NCBI). A component of the National Library of Medicine, which is part of the United States National Institute of Health (NIH). Hence we can talk of PubChem Compound ID (CID) (PubChem and ACS, 2018).

3. Results and discussions

The proximate profiles of the maize samples were shown in Table 1. Total ash of 0.73-1.34 had mean value of 1.10±0.327 g/100g with highest CV% of 29.7 showing the highest disparity of values in the three samples. Ash value reduced from raw maize (B11) down to 0.73 g/100g (B33) shown as follows in g/100g: 1.34 (B11) > 1.24 (B22) > 0.73 (B33). The next highest CV% came from crude fibre (CV% = 18.5) with low levels of fibre having values of (g/100g): 1.07 (B11) ≡ 1.07 (B22) > 0.76 (B33). Dry matter (94.2-95.3 g/100g) with mean of 94.9 ± 0.635, CV% (0.669); organic matter (92.9-94.6g/100g), mean of 93.9 ± 0.874 and CV% (0.931) had the highest concentration values but least variations of 0.669-0.931%. The carbohydrate was also high at 74.4-75.8g/100g, mean of 75.3 ± 0.757g/100g and CV% of 1.01. The protein value was relatively low in each sample with values of 10.9-13.2g/100g, mean of 12.4 ± 1.27 and CV% of 10.3. The crude fat was low at values range of 5.05-5.06g/100g, mean of 5.23 ± 0.309g/100g with CV% of 5.90. Moisture was low and had CV% of 12.2. We recall that the samples underwent these treatments: raw (B11) had no special treatment, steeped (B33) had the seeds soaked in water for some days with probably high microbial activities likely due to the high enabling environment due to interplay of water, air and enzyme activities. These scenario might have happened in total ash where we observed (g/100g): B11 (1.34) > B22 (1.24) > B33 (0.73) respectively; crude fire: B11 (1.07) ≡ B22 (1.07) > B33 (0.76). However, treatment enhanced dry matter where B11 < B22 ≡ B33, organic matter: B11 < B22 < B33 and protein: B11 < B22 < B33. No definite trend existed in moisture, carbohydrate and crude fat. The reduced moisture content in B22 and B33 was important as it would lead to lower microbial activities and therefore longer shelf life for the grains, it would reduce the bulk of the samples. Protein was enhanced along the line of treatment as B33 > B22 > B11; this might be because microbial activities were more prolonged in B33 (steeped) processing, some chelated protein materials being released in the treatment process which was more in B33 than in B22 and none in B11. The fat content had the trend: B11 (5.06) < B22 (5.59) > B33 (5.05) that is B22 > B11 by a value of 9.48% and B22 > B33 by a value of 9.66%. The high increase in crude fat in B22 showed that some proximate components could have been used up by microorganisms to elevate the fat content level; also, it could have been possible for lipolytic microorganisms to have decomposed some of the fat in the steeped (B33) sample.

Table 1. Proximate composition of the maize samples: raw maize (B11), germinated maize (B22) and steeped maize (B33) at g/100g value on dry weight basis

Parameter	B11	B22	B33	Mean	SD	CV%
Total ash	1.34	1.24	0.73	1.10	0.327	29.7
Moisture	5.79	4.71	4.72	5.07	0.621	12.2
Crude fibre	1.07	1.07	0.76	0.967	0.179	18.5
Carbohydrate	75.8	74.4	75.6	75.3	0.757	1.01
Crude protein	10.9	13.0	13.2	12.4	1.27	10.3
Crude fat	5.06	5.59	5.05	5.23	0.309	5.90
Dry matter	94.2	95.3	95.3	94.9	0.635	0.669
Organic mater	92.9	94.1	94.6	93.9	0.874	0.931

For example, a diversity of moulds such as *Aspergillus* spp., *Penicillium* spp. (Ogundiwin *et al*., 1991; Lefyedi, 2006) and bacteria such as *Pseudomonas aeruginosa* (Ilori *et al*., 1991; Ahmed, 2013) have been identified as microorganisms associated with sorghum grains and malt. This could be similar with maize grains. The lowest level of fibre (0.76g/100g) in B33 could be due to highest level of protein in B33. The carbohydrate trend could not had been out of place as it is the first source of energy for organisms and since the process was raw → steeped → germinated; the diminishing level of carbohydrate would have followed that path.

Maize protein had been classified into five groups based on its solubility in various solvents (Obi, 1991). They are: (i) prolamines (soluble in 70-80% ethanol). Prolamine is mainly Zein that accounts for about 50% of the total protein in the normal maize seed. Zein is deficient in Trp and Lys which are essential amino acids. Zein is located in the endosperm. It has an economic value in that it can be converted into a protein fibre called "vicara". Vicara is used in blends with wool for manufacturing socks, sweaters and swimming suits (Milner, 1954). Number (ii) the globulins (soluble in neutral salt solution, e.g. 5% NaCl); (iii) glutelins (soluble in sodium hydroxide, e.g. 0.2% NaOH); (iv) albumins (soluble in water, e.g. 50ml distilled water/g of defatted endosperm); (v) scleroproteins (insoluble in aqueous solvents), it amounts to about 4.3% of the endosperm protein of normal maize.

Profiled in Table 2 were the differences and the percentage differences in B11 – B22; B11 – B33 and B22 – B33. The highest percentage difference was B11 – B33 (+49.2%) in total ash followed by B11 – B33 ≡ B22–B33≡ 29.0% in crude fibre. The third major difference was in crude protein where B11-B33 = -20.5%; for the signs, positive (+) meant the left hand value was higher than the right hand value and vice versa of the compared pair. On the whole we have this distribution: B22>B11 = 57.1% / 42.9%; B22≡ B33≡ 50.0%; B11> B33 = 62.5% / 37.5% in terms of concentration ratios.

Table 2. Proximate composition differences in the maize samples as B11-B22, B11-B33 and B22-B33

Parameter	B11 – B22(%)	B11 – B33 (%)	B22 – B33 (%)
Total ash	+0.100 (+7.46)	+0.610 (+49.2)	+ 0.510 (+41.1)
Moisture	+ 1.08 (+18.7)	- 0.010(- 0.212)	- 0.010 (-0.212)
Crude fibre	0.00 (-)	+0.310 (+29.0)	+0.310 (+29.0)
Carbohydrate	+1.46 (1.93)	+0.24 (+0.317)	- 1.22 (-1.64)
Crude protein	-2.11 (-19.3)	-2.24(-20.5)	- 0.130 (-0.997)
Crude fat	- 0.530 (-10.5)	+0.010 (+0.198)	+0.540 (+9.66)
Dry matter	-1.08 (-1.15)	+0.010(+0.010)	+0.010 (+0.010)
Organic matter	- 1.18 (-1.27)	-0.500(-0.532)	-0.500(-0.532)
Summary: B22 > B11 = 57.1% / 42.9%; B22 ≡ B33 ≡ 50.0%; B11 > B33 = 62.5% / 37.5% in terms of concentration ratios			

+ = in the two compared values, when sample in the left hand is higher than the right hand, the sign is positive and vice versa

The lipid distribution of the samples were depicted in Table 3. The crude fat was converted to total fatty acid (TFA) by multiplying the crude fat by 0.72. The TFA or g/100g Ep (edible portion) ranged between the 3.64 – 4.02g/100gEp, mean of 3.77± 0.219 and CV% of 5.82%; with TFA distributed as (g/100g EP): B11 ≡ B33 ≡ 3.64 < B22 (4.02). Other lipids without TFA in the samples ranged from 1.41-1.57g/100g, mean of 1.47±0.09g/100g and CV% of 6.11. The other lipids would be made up of sterols, phospholipids, etc. The percentage value for each TFA was 72.0% whereas other lipids percent was 28.0% in each sample. The values of constant percentage of 72 (TFA) and 28 (other lipids) was due to the constant conversion factor of 0.72. The crude energy range was 45.5-50.3 kcal/100g and 187-207 kJ/100g; for g/100gEp (TFA), we have 32.7-32.8 kcal/100g and 135 - 149kJ/100g; whereas other lipids had 12.7-14.1kcal/100g and 52.3-57.9 kJ/100g. The total energy from TFA and other lipids (kcal/100g) was 45.6 (B11) = 45.5 (crude fat); 50.3 (B22) = 50.3 (crude fat); 45.4 (B33) =45.5 (crude fat); each case giving virtually equivalent values. For both kcal and kJ energy percentages, each group recorded similar values: %TFA = 36.0 for all and % other lipids =14.0 for all.

Table 3. Fat (g/100g) distribution of the maize samples.

Parameter	B11	B22	B33	Mean	SD	CV%
Crude fat	5.06	5.59	5.05	5.23	0.309	5.90
Crude fat x 0.72* (Total fatty acid)	3.64	4.02	3.64	3.77	0.219	5.82
Other fats	1.42	1.57	1.41	1.47	0.090	6.11
%TFA	72.0	72.0	72.0	72.0	0.00	0.00
% other fats	28.0	28.0	28.0	28.0	0.00	0.00
Energy (kcal) crude fat (E)	45.5	50.3	45.5	47.1	2.77	5.88
TFA (E)	32.8	36.2	32.7	33.9	1.99	5.88

Other lipids (E)	12.8	14.1	12.7	13.2	0.781	5.92
Total E (kcal)	91.1	101	90.9	94.3	5.77	6.12
% Crude fat (E)	49.9	50.0	50.1	50.0	0.100	0.200
%TFA (E)	36.0	36.0	36.0	36.0	0.00	0.00
% other fats (E)	14.1	14.0	14.0	14.0	0.058	0.411
Energy (kJ)						
Crude fat (E)	187	207	187	194	11.5	5.96
TFA (E)	135	149	135	140	8.08	5.79
Other lipids (E)	52.4	57.9	52.3	54.2	3.20	5.91
Total E (kJ)	374	414	374	387	23.1	5.96
% crude fat (E)	49.9	50.0	50.0	50.0	0.058	0.116
% TFA (E)	36.1	36.0	36.1	36.1	0.058	0.160
% other lipids	14.0	14.0	14.0	14.0	0.00	0.00

B11= raw maize; B22 = germinated maize; B33= steeped maize; 0.72 = conversion of crude fat to fatty acid

Table 4. Energy density in raw maize (B11), germinated maize (B22) and steeped maize (B33) from carbohydrate, crude Fat and crude protein

Parameter	B11 (%)	B22 (%)	B33 (%)	Mean	SD	CV%
Energy (kcal/100g)in:						
Protein	43.7 (11.1)	52.2 (13.0)	52.7 (13.2)	49.5	5.06	10.2
Carbohydrate	303 (77.3)	297 (74.4)	302 (75.5)	301	3.21	1.07
Crude fat	45.5 (11.6)	50.3 (12.6)	45.5 (11.4)	47.1	2.77	5.88
Total	392	400	400	397	4.62	1.16
Energy (kJ/100g)in:						
Protein	186 (11.2)	222 (13.1)	135 (8.40)	181	43.7	24.2
Carbohydrate	1289 (77.6)	1264 (74.7)	1285(80.0)	1279	13.4	1.05
Crude fat	187 (11.3)	207 (12.2)	187 (11.6)	194	11.5	5.96
Total	1662	1693	1607	1654	43.6	2.63
UEDP (%)in:						
Kcal	6.66	7.80	7.92	7.46	0.695	9.32
kJ	6.72	7.86	5.04	6.54	1.42	21.7

UEDP = utilization of 60% of proportion of total energy due to protein percent

The total energy density for each sample was shown in Table 4. Both crude fat and protein contributed low values into the energy density whereas carbohydrate contributed very high percentage. The total energy density (kcal/100g) in the samples ran thus: B11 (392) with percentage contribution of 11.1% (protein), 11.6% (crude fat) and 77.3% (carbohydrate); in B22, total energy was 400 having distribution of 13.0% (protein), 12.6% (fat) and 74.4% (carbohydrate); and in B33 we have total energy of 400 kcal/100g with protein being 13.2%, fat (11.4%) and carbohydrate (75.5%). For energy in kJ/100g, total energy was B11 (1662), B22 (1693) and B33 (1607) with percentage distribution virtually similar to the observation in kcal/100g. On the whole CV% showed that the energy values were close. CV% range was 1.05-24.2. The total energy values of 1.61-1.69mJ/100g were close to the literature energy ranges of cereals put at 1.61-1.71 MJ/100g (Paul and Southgate, 1978). About 50-60% of somebody's total daily calories should come from carbohydrate.

Carbohydrate contains mostly glucose and gives the quickest form of energy. The body has the capacity to change 100% carbohydrate to glucose.

This is even lower than the recommended safe level of 8% for adult man that requires 55 protein per day with 60% utilization (Femi *et al*., 2015). This is not high enough to prevent energy malnutrition in children and adults that depend solely on maize as the main protein source. It is important to note that ogi produced from cereals is inherently deficient in nutrients, especially protein and cannot guarantee an adequate supply of nutrients (Femi *et al*., 2015). Such deficies may result in protein malnutrition among ogi consumers particularly the young children who are fed with the product as weaning food. Ogi has been reported as contributing to the prevalence of kwashiorkor among infants owing to its high energy density (due to carbohydrate) and reduced proteins (Sengev and Nwobi, 2016). The recommended PEF% from food sources is 30% of the total energy requirement (NACNE, 1983) or the value of 35% (COMA, 1984) for total energy intake. The present PEF% value of 11.4 -12.6 were much lower than the two extreme energy levels. This might be an advantage The utilizable energy due to protein (UEDP%) was low at 5.04 -7.88 (kJ model) and 6.66 – 7.92 (kcal model), assumption of 60% of protein utilization. and useful to people wishing to adopt the guidelines for a healthy diet.

For energy need, the daily energy requirement for infants is 740 kcal (Bingham, 1978). From Table 5, this translated that an infant would have to consume about 189g (raw), 185g (germinated) and 185g (steeped) to satisfy its needs per day. Sample total in kcal/100g was also indicated in the Table 5. As changes occur in dietary, nutritional status and age of an animal, appreciable shifts occur in the tissue compartments water and protein levels (Cowgwill, 1958). For effective utilization and conversation of food within the human body, water is indispensable (Snively Jr., and Wessener, 1954), this is because the water content of the body changes with the types of diet (White House Conferences, 1932). This important connection of water with other food substances is the fact that the biochemical basis for this relationship arises from the fact that the water deficit created by protein metabolism is about seven times that for equivalent calories of carbohydrates or fat.

Table 5. Calculated energy requirements for infants and water required for complete metabolism by the samples

Parameters	B11	B22	B33	Mean±SD	CV%
Daily infant energy requirement (kcal)	740	740	740	740±0.00	0.00
Sample total kcal/100g	392	400	400	397±4.62	1.16
Sample equivalent/gramme	189	185	185	186±2.31	1.24
Protein energy (kcal/100g; X)	43.7	52.2	52.2	49.5±5.06	10.2
Kcal equivalent for water excretion; X× 3[a](= y)	131	157	158	149±15.3	10.3
Water deficit 3.5b × X (= Z)	153	183	184	173±17.6	10.2
Water required for complete metabolism = Z-Y (cm^3)	21.9	26.1	26.4	24.8±2.52	10.1

B11 = raw maize seed; B22 = germinated maize; B33 = steeped maize; [a] = 1calorie of protein requires 3.0ml water for excretion of the urea and sulphate formed from it; [b] = water deficit = 350/100 (3.5); SD = standard deviation; CV = coefficient of variation percent

Therefore, in young children an increase in calories from carbohydrate causes hydration; whereas an increase in calories from proteins causes dehydration (Pratt and Snyderman, 1953). The increased output of ketones and acids that accompanies a shift to high-fat diets is associated with increased water loss that can be offset by increase in carbohydrate intake. Protein quality as well influences the degree of tissue hydration. Albanese (1959) had estimated grammes of water needed for complete metabolism of 100 calories of some food substances. Food materials (protein, starch and fat) all have pre-formed water of 0.00ml in each case; water gained by oxidation: 10.3 (protein), 13.9 (starch) and 11.9 (fat); lost in dissipating heat: 60.0 for each of the food materials; water lost in excreting end products (1 calorie of protein requires 3.0ml of water for the excretion of the urea and sulphate formed from it, 1g of ash requires 65ml of water for its excretion): 300 (protein), both 0.00 in starch and fat; deficit : 350 (protein), 46 (starch) and 48 (fat). Shown in Table 6, the following protein energy values were shown: B11 (43.7 kcal), B22 (52.2 kcal) and B33 (52.7 kcal) g/100g sample. Column 3 in Table 6 showed the kcal equivalent of water needed for urea and sulphate excretion and column 4 showed the water deficit. To balance for the water deficit, column 5 showed the values to range from 21.9 -26.4 ml. Distribution of values ran thus (ml): B11 (21.9) <B22 (26.1) < B33 (26.4). These water deficit values were low because the protein content of each sample was low.

In Table 6 we have the statistical evaluation of the data from Table 1. The comparisons were B11/B22, B11/B33 and B22/B33. In all the comparisons, r_{xy} was values positively high and significant with values ranging between 0.9996 – 0.9999 with the trend being B11/B22 > B11/B33 >B22/B33. These high r_{xy} levels were followed by similar r_{xy}^2 (variance) levels of 0.9992 – 0.9999. In the R_{xy}, we B11/B22 (0.9922) < B11 / B33 (1.01) ≡ B22 / B33 (1.01).

Table 6. Statistical analysis of the data from Table 1 concerning the proximate composition of raw (B11), germinated (B22) and steeped grains of *Zea mays*

Statistics	Raw/Germinated			Raw / Steeped			Germinated / Steeped		
	B11		B22	B11		B33	B22		B33
r_{xy}		0.9996			0.9997			0.9999	
R_{xy}^2		0.9992			0.9994			0.9999	
Rxy		0.9922			1.01			1.01	
Mean	35.9		36.2	35.9		35.9	36.2		36.2
SD	43.3		43.4	43.3		43.3	43.4		43.8
CV%	121		120	121		121	120		121
C_A		0.0284			0.0241			0.0100	
IFE		0.9716			0.9759			0.9900	
Remark		*			*			*	

r_{xy} = correlation coefficient; r_{xy}^2 = variance; R_{xy} = regression coefficient; C_A = coefficient of alienation; IFE = index of forecasting efficiency; * = Results were significantly different a t n-2 and $r_{=0.01}$ (critical value = 0.834) [NOTE: n-2 = 8-2 = 6df)

The mean values were close at 35.9 ± 43.3 – 36.2± 43.4 g/100g whereas the CV% values were also very close at 120-121. The C_A (coefficient of alienation) was generally low at 0.0100-0.0284 with corresponding high but inverse relationship of 0.9716 – 0.9900. The values of 0.9716 -0.9900 were index of forecasting efficiency (IFE) values. IFE is a reverse of C_A; also, IFE + C_A = 1.0 or 100%. Whereas C_A designates error value in forecasting the relationship between two compared entities, IFE represents the reduction in the error of predicting the relationship between two compared entities. When C_A <IFE, prediction of relationship is easy but vice versa when the C_A >IFE. From Table – 7, reduction in error of prediction of relationship ranged between 97.3 – 99.0. Since IFE > C_A in each case, each member of a pair would be able to carry out the metabolic functions of the other pair member and vice versa.

In Table 7, we have the display of the mineral profiles of the samples. The least concentrated mineral was Pb which had similar value of <0.001 mg/100g in each of the samples. Minerals of high concentration were K (550 – 661mg/100g). P (369-401mg/100g) and Mg (220-235mg/100g) with B22 predominating in each of the samples. Moderate mineral values were observed in Na (62.2 – 81.9mg/100g) and Ca (13.3 – 20.9mg/100g); low levels were in Fe (4.27 5.59mg/100g and Zn (4.24 – 6.60mg/100g). Very low mineral levels were in Cu, Co, Mn and Se. Enhanced minerals in B22 greater than B11 and B33 were Fe, Cu, Co, Mn, Zn, Mg, K, P and Se whereas similar minerals in B33 were Ca and Na. The CV% values were generally low with highest CV% being 25.8 in Mn and CV% of 0.00 in Pb (being the lowest CV%). The total sample loads of the samples were (mg/100g): B11 (1227) < B22 (1403) > B33 (1313). The percentage values of each mineral in each sample were indicated in the Table 8.

Table 7. Mineral profiles (mg/100g) of raw (B11) germinated (B22) and steeped (B33) grains of *Zea mays*

Mineral	**B11 (%)**	**B22 (%)**	**B33 (%)**	**Mean**	**SD**	**CV%**
Fe	4.42 (0.361)	5.59 (0.398)	4.27(0.325)	4.76	0.723	15.2
Cu	0.543 (0.044)	0.811 (0.0580	0.513(0.040)	0.628	0.158	25.2
Co	0.008 (0.001)	0.012 (0.001)	0.009 (0.001)	0.010	0.002	21.5
Mn	0.864 (0.070)	1.28 (0.092)	0.817 (0.062)	0.987	0.255	25.8
Zn	4.24 (0.345)	6.60(0.471)	5.68(0.432)	5.51	1.19	21.6
Pb	<0.001 (0.0001)	<0.001 (0.0001)	<0.001 (0.0001)	0.001	0.00	0.00
Ca	13.3 (1.09)	16.5(1.17)	20.9 (1.59)	16.9	3.82	22.6
Mg	220 (17.9)	235 (16.8)	230 (17.5)	228	7.64	3.34
K	550 (44.8)	661 (47.1)	600 (45.7)	604	55.6	9.21
Na	62.2 (5.07)	74.8 (5.34)	81.9 (6.23)	73.0	9.98	13.7
P	371 (30.2)	401 (28.6)	369 (28.1)	380	17.9	4.71
Se	0.028 (0.002)	0.036 (0.003)	0.032 (0.002)	0.032	0.004	12.5
Total	1227	1403	1313	1314	88.0	6.70
Ratio	B11/B22 = 0.875:1.00; B11/B33 = 0.935:1.00; B22/B33 = 1.07:1.00					
Superiority of B22 over B11 and B33 B22 > B11; 12/12 = 100%; B22 > B33; 10/12 = 83.3%; B33> B11; 8/12 = 66.7%. i.e. B22 > B33 > B11						

Minerals of significant percentage levels were: Mg (16.8 – 17.9%), K (44.8-47.1%) and P (28.1-30.2%). Values of percentage levels greater than 1.0 were observed in Na (5.07-6.23%) and Ca (1.09 – 1.59%) whilst all others were less than 1.00% each. The superiority (in concentration) of B22 over B11 and B33 ran thus: B22 > B11, 12/12 = 100%; B22>B33, 10/12 = 83.3%; B33>B11, 8/12 = 66.7%; that is B22 > B33 > B11.

The improvement status of the minerals was qualitatively displayed in Table 8. These minerals were under "definite improvement (++)" in B22: Fe, Cu, Co, Mn and K whereas it was only Na in B33 since they were considerably improved in their corresponding samples. Minerals classified under "usually some improvement (+)" cut across the samples (B11, B22, B33) and no improvement (-) was observed only in Pb for the samples.

Table 8. Improvement status of the minerals of maize grains during sprouting and fermentation

Mineral	Raw grains	Germinated grains	Steeped grains
Fe	+	++	+
Cu	+	++	+
Co	+	++	+
Mn	+	++	+
Zn	+	+	+
Pb	-	-	-
Ca	+	+	++
Mg	+	+	+
K	+	++	+
Na	+	+	++
P	+	+	+
Se	+	+	+
Total	+	+	+

++ = definite improvement; + = usually some improvement; - = no improvement

Minerals are necessary for life. Mn has always been low in the Nigerian food sources. Examples: in eight organs of African giant pouch rat (*Cricetomys gambianus*) (Adeyeye and Adesina, 2018), Mn was not detected in them but recorded 1.86mg/100g (muscle) and 0.01mg/100g (skin) in the same animal; it was 1.9 $\pm$ 0.04mg/kg (meat pie), 1.0 $\pm$ 0.00mg/kg (doughnut), 2.9 $\pm$ 0.01 mg/kg *(moin moin*) and 2.80 $\pm$ 0.01mg/kg (cake) (Adeyeye *et al*., 2012). Both Co and Cu are minor but essential minerals which were also low in the samples under discussion. Fe was at moderate level in the samples ranging from 4.27 – 5.59mg/100g; these values were low to the needed Fe in human metabolism. Usually about 1-10% of Fe from plant sources is usually absorbed by the body although this value can be improved upon when plants are consumed with meat or other animal Fe source (Adeyeye *et al*., 2012). Minimum Zn allowance (about 15-20 mg/day) could not be met by any of the samples. Zinc is a major constituent of the body tissues and it is a component of more than 50 enzymes (Adeyeye *et al*., 2012). Calcium is an important constituent of body fluids being a coordinator of inorganic elements particularly K, Mg or Na where Ca is capable of assuming a corrective role when such metals are in excessive amount in the body (Fleck, 1976). Ca, P and vitamin D combine together to avoid rickets in children and osteoporosis (bone thinning) among older people (Adeyeye *et al*., 2012). A dietary regime of adequate dietary Ca over the years would be a deterrent to this condition. Phosphorus has always been found with Ca in the body, both contributing to the supportive structures of the body. Phosphorus exists in cells and in blood as soluble phosphate ion, as well as in lipids, proteins, carbohydrate and energy transfer enzymes (Adeyeye *et al*., 2012). Mg was the third highest concentrated mineral in the samples; it is an activator of many enzyme systems and also maintains the electrical potential in nerves. Potassium is primarily an intercellular cation in large part being bound to protein and together with Na influences osmotic pressure and contributes to normal pH equilibrium (Adeyeye *et al*., 2012).

In Table 9, differences in the mineral profiles of maize samples between B11/B22, B11/B33 and B22/B33 were shown, and accompanied by the percentage differences. Percentage differences of 50 and >50 were observed in Co (-50.0, B11 –B22) and Zn (-55.9, B11 – B22), all being positive towards B22; in B11-B33, Ca and value of -56.7% (being positive towards B33) and none in that range for B22-B33. The low level of differences showed the low differences between the compared samples.

Table 9. Differences in the mineral profiles of *Zea mays* between raw/germinated (B11-B22), raw/fermented (B11-B33) and germinated / fermented (B22-B33) grains

Mineral	B11 – B22 (%)	B11 – B33 (%)	B22 – B33 (%)
Fe	-1.16 (-26.2)	+0.150 (+3.39)	+1.31 (+23.5)
Cu	-0.268 (-49.4)	+0.012 (+2.21)	+0.280 (+34.5)
Co	-0.004 (-50.0)	-0.001 (-12.5)	+0.003 (+25.0)
Mn	-0.419 (-48.5)	+0.047 (+5.42)	+0.466 (+36.3)
Zn	-2.37 (-55.9)	-1.44 (-34.1)	+0.924 (+14.0)
Pb	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Ca	-3.13 (-23.5)	-7.55 (-56.7)	-4.42 (-26.8)
Mg	-15.2 (-6.89)	-10.0 (-4.59)	+5.07 (+2.15)
K	-110 (-20.0)	-50.0(-9.09)	+60.2 (+9.11)
Na	-12.7 (-20.4)	-19.7 (-31.7)	-7.05 (-9.42)
P	-30.5 (-8.33)	+1.92 (+0.519)	+32.4 (+8.08)
Se	-0.008 (-28.6)	-0.004 (-14.3)	+0.004 (+11.1)
Total	-176 (-14.3)	-86.7 (-7.07)	+89.2 (+6.36)

+ = in the two compared values, when sample in the left is higher than the right hand, the sign is positive and vice versa

A study by Zhang et al. (Zhang *et al*., 2015) on buckwheat showed that phytic acid in buckwheat decreased with increase in the germination time due to activation of phytase which hydrolyses phytic acid into phosphoric acid and myinositol thereby making minerals more bioavailable (Liang *et al*., 2008; Mbithi *et al*., 2000). Mineral availability had been said to be grain specific with highest availability for Fe in wheat, Zn in rice and wheat, Mn in rice and soybean and Ca in soybean, rice and faba beans (Luo *et al*., 2015). The difference in mineral availability from different cereals and also legumes after germination for similar period may be related to differences in phytate content, phytase activation, extent of binding of minerals within the matrix, or interaction of these factors. Malting of sorghum, foxtail and chickpea significantly increased the content of Na, K, P, Ca and Mg (Desal *et al*., 2010; Idris *et al*., 2007; Laxmi *et al*., 2015) but decreased Ca and Fe (Desal *et al*., 2010; Laxmi *et al*., 2015; Ogbonna *et al*., 2012). This difference could be accounted for by different processing methods such as steeping times and freeing of bound minerals during malting (Onyango *et al*., 2013).

Table 10 contained the various computed mineral ratios which were: Ca/Mg, Ca/K, Zn/Cu, Ca/P, Fe/Cu, Ca/Pb, Fe/Pb, Fe/Co, Na/Mg, K/Co, Na/K, Zn/Pb and K [(Ca+Mg)]. Mineral ratios normally reveal the important balance between the elements, provision of information regarding the many factors they may be represented by a disruption of their relationships, such as disease states, physiological and developmental factors, the effects of diet and drugs (Watts, 2010).

Table 10. Mineral ratios of the minerals analyzed for in the variously treated maize samples

Appropriate minerals	Mineral ratio	(Reference balance ideal)	Acceptable ideal range	B11	B22	B33
Fe	Ca/Mg	7.00	3 to 11	0.061	0.070	0.091
Cu	Ca/K	4.20	2.2 to 6.2	0.024	0.025	0.035
Co	Zn/Cu	8.00	4 to12	7.80	8.14	10.7
Mn	Ca/P	2.60	1.5 to 3.6	0.036	0.041	0.057
Zn	Fe/Cu	0.90	0.2 to 1.6	8.15	6.89	8.05
Pb	Ca/Pb	84.0	126 to 168	13318	16451	20866
Ca	Fe/Pb	4.40	6.6 to 8.8	4424	5585	4274
Mg	Fe/Co	440	-[a]	553	465	475
K	Na/Mg	4.00	2 to 6	0.282	0.318	0.356
Na	K/Co	2000	-[a]	68807	55054	66718
P	K/[(Ca + Mg)]	2.2	- [a]	4.72	5.25	4.78
	Na/K	2.40	1.4 to 3.4	0.113	0.113	0.136
	Zn/Pb	-[a]	-[a]	4235	6603	5679

-[a] = not available

Of all the ratio values, only Zn/Cu (7.80-10.7) fell within the acceptable ideal range of 4-12 whereas all other ratios fell much below the acceptable ideal range. The advantages / disadvantages of such lower than ideal acceptable range had been variously discussed (Watts, 2010; Adeyeye *et al*., 2017; Nieman *et al*., 1992; Adeyeye *et al*., 2012; National Research Council, 1989).

Table 11. Statistical analysis of the data from Table 8 concerning the mineral profiles of raw (B11), germinated (B22) and fermented grains of *Zea mays*

Statistics	Raw Versus Germinated			Raw Versus Fermented			Germinated Versus Fermented		
	B11		B22	B11		B33	B22		B33
r_{xy}		0.9983			0.9986			0.9995	
r_{xy}^2		0.9966			0.9972			0.9991	
R_{xy}		1.16			1.06			0.9132	
Mean	102		117	102		109	117		109
SD	183		212	183		194	212		194
CV%	179		181	179		177	181		177
C_A		0.0586			0.0532			0.0303	
IFE		0.9414			0.9468			0.9697	
Remark		Significant			Significant			Significant	

r_{xy} = correlation coefficient; r_{xy}^2 = variance; R_{xy} = regression coefficient; SD = standard deviation; CV% = coefficient of variation percent; C_A = coefficient of alienation; IFE = index of forecasting efficiency; r_{xy} = significant at n-2 and $r_{0.01}$ (critical value = 0.708) [NOTE: n-2 = 12-2 =10 df]

The statistical analysis results of the data from Table 7 had been profiled in Table 11. All the r_{xy} values were positively high and significant at $r_{=0.01}$; this was followed by high values of r_{xy}^2. R_{xy} were high at 0.9132 – 1.16. Both mean, SD and CV% were higher than observed in the proximate statistical results. The C_A values were higher than reported for the proximate values but still lower than their corresponding IFE levels in the minerals; this made comparison between B11/B22, B11/B33 and B22/B33 easy since all C_A < all IFE.

Figure 1 had all the mineral safety index (MSI) values of Fe, Ca, P, Mg, Zn, Cu, Se and Na in the maize samples. Levels of MSI within the 10th unit range were in Mg (8.26-8.82), Cu (5.84 – 8.92), Se (5.60 – 7-20), P (3.07 – 3.34) and Fe (1.91 – 2.49), whereas only Zn was in the 20th unit range (9.32 – 14.5); other MSI for Ca and Na had values less than 1.00. Highest MSI values were observed in B22 for Fe, P, Mg, Zn, Cu and Se.

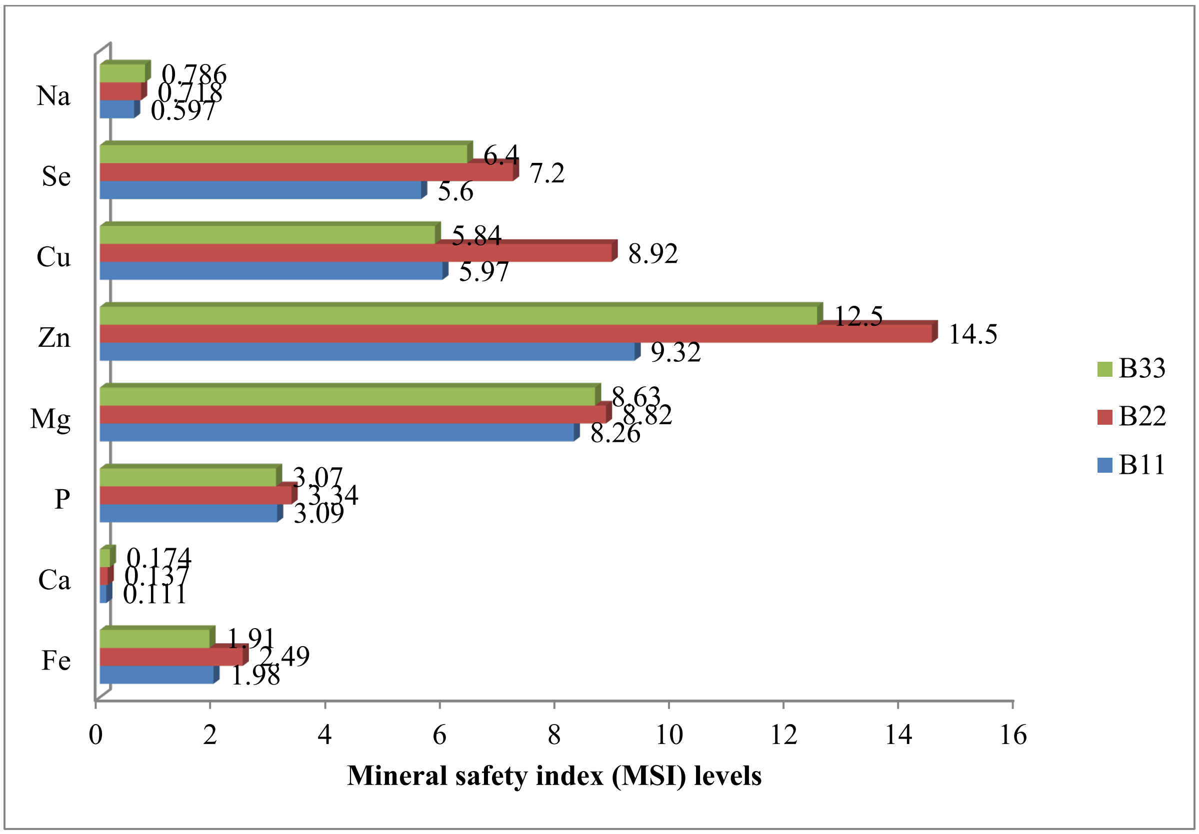

Figure 1. Mineral safety index (MSI) of Fe, Ca, P, Mg, Zn, Cu, Se and Na of *Zea mays* grains

In Figure 2, the MSI differences between the standard MSI values and the sample calculated MSI values from *Zea mays* samples were profiled. All the calculated MSI values were less than the standard MSI values. The implication of this would be that none of the minerals would have any deleterious effect on any of the sample consumers. The percentage differences showed that the following trends could be observed: Ca (98.3 – 98.9%), Na (83.6 – 87.6%), Cu (73.0 – 82.3%), Fe (62.8 – 71.5%), Zn (56.1 – 71.8%) whereas others were less than 70.0%.

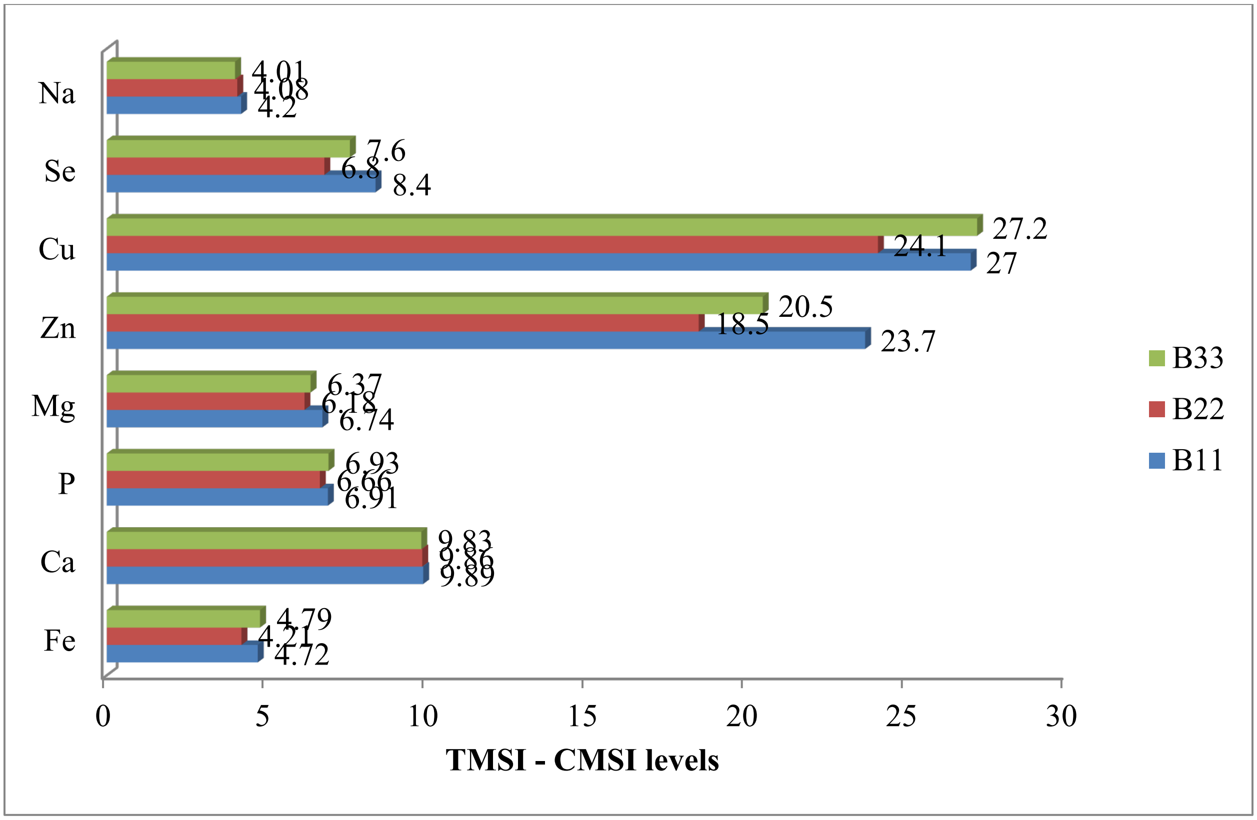

Figure 2. Mineral safety index (MSI) differences between the Table MSI (TMSI) values and sample calculated MSI (CMSI) values from *Zea mays* samples

4. Conclusions

The three differently processed samples of *Zea mays* L.Dk 818 grains exhibited high and positive significant differences among their compared groups both in the proximate and mineral results. The variations between parameters (both in proximate and minerals) in each sample were low as seen in the CV%. There was evidence of likely microbial influence in both the steeped and germinated samples both in proximate and minerals. All sample pairs: raw (B11)/ germinated (B22), raw (B11) / steeped (B33) and germinated (B22) / steeped (B33) had low C_A but corresponding high IFE showing that biochemical vice versa functions can occur in B11/B22, B11/B33 and B22/B33 both in proximate and mineral levels. To show the better improvement of germination over raw maize, we have B22> B11 = 57.1% / 42.9%; B22 over B33, we had B2≡ B33 ≡ 50.0%/50.0%; but B11 > B33 = 62.5% / 37.5% in terms of concentration ratios in the proximate composition. For mineral composition, we had a reverse observation; B22 > B11, 12/12 = 100%; B22 > B33, 10/12 = 83.3%; B33 > B11, 8/12 = 66.7%; i.e. B22 > B33 > B11.

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