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Dietary Fat and Energy Content of Steeped, Germinated and Unprocessed Maize Grains Meant For Complementary Feeding In Nigeria

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ABSTRACT

Household technologies such as fermentation, soaking, roasting and malting are traditionally used in many societies with the assumption that they can contribute to improving the safety and quality of complementary foods. To observe the dietary lipid quality, unprocessed, steeped and germinated maize grains were used to evaluate their effect on the enhancement of fatty acids, phospholipids and phytosterols. Maize samples were denoted as B1 (unprocessed) B2 (sprouted) and B3 (steeped) maize. In crude fat, B2 was enhanced by 0.47g/100g (9.23%). Calculated fatty acids had values (g/100g) of:B1(3.66)<B2(4.00)> B3(3.63). Highest levels of these fatty acids were observed as follows: SFA(B2, 27.2%), MUFA(B1,34.7%) and PUFA(B1,47.0%); but B3 was more concentrated in MUFA and PUFA than B2 but less than B1.Both oleic and linoleic fatty acids slightly increased during steeping stage of malting but later declined during germination phase particularly oleic acid. Total energy density (kcal/100g) concentration in the samples with the percentage linoleic acid had these values: B1(32.9, 43.7%), B2(36.0, 37.2%) and B3(32.7, 41.9%). Total phytosterol (mg/100g) values were low: B1(52.3), B2(43.7) and B3(45.1) with sitosterol predominating in all: 33.5 > 28.8 < 29.6 respectively. In phospholipids, values were generally higher than the phytosterols as we have total values (mg/100g) of: B1(74.4); B2(71.3) and B3(62.0) with phosphatidylinositol predominating in all samples: 25.5 > 25.1 > 22.4 respectively. Raw maize sample had highest concentration of phospholipids, phytosterols, MUFA and PUFA. The declines in B2 and B3 in the above parameters suggested that lipids were used for biochemical processes. However, B3 was better concentrated than B2 in phytosterols, MUFA, PUFA, linoleic and oleic acids. This showed germination reduced fat content due to hydrolysis and utilization of fat as an energy source in germination. Observations had depicted the contribution of maize to presence of high level phosphatidylinositol and sitosterol to the infant. It also contributed to information on discrepancies on the effect of fermentation/ germination on cereal lipids in literature. Either steeped or sprouted maize is good as complementary food.

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Introduction

Maize is cultivated throughout the world and greater weight of maize being produced per year than any other grain [1]. The 2018 total world production was about 1.15 billion tonnes, led by the USA with 34.2%, China had 22.4% and Nigeria with 0.889% [2]. In Nigeria, the usual first complementary food is ogi which is a locally prepared semi-solid food from fermented cereal (sorghum, maize and millet) [3,4]. Ogi is also consumed as breakfast meal by many adults in Nigeria, it is a fast food of choice for the sick [3]. Processing of agricultural products is an important food and nutrition security aspect in the modern world [5]. Fermentation is a process of biochemical modification of primary food matrix brought about by microorganisms and their enzymes [6]. Germination or malting is a process in which cereals are steeped and then germinated. Germination is the process occurring at the beginning of the development of seed into plants, during which they sprout [7].

In Nigeria, by the age of 4-5 months infants are given complementary foods in the form of porridge. A majority of children consumed

porridge prepared from locally available foodstuffs such as cereals, legumes, tubers, animal protein, fruit juices and mashed vegetables mixed with palm oil, after which the child is introduced to solid food from age 10-11 months [8].

Due to the current knowledge concerning low fat intakes from mixed diets in developing countries, there is a requirement to aim for final total diets with approximately 30% energy derived from fat [9]. The implication of this is that complementary foods would need to contain as much as 21% of energy as fat if mothers` milk fat concentration are in the normal range, or 24% of energy as fat if their milk fat concentrations are low. Thus, a level of 25% of energy as fat in complementary foods would meet this target for all age groups, regardless of maternal milk fat content [10].
The objective of this study was to analyse unprocessed and processed maize grains for their lipid concentrations and their corresponding energy density calculations to see how they can contribute to the energy needs of infants when such maize grains porridge are used in complementary feeding.

Materials and Methods

Variety Used

The maize sample used was *Zea mays* of local variety (not genetically improved). This was obtained from the local market of Ado-Ekiti, Ekiti State, Nigeria.

Sample Treatment

The portion labelled as unprocessed (0.50kg) was not specially treated but only dried to constant weight (5.79g/100g moisture), labelled as B1. The portion labelled for fermented (0.50kg) was placed in plastic container, distilled water added to cover the grains and left in laboratory at ambient temperature (30.9°C) at 0.41 Im2/ft light intensity for four days. The grains were later washed with distilled water, dried in the sun to constant weight (4.71g/100g moisture), stored in a covered plastic container labelled B3. The portion for germination (sprouting) (0.50kg) grains were steeped in water at room temperature for 24h; grains spread on damp fabric, protected from direct sun for about 48h until about 5.04 cm sprouts developed. Germinated grains were dried in the sun for three days until constant weight of 4.72g/100g moisture. Sprouts were manually removed [8] and stored in plastic container as sample B2. The flow chart detailing the processes in the preparation of fermented and germinated grains followed the steps of Adeyeye et al. [11]. All the samples were pulverized before analysis.

Extraction of lipid

The lipid extraction from the pulverized samples followed the procedure of AOAC [12].

Sample Analysis

Preparation of methyl esters and analysis

The methylation of fat followed the steps enumerated in AOAC [12]. The fatty acid methyl esters were analysed following the detail shown in Adeyeye [13].

Phytosterol analysis

Phytosterol was analyzed as described by AOAC [12].

Phospholipid analysis

The method of Raheja et al. was employed in the analysis of phospholipids[14].

Quality Assurance

Standard chromatograms were prepared for phytosterols, phospholipids and fatty acid methyl esters which were then compared with respective analytical results; calibration curves were prepared for all the standard mixtures and correlation coefficient determined for each fatty acid parameter, same for phytosterols and phospholipids. Correlation coefficient should be >0.95 for the result to be acceptable. It was performed with Hewlett Packard Chemistry (HPCHEM) software (GMI, Inc, 6511 Bunker Lake Blvd Ramsey, Minnesota, 55303, USA).

Calculation of Fatty Acid as Food Per 100g in Sample

At the data source and reference database levels, values for individual fatty acids are usually expressed as percentages of total fatty acids. At the user database level, values per 100g of food are required. When the content of total fatty acids in food or fat is not given, it is necessary to calculate it by using fatty acid conversion factor (XFA). The conversion factor reflects the ratio between the sum of fatty acids and total lipids (TL) in the food [15].

$$FACID(g/100g\ EP) = TL(g/100g\ EP) \times XFA$$

Total lipid (TL=crude fat) level was multiplied by a conversion factor of 0.72 (in each case) to convert to total fatty acids [16]. For fatty acids, precision is best limited to 0.1g/100g of fatty acids [17]. Further calculations were the conversion of edible portion (EP) into two different units of energy: kJ/100g EP and kcal/100g EP.

Statistical Evaluation

Both descriptive and inferential statistics were used in discussing data generated. For descriptive statistics, mean, standard deviation (SD), and coefficient of variation (CV%) were all calculated as appropriate. In differential statistics, evaluated for were correlation coefficient (r_{xy}), variance (r_{xy}^2),and regression coefficient (R_{xy}) setting the critical value at r=0.01 as appropriate. Furthermore, r_{xy} was subjected to the calculation of coefficient of alienation (CA) and index of forecasting efficiency (IFE) [18].

Results

Crude fat and other lipid profiles

The parameters in Table 1 depicted the crude fat and its conversion to total fatty acid (crude fat x 0.72) and other lipids content. The energy levels of crude fat, total fatty acid (TFA) and other lipids were shown in both kJ/100g and kcal/100g. In the crude fat, trend run was (g/100g): B1(5.09) < B2(5.56) > B3(5.04). Other parameters followed this trend since crude fat determined other results in terms of quantity, that is in all trends like TFA, other lipids and energy density, we had B2 > B1 > B3. TFA when taken from crude fat resulted into other lipids (like phytosterols and phospholipids). Ratios of other lipids to TFA were B1 (1:2.56), B2(1:2.56), and B3(1:2.57). TFA energy density ranged from 32.7-36.0 kcal/100g with low coefficient of variation (CV) of 5.46%; energy due to other lipids ranged from 12.7- 14.0 kcal/100g and CV% of 5.55.

Table 1: Crude fat and other lipid profiles (with energy) of maize [unprocessed maize grains (B1) sprouted maize (B2) and steeped maize (B3)] in g/100g

Parameter	Unprocessed maize seed (B1)	Sprouted maize seed (B2)	Steeped maize seed (B3)	Mean	SD[b]	CV%[c]
Crude fata	5.09	5.56	5.04	5.23	0.287	5.49
Total fatty acid (TFA)	3.66	4.00	3.63	3.76	0.206	5.46
Other Lipids	1.43	1.56	1.41	1.47	0.081	5.54
Crude fat (energy) kcal/100g kJ/100g	 45.8 188	 5.00 206	 45.4 186	 47.1 194	 2.58 10.6	 5.49 5.49
TFA (energy) kcal/100g kJ/100g	 32.9 135	 36.0 148	 32.7 134	 33.9 139	 1.85 7.60	 5.46 5.46
Other lipids (energy) kcal/100g kJ/100g	 12.9 529	 14.0 57.7	 12.7 52.2	 13.2 54.3	 0.733 3.01	 5.55 5.54

[a]Crude fat x 0.72 = TFA; [b]SD = standard deviation; [c]CV% = coefficient of variation percent.

Fatty acid content of samples

In Figure 1, fatty acids of note were depicted. For the SFA, B3 was highest (15.3% of total fatty acid) in C16:0 but B2(9.94%) was highest in C18:0. In MUFA, C18: 1 cis-6 values of B1 was equivalent to B2 at 15.8%, in C18: 1 cis-9, B3 had highest value of 19.4%. In C18 : 2 cis-9, 12, trend was B1(43.6%) > B2 (37.1%) < B3(41.9%). All CV% values were low in SFA and MUFA where the range was 8.24 - 21.1. In C18:3 cis-9, 12, 15, trend was B1(1.95%) > B2(1.45%) > B3(0.491%) with much higher CV% of 57.1.

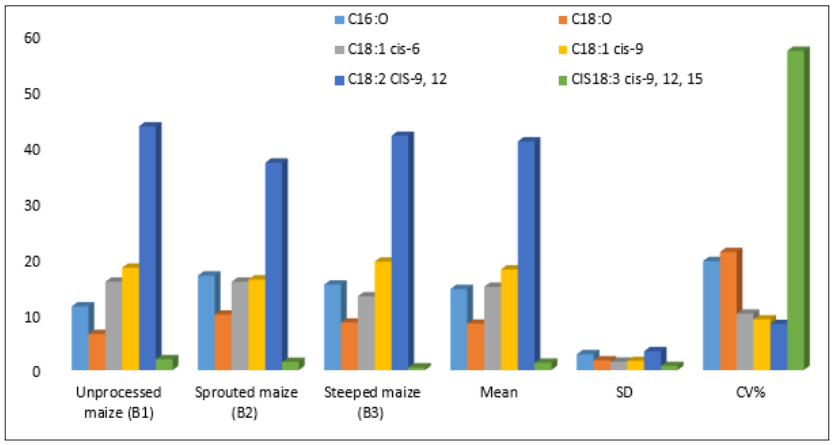

Figure 1: Fatty acid content of maize samples: B1 (unprocessed maize) B2 (sprouted maize) and B3 (steeped maize) (percent).

Statistical analysis of comparisons from the data in figure 1

The statistical comparisons from Figure 1 had these pairwise comparisons for B1/B2, B1/B3, and B2/B3 as shown in Table 2. Calculated for were the r_{xy}, r_{xy}^2, R_{xy}, mean, SD, CV%, CA and IFE. The critical level was 0.917 at significant level of $r =_{0.01}$. All the rxy levels were significantly different in B1/B2, B1/B3, and B2/B3. The r_{xy}^2 values were high at 0.9457 – 0.9763. R_{xy} showed that for every 1.00% total acid increase in B1, B1 and B2, the Table values would be the corresponding in B2(0.7810% in B1/B2), B3 (0.9433%, in B1/B3), and B3(1.18%, in B2/B3). All the mean values were low with CV% range of 72.6 – 90.3 (for B1, B1, B2) and CV% range of 72.6 – 85.3 (for B2, B3, B3). The C_A was low at values of 0.1539 – 0.2329 with a corresponding high values of IFE at 0.7671 – 0.8461. C_A + IFE would give 1.00 or 100% depending on the unit used. Coefficient of alienation (C_A) equals error of prediction of relationship between two compared entities whereas IFE equals reduction in the error of prediction of relationship between two compared entitles; when IFE > C_A, prediction of relationship is easy and biochemical activities would be about very similar between the compared entities. In all B1/B2, B1/B3, and B2/B3, IFE > C_A, hence prediction was easy.

Table 2: Statistical analysis comparisons between unprocessed maize/sprouted maize (B1/B2), unprocessed maize/steeped maize (B1/B3) and sprouted maize/ steeped maize (B2/B3) fatty levels from Figure 1

Statistics	B1/B2	B1/B3	B2/B3
rxy	0.9725	0.9854	0.9881
rxy^2	0.9457	0.971	0.9763
Rxy	0.781	0.9433	1.18
$Mean_1$	16.3	16.3	16.2
SD_1	14.7	14.7	11.8
$CV\%_1$	90.3	90.3	72.6
$Mean_2$	16.2	16.5	16.5
SD_2	11.8	14	14
$CV\%_2$	72.6	85.3	85.3
CA	0.2329	0.1703	0.1539
IFE	0.7671	0.8297	0.8461

Mean, SD, and CV%, all representing the corresponding values in the first member of a pair whereas 2, 2, 2 series corresponded to the second pair of the group; r_{xy} = correlation coefficient; r_{xy}^2 = variance; R_{xy} = Regression coefficient; C_A = Alienation coefficient; IFE = Index of forecasting efficiency; *rxy was significantly different at n – 2 (df) = 6 – 2 = 4 at r = $_{0.01}$ with critical value of 0.917.

Edible portion (Epg/100g) and energy density of the fatty acids

In Table 3 the Epg/100g and energy density values predicated the significance of C18:2 cis-9,12 among the fatty acids and least of significance was C18:3 cis-9, 12, 15. Epg/100g ranged from 1.49 – 1.60 in linoleic acid showing the effect of microogranisms metabolism in B2 more than B3. Other Epg/100g values were less than 1.00 in each of SFA and MUFA. The total energy density from the EPg/100g ran thus (kcal/100g): B1(32.2) < B2 (35.1) >B3(32.3). The total energy level of B2 (35.1kcal/100g) came higher than B1 and B3 in C16:0, C18:0, and C18:1 cis-6.

Table 3: Edible portion (EPg/100g) and corresponding energy values (kJ/100g, kcal/100g) of the fatty acids)

	EPg/100g			Energy (kJ/100g)			Energy (kcal/100g)		
Fatty acid	**B1**	**B2**	**B3**	**B1**	**B2**	**B3**	**B1**	**B2**	**B3**
C16:0	0.417	0.677	0.555	15.4	25.0	20.5	3.76	6.09	5.00
C18:0	0.236	0.398	0.308	8.75	14.7	11.4	2.13	3.58	2.77
C18:1 cis-6	0.578	0.633	0.479	21.4	23.4	17.7	5.20	5.69	4.31
C18:1 cis-9	0.670	0.649	0.704	24.8	24.0	26.1	6.03	5.84	6.34
C18:2 cis-9, 12	1.60	1.49	1.52	59.0	55.0	56.3	14.4	13.4	13.7
CIS18:3 cis-9, 12, 15	0.071	0.058	0.018	2.64	2.15	0.659	0.642	0.522	0.160
Total	3.57	3.90	3.59	132	144	133	32.2	35.1	32.3

Some quality parameters of the fatty acids

These ratios: MUFA/SFA (1.20 – 1.91) and PUFA/SFA (1.47 – 2.58) were nutritionally favourable in the samples. The essential PUFA status index (ESPI) values were highly favourable nutritionally at 0.765 – 0.829. The usual trend of C16:0 being highest in the SFA was depicted with very close values of 62.1 – 63.8% as against percentage of 35.4 – 36.5 in C18:0 in TSFA. The Epg/100g range was 3.63 – 4.00 and energy of 32.7 – 36.0 kcal/100g. Figure 2 depicted all these observations.

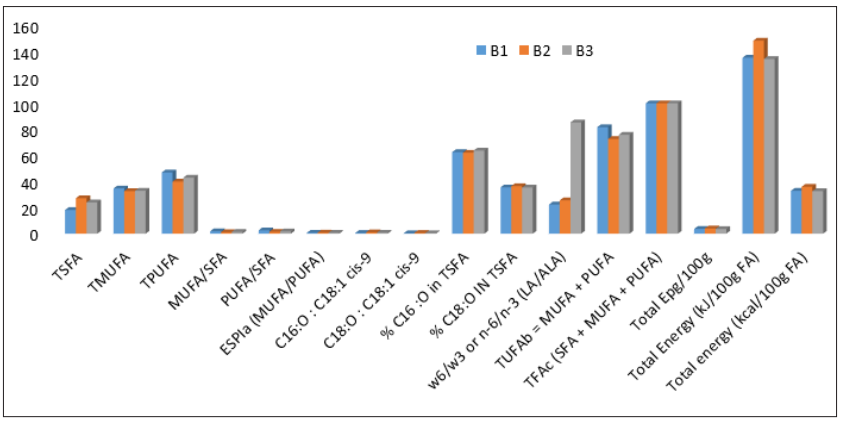

Figure 2: Some quality parameters of the fatty acids of maize samples from Tables 1 and Figure 1.

Phytosterol levels of samples

Whereas cholesterol recorded 0.00mg/100g in all the samples, cholestanol and ergosterol were detected at ultra-trace levels as shown in Table 4. Total phytosterol ranged from 43.7 – 52.3 mg/100g in the samples and was dominated by sitosterol levels of 28.8 – 33.5 mg/100g (64.1- 65.9%). Sample B1 showed highest levels in all parameters except cholesterol (0.00% for each sample).

Table 4: Phytosterol levels (mg/100g) of the maize samples

Phytosterols	B1 value %	B2 value %	B3 value %	Mean	SD	CV%
Cholesterol	0.00	0.00	0.00	0.00	0.00	0.00
Cholestanol	1.99e-5	1.59e-5	1.55e-5	1.71e-5	2.43e-6	14.2
Ergosterol	1.85e-3	1.84e-3	1.84e-3	1.84e-3	5.77e-6	0.313
Campesterol	13.4 (25.6)	11.4 (26.1)	11.0 (24.4)	11.9	1.29	10.8
Stig-masterol	5.00 (9.56)	3.04 (6.96)	4.07 (9.02)	4.04	0.980	24.3
5-Avenasterol	4.87e-1 (0.0931)	4.45e-1 (0.102)	4.22e-1 (0.936)	0.451	0.033	7.30
Sitosterol	33.5(64.1)	28.8 (65.9)	29.6 (65.6)	30.6	2.51	8.21
Total	52.3	43.7	45.1	47.0	4.61	9.81

Statistical analysis of phytosterol levels

The Table 5 showed the r_{xy} levels to be high and significant at $r=_{0.01}$ and critical level of 0.990. The rxy2 values were high and Rxy depicted the observation noted in Table 2. The mean values were low but CV% values were each slightly above 100%. All CA values were lower than their corresponding IFE values thereby making the prediction of relationship between each pair: B1/B2, B1/B3 and B2/B3 easy.

Table 5: Statistical analysis comparisons between unprocessed maize/sprouted maize (B1/B2), unprocessed maize/steeped maize (B1/B3) and sprouted maize/steeped maize (B2/B3) phytosterol levels from Table 4

Statistics	B1/B2	B1/B3	B2/B3
r_{xy}	0.9989*	0.9995*	0.9987*
r_{xy}^2	0.9979	0.9991	0.9975
Rxy	0.875	0.8877	1.01
$Mean_1$	13.1	13.1	10.9
SD_1	14.6	14.6	12.8
$CV\%_1$	112	112	117
$Mean_2$	10.9	11.3	11.3
SD_2	12.8	13	13
$CV\%_2$	117	115	115
C_A	0.0449	0.0301	0.0505
IFE	0.9551	0.9699	0.9495

*rxy was significantly different at n – 2 (df) = 4 – 2 = 2 at r=0.01 with critical value of 0.990

Phospholipid levels of the maize samples

Table 6 showed the total sample phospholipid levels to range from 62.0 – 74 .4 mg/100g. The CV% levels were low: 3.38 – 12.5. The most concentrated phospholipid was phosphatidylinositol at 22.4 – 25.5 mg/100g (34.3 – 36.1%) followed by phosphatidylethanolamine at 15.9 – 20.4 mg/100g (25.6 – 27.4%) and third highest being phosphatidylserine at 14.5 – 18.1mg (23.4 – 24.3%). Sample B1 predominated in each parameter.

Table 6: Phospholipid levels (mg/100g) of the maize samples

Phospholipid	B1 value, %	B2 value, %	B3 value, %	Mean	SD	CV%
Phosphatidylethanolamine (PE)[a]	20.4 (27.4)	19.1 (26.8)	15.9 (25.6)	18.5	2.32	12.5
Phosphatidylcholine (PC)[a]	7.18 (9.65)	6.90 (9.68)	6.12 (9.87)	6.73	0.549	8.16
Phosphatidylserine (PS, Ptd-L-Ser)	18.1 (24.3)	16.9 (23.7)	14.5 (23.4)	16.5	1.83	11.1
Lysophos phatidylcholine (LPC)	3.23 (4.34)	3.29 (4.61)	3.08 (4.97)	3.20	0.108	3.38
Phosphatidylinositol (PI, PtdIns)	25.5 (34.3)	25.1 (35.2)	22.4 (36.1)	24.3	1.69	6.94
Total	74.4	71.3	62.0			

[a]PE is also called cephalin and PC is also called lecithin

Statistical analysis of the phospholipids data

Statistical comparison of the data from Table 6 had been depicted in Table 7. The values of r_{xy}^2 and R_{xy} were high but none in the Rxy reached 1.00mg/100g as seen in B2/B3 in Tables 2 and 5. The r_{xy} values were each highly positive and significant at r=0.01 and critical level of 0.959. Mean values were generally low; CV% ranged at 62.7 – 63.0 which were relatively low and close to each other. All C_A values were lower than all IFE values making prediction of relationship easy.

Table 7: Statistical analysis comparisons between unprocessed maize/sprouted maize (B1/B2), unprocessed maize/steeped maize (B1/B3) and sprouted maize/steeped maize (B2/B3) phytosterol levels from Table 6

Statistics	B1/B2	B1/B3	B2/B3
rxy	0.9986*	0.9937*	0.9981*
rxy^2	0.9973	0.9875	0.9962
Rxy	0.9603	0.8296	0.8664
$Mean_1$	14.9	14.9	14.3
SD_1	9.34	9.34	8.98
$CV\%_1$	62.7	62.7	63
$Mean_2$	14.3	12.4	12.4
SD_2	8.98	7.79	7.79
$CV\%_2$	63	62.9	62.9
CA	0.0522	0.1118	0.0908
IFE	0.9478	0.8882	0.9092

*rxy was significantly different at n – 2 (df) = 4 – 2 = 2 at r=0.01 with critical value of 0.990.

Discussion

In Table 1, sprouted sample (B2) was better enhanced in total crude fat and other lipids than in B1 and B3 but B3 had the least crude fat; this was observed in total fatty acid (TFA) and other lipids. The various energy calculations also followed this trend. Similar observation had been reported in *sorghum bicolor* with these results (g/100g) in crude fat: unprocessed (3.32) < geminated (3.47) > steeped (3.14) although maize had superior quantity values [19]. The pattern of calculation for the lipids in Table 1 had been reported for eight organs of Muscovy duck-hen [20]. The present results were higher than the value of 1.83% (sorghum), 1.10% (millet), 1.72%(maize) and 0.63% (rice) [21]; although the results were favourably comparable to those compiled by Oyenuga [22] from different sources (%): 4.09 (maize), 0.14 (rice), 3.25(guinea corn), 4.99(millet), 2.00(wheat), 1.00(barley) and 7.40(oats).

The fatty acid levels of the samples as shown in Figure 1 had a reverse order in C16:0 and C18:0 for B1, B2, B3. In Table1, B2>B1>B3; but in Figure 1, B2>B3>B1 in C16:0 and C18:0 respectively. In C18:1cis-6, value of B1=B2>B3 and a reverse in C18:1 cis-9 being B3>B1>B2. C18:2 cis-9,12 had a trend of B1>B3>B2; again a reverse trend in C18:3 cis-9,12,15 being B1>B2>B3. Maize values in C16:0 were lower than in sorghum (16.6-18.3%) but higher than in C18:0 (1.93-3.86%); other results higher in maize than sorghum were in C18:1cis-6, C18:1cis-9 and C18:2cis-9, 12 but not in C18:3cis-9,12,15 [19]. Some literature cereal fatty acid results were (%); C16:0, rice (14.7), sorghum (10.9), millet (21.0) and maize (18.3); C18:0, sorghum (2.7), millet (23.9), maize (33.7) and rice (2.0); C18:1 (oleic), sorghum (28.4), millet (23.9), maize (33.7) and rice (43.7); C18:2, sorghum (50.9), millet (48.7), maize (46.3) and rice (36.8); C18:3, sorghum (7.11), millet (3.2), maize (-) and rice (2.2) [21]. These literature values were unprocessed samples and many of their parameters had higher values than the values in the present maize study.

Lipid content of cereals slightly increases during steeping stage of malting but later declines during the germination phase as lipids are used in the respiration process [23]. The observation of Traore et al. [23] did not apply in the present study as germination crude fat of 5.56g/100g was higher than in the steeped stage value of 5.04g/100g (Table 1). Kim et al. observed an increase in crude lipids, linoleic acid, and oleic acid in germinated rice, while Moongngarm and Saetung did not find changes in fat content when rice grains were germinated [24,25]. Present study agreed with Kim et al. only in crude lipids but not in linoleic and oleic acid but in total disagreement with the report of Moongngarm and Saetung in germinated rice [24,25]; however, this was with the exception of C18:1cis-6 where B1(15.8%)= B2(15.8%). Germination reduced fat levels of C18:1cis-9, C18:2cis-9,12 and C18:3cis-9,12,15 which were in agreement with other studies that have reported that germination reduces fat content due to hydrolysis and utilization of fats as an energy source for biochemical reactions during germination [25-28].

The lipids profile statistical details in Table 2 demonstrated the superiority of a member of the pair over the other in the B1/B2, B1/B3, and B2/B3. This superiority details were shown in the rxy, Rxy, mean and IFE. All rxy values were significantly different at r=0.01 with B1/B2 < B1/B3 < B2/B3. The Rxy showed these results: B1>B2 in B1/B2, B1 > B3 in B1/B3, and B2 < B3 in B2/B3. In the mean, B1 > B2 in B1/B2, B1 < B3 in B1/B3, and B2 < B3 in B2/B3. The IFE showed the best pair of comparison was in B2/B3 as shown in this trend: B1/B2 (0.7671) < B1/B3 (0.8297) < B2/B3 (0.8461). Because all the paired IFE were each greater than their corresponding CA, it meant each member of pair could perform the biochemical functions of the other member of the pair. This being the case, both B2 and B3 would behave very similarly as complementary food sources.

From six months onwards, when breast milk is no longer sufficient to meet all nutritional requirements, infants enter a particularly vulnerable period of complementary feeding during which they make a gradual transition to eating family food [29]. Reaching an adequate nutrient level from complementary foods remains a concern, particularly in diets that are mainly plant-based, like

determining the optimal amount and type of lipids intake by children. The nature of body fat in the infant is largely determined by the quality of the fat in the diet [30]. Fat is an important constituent of the nervous system and intake of biologically inappropriate kinds of fatty acids may have long-lasting effects on the growth of the nervous system. Dietary fats provide the young child with essential fatty acids (EFAs), energy and fat-soluble vitamins [9]; fats may heighten the palatability of the diet and thus promoting greater total intake [31].

FAO/WHO [9] recommended that linoleic acid provide at least 3% of total energy in diet. Thus, if seed oils like maize oil or soybean oil, which contain more than 50% linoleic acid, are the major sources of dietary fat no more than 60% of total energy would have to be supplied by these sources to meet theoretical requirements for linoleic acid. In Table 3, both the Epg/100g and corresponding energy values in kJ/100g and kcal/100g were depicted. The kcal/100g energy values for linoleic acid were: B1(14.4, 44.7%), B2(13.4, 38.2%), and B3(13.7, 42.4%); all these percentage levels were highly comparable to the value of 50%. The energy needs from complementary foods for infants with "average" breast milk intake in developing countries [10] are approximately 200 kcal per day at 6-8 month of age, 300 kcal per day at 9-11 months of age and 550 kcal per day at 12-23 months of age. The energy from 100g of the samples were (kcal/100g): B1(393), B2(400), and B3(400) which were highly comparable to the WHO [10] values. However, the percentage contributions of fat were low at B1(11.7), B2(12.5), and B3(11.3) compared to the value of 21% in complementary foods [10].

Some quality parameters of the lipid profiles were contained in Figure 2. Unsaturated lipids had total level range of 72.7-81.7% as compared to 86.4(sorghum), 75.8(millet), 80.0 (maize) and 82.9 (rice); present EFA range was 38.6 – 45.6% and literature values were 58.0 (sorghum) 51.9 (millet), 46.3 (maize), and 39.0 (rice) [21] which were of good comparisons with the present study. The MUFA/SFA of 1.20 – 1.91 could be said to be positive. PUFA/SFA is important in determining the detrimental effects of dietary fats. This is because the severity of atherosclerosis is closely related with the proportion of total energy supplied by SFA and PUFA [32]; the ratio here was good at 1.47 – 2.58. LA/ALA ratio 22.4 – 85.3, this ratio was poor and the diet would need a balance from ALA sources. A suitable indicator of essential PUFA status is the PUFA status index (EPSI) which is this ratio: MUFA/PUFA, values here ranged between 0.765 to 0.829; being above average. The higher the EPSI value, the better the essential PUFA status.

The phytosterol concentration showed significant levels in sitosterol (64.1 – 65.9%), campesterol (24.4 – 26.1%) but low in stigmasterol at 6.96 – 9.56%. In guinea corn (*S. bicolor*), sitosterol (60.9 – 73.1%) predominated whereas campesterol (17.1 – 20.4%) and stigmasterol (9.86 – 18 .8%) were almost at per [19]. Total phytosterol levels in maize samples ranged from 43.7 -52-3 mg/100g, the range was 45.0 – 58.3 mg/100g in *S. bicolor*. β-sitosterol has a chemical structure similar to that of cholesterol. Alone and in combination with similar phytosterols, β-sitosterol reduces blood levels of cholesterol and is sometimes used in treating hypercholesterolemia. Plant sterols have been suggested to have dietary significance and to protect vegetable oils from oxidative polymerization during heating at frying temperature [33]. Statistical comparisons of the phytostosterol data followed earlier trends where rxy values were high, positive and statistically significant at r=0.01 at critical level of 0.990. Values of r_{xy}^2, R_{xy}, SD, IFE and CV% were high. Because C_A < IFE, prediction of relationship was easy with very low error of prediction; this made biochemical functionality conversion easy between each member of a pair compared.

Phospholipid values were generally low at total levels of 62.0 – 74.4 mg/100g. Unlike in animal phospholipids, phosphatidylinositol (PIdIns) had the highest concentration of 34.3 to 36.1% and closely followed by phosphatidylethanolamine (PE) with values of 25.6 – 27.4% and phosphatidylserine (PS, Ptd – L – Ser), 23.4 – 24.3%. Phospholipids functions in the animal body include its role as intermediary metabolite in fat metabolism and its role in oxidation – reduction system. PS had been demonstrated to speed up recovery and prevent muscle soreness. The USFDA had stated that consumption of PS may reduce the risk of dementia and cognitive dysfunction in the elderly [34]. PE is a major phospholipid in nervous tissue such as the white matter of brain, neural tissue, nerves and in spinal cord. PI can be phosphorylated to form PIP, PIP2, PIP3 and DAG and functions as second messenger in signal transduction. (PIP, PIP2, and PIP3 are the phosphoinositides.) PC protects cell from oxidation and largely comprises the protective sheaths surrounding the brain. Statistical comparisons of the phospholipid levels showed the compared pairs of B1/B2, B1/B3 and B2/B3 to have significant r_{xy}, high levels of r_{xy}^2, Rxy, CV%, IFE; but low values of mean, SD and C_A. All the pairs were capable of biochemical interconversion between each member. The quality assurance for the analyses showed correlation observed for all the standards were 0.98978 – 0.99999 (fatty acids), 0.99994 – 0.99999 (phospholipids) and 0.99989 – 0.99999 (phytosterols); all being of greater than 0.95 (critical correlation for acceptance of analytical results).

Conclusions

Trends of lipids [crude fat, TFAs, other lipids (phytosterols + phospholipids)], EPg/100g and energy followed the concentration pattern of sprouted (B2)> unprocessed (B1)> fermented (B3) samples; with close values as depicted by CV% of 5.46 – 5.55. Best sources of FAs were: SFA (B2), petroselinic acid (B1 = B2), oleic acid (B3) and PUFA (B1). In MUFA/SFA and PUFA/SFA ratios, trend was B1>B3>B2 but ESPI was B2>B3>B1. Phytosterols of significance were sitosterol, campesterol and stigmasterol with B1 being highest in all the three parameters, B3 second in sitosterol and B2 being second in campesterol. The five phospholipids values evaluated were close among the samples with low CV% of 3.38 – 12.5; concentration pattern being B1>B2>B3. In all statistical comparisons: B1/B2, B1/B3 and B2/B3, rxy values were significant at r= 0.01, all CA < IFE, making prediction of relationship positively high between each pair; it also predicted inter conversion of biochemical functionality between each member of a pair. This work had shown that sprouted and fermented maize samples would function almost in similar ways in the lipid characteristics when used in complementary feeding. The work further added information on both phytosterols and phospholipids in maize which are uncommon in literature.

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