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Nutrient composition of commonly consumed edible insects in the Lango sub-region of northern Uganda

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Abstract

The study aimed at nutritional characterization of commonly consumed insects in Lango-sub region, northern Uganda. Proximate composition, mineral and fatty acid profile of *Syntermes* soldiers, *Macrotermes bellicosus* and *Brachytrupes* spp were determined using standard analytical methods. Analysis of Variance (ANOVA) was performed and means were separated using Least Significant Difference (LSD) test at 5% (P=0.05). Nutrient contents of *Syntermes* soldiers, *Macrotermes bellicosus* and *Brachytrupes* spp were: 64.72, 40.72, 65.35% protein; 4.99, 44.84, 11.76% fat; 23.03, 8.38, 16.87% dietary fibre and; 4.19, 5.69, 4.88% ash, respectively. Energy content was 502.86, 696.10, 536.42 kcal/100 g while protein digestibility was 31.39, 44.39, 50.22%, respectively. Essential minerals were abundant with 897.15, 676.96, 877.26 mg/100 g potassium; 32.50, 42.71, 33.60 mg/100 g iron and; 17.64, 16.90, 23.02 mg/100 g zinc, respectively. Levels of essential fatty acids were appreciable with: 16.74, 8.92, and 22.14% Linoleic acid and 2.88, 0.63, and 2.55% Linolenic acid, respectively. Oleic acid was the most abundant at 37.64, 47.73 and 38.27%. While the ratio of total polyunsaturated fatty acid to total saturated fatty acids were; 1.32, 0.24, and 0.71 respectively. Consumption of these insects could contribute to the dietary intakes of the essential nutrients.

Introduction

The rapid growth of the world population requires proportionate increases in food production. However, it is difficult to increase productivity to a level that satisfies food demand, mainly because of limited availability of new farm land (DeFoliart, 1995; Verkerk *et al*., 2007; Mitsuhashi, 2010). This has led to shortage of food particularly animal protein. Therefore, it has become essential to look for new sources of animal protein. Some food resources which were neglected like edible insects are re-emerging and information about their nutritive values is becoming significant. Insects have played an important part in the history of human nutrition in Africa, Asia and Latin America (Ramos-Elorduy *et al*., 1997; Kampmeier and Irwin, 2009).

In the Lango sub-region as in most parts of Uganda, insects have been part of the cultural diet since time immemorial. Commonly consumed insects include species of edible winged termites such as; *Macrotermes nigeriensis*, *Macrotermes notalensis*, *Macrotermes subhylinus* and *Macrotermes bellicosus* which are harvested during the swarming seasons (Mbah and Elekima, 2007). Winged termites (*Macrotermes* species) often emerge with the first rains at the ends of the dry season. They are usually differentiated by the morphological features, the time and season when they emerge. Other commonly consumed insects are *Brachytrupes* spp and *Ruspolia nitidula*. The latter is a special delicacy in central Uganda and may be boiled and sun-dried, fried and flavored with onions, or used to make soup (Agea *et al*., 2008).

While the chemical composition and nutritional value of some edible insects have been determined (Finke *et al*., 1985; Bukkens 1997; Ramos Elorduy *et al*., 1997; DeFoliart *et al*., 2002; Paoletti *et al*., 2003; Kinyuru *et al*., 2013), there's still a dearth of information on nutritional quality of the most

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commonly consumed insects. Edible insect species are rich in proteins, amino acids, fats, vitamins and trace elements (Oyarzun *et al*., 1996; Paoletti *et al*., 2003; Banjo *et al*., 2006; Igwe, 2011; Ajayi, 2012; Ntukuyoh *et al*., 2012; Kinyuru *et al*., 2013). However, the nutrient levels reported vary greatly by species, environmental conditions, geographical location, feeding habits and the developmental stages of the insects (Defoliart, 1992; Verkerk *et al*., 2007; Srivastava *et al*., 2008; Raksakantong *et al*., 2010). This work aimed at evaluating nutritional quality of *Macrotermes* bellicosus, *Syntermes* soldiers and *Brachytrupes* spp consumed as delicacies in the Lango sub-region of Northern Uganda, specifically to determine proximate composition, *in vitro* protein digestibility, mineral and fatty acid profiles in order to provide a scientific evidence and encourage consumption amongst the current generation.

Materials and Methods

Selection of insect species for nutritional assays

Selection of insect species for nutritional assays was guided by availability of the species, frequency of consumption, local preference, market value, perceived nutritional value by the community and extent of anthropogenic pressure on species. This information was obtained from literature review, a household survey and focus group discussions that were conducted in the Lango Sub-region of Northern Uganda. Three species of insects were selected based on the inclusion criteria; *Macrotermes* bellicosus, *Syntermes* soldiers *Brachytrupes* spp.

Collection of insects and nutritional analysis

The insects were collected from croplands in the study area using methods described by (Van Huis 2003); Attraction to light at the termite mound (*Macrotermes* bellicosus), "termite fishing" (*Syntermes* soldiers) and location by sound or digging out of their holes (*Brachytrupes* spp). Insects were stored in a cool box with ice and transported to the laboratory at the school of Food Technology, Nutrition and Bio-Engineering, Makerere University. Morphological features were used to identify the insects. Insects were de-winged, de-leged, washed three times to remove soil and dirt then eventually oven-dried at 40°C for 8 hours. Dried insects were ground into powder, vacuumed packed, labeled and stored at -4°C until analysis.

Samples were analyzed for proximate composition in triplicate: Moisture content was determined by loss in weight on drying at 95-100oC for 8 hrs in Gallenkamp UK, hot box oven fitted with a fan, according to (AOAC) (1999. NO 934.01). Total protein was quantified by determining total nitrogen using Kjeldahl method. A conversion factor of 6.25 was used (AOAC, 1999; No. 928.08).

In vitro protein digestibility was determined according to ICRISAT (1997). About 0.2 g of samples were suspended in 15 ml of pepsin buffered solution in a conical flask and incubated for 3 hrs, shaken gently after every 20 minutes. Digested samples were centrifuged at a force of 4025 g for 15 minutes and the supernatant was discarded. The residue was digested, centrifuged as before and filtered. The final residue was rolled up in the filter paper, placed into a Kjeldahl flask and dried in the oven at 100°C for 15 minutes. Ten (10 ml) of concentrated sulphuric acid and Kjeldahl catalyst was added to the sample residues followed by heat digestion. Protein digestibility was calculated as;

In vitro protein digestibility (%)=[(A-B)/A]×100

where A= Protein in the sample, B= Protein after digestion

Crude fat was quantified according to AOAC (1999; No. 920.85) method. Extraction of fat was done on a soxhlet extracting machine (HT 1043 extraction unit, Tecator, Hoganas, Sweden), using petroleum ether (40-60 boiling points) as the extractant. Dietary fibre was determined according to Pearson *et al*. (1981) procedure. About 1g of each sample was placed in a 600 ml beaker; 100 ml of cetyl trimethyl ammonium bromide in 1 N H2SO4 solution was added and the mixture was boiled under reflux for 1hr on Labconco fibre analyser, Kansas City, Missouri, 64132. The beaker was left to cool for 2 minutes and the content filtered through a cheese cloth- polyester material on bunchunar funnel connected to a vacuum pump through a glass fibre. The residue was washed with distilled water 4 times to free it of any acid, transferred into pre weighed nickel crucibles and dried at 100 °C for 1 hr in Gallenkamp UK, hot box oven. Total dietary fibre was reported as;

Dietary fibre (%)=[W_2/W_1]×100

Where W_2 = Weight (g) of the fibre, W_1 = Weight (g) of the sample.

Total ash was by oxidizing the samples (AOAC, 1999; No. 923.03). About 2 g of sample was weighed into a dry pre weighed porcelain dishes, transferred into the Carbolite furnace CNF13/5 (Carbolite, parson's Lane, Hope Valley s33 6RB, England) and the content was completely oxidized at 550-600°C for 8 hrs. The ash content was reported as the loss in weight which occurred from complete oxidation of the sample.

Total energy was determined by combusting one gram of the sample in a bomb calorimeter (Gallenkamp Auto Bomb, UK) according to (AOAC, 1999). The initial temperature of the calorimeter was recorded (Ti), the sample was ignited and the final temperature recorded (Tf). Energy value of the sample was computed as;

Total energy (Kcal/g)=[(ΔT×Cs)-length of wire burnt]/(W_t×1000)

Where; ΔT = Temperature change (T_f- T_i), W_t = Weight of sample, Cs = Energy equivalent of the bomb system (2464 Cal/g).

Samples were analyzed for major minerals; iron, zinc, calcium, potassium, phosphorous and sodium using PerkinElmer 23080 Atomic Absorption Spectroscopy (AAS) following wet digestion according to the method described by (Okalebo *et al*., 2002).

Lipids were extracted according to the methods; (Yang *et al*., 2006; Bligh and Dyer 1959). Direct methylation of the lipid was carried out in 15 ml thick-walled glass tubes with Teflon lined screw caps. Nonadecanoic acid (19:0) was used as internal standard. Samples (30-45 mg) were placed in weighed test tubes containing a known weight of the internal standard and 1 ml of acidified methanol was added prior to heating in the oven for 2 hours at 90oC. After cooling to room temperature, 0.5 ml of distilled water and 1 ml of hexane was added; tubes were shaken for 3 minutes and centrifuged at 3000 rpm for 3 minutes to enhance the separation of the hexane layer containing the Fatty Acid Methyl Ethers (FAMEs) and the residual layer. The FAMEs were siphoned from the hexane layer. Concentration of FAMEs in pooled hexane extracts was adjusted by evaporation of hexane to obtain a suitable chromatographic response.

Mixed hexane extracts (1 µl) was injected onto a 25 x 0.25 mm fused silica column with polyethylene-glycol (PEG) as the stationary phase with a 0.2 µm thickness (CP-WAX 52CB Chrompack) and helium gas at 20 psi as the mobile phase. The column was mounted in a GC/MS Agilent 6890N with autosampler 7683B series, fitted with an electronic pressure control and mass selective detection (ionizing energy, 70 eV; source temperature, 250°C). Injector temperature was 260°C. Temperature of the column was kept at 90°C for 4 min after injection and thereafter increased to 165°C at a rate of 30°C/min, followed by an increase of 3°C/min to 225°C. The temperature was then maintained at 225°C for 11 min. Fatty acids in samples were identified by comparing with the standard mixture GLC-68D from Nu-Chek-Prep (Elysian, Minn., USA) containing 20 fatty acids and by mass spectrometry. Quantification of the esters was by integration of the peaks using Chemstation software obtained from Thermo LabSystems.

Data on the nutritional composition of the different insect species was analyzed using Statistix version 9.0 analytical software. Analysis of Variance (ANOVA) was performed and difference between mean was separated using Least Significant Difference (LSD) test at 5% (P=0.05). Results were reported as means ± standard deviations.

Results

Proximate composition and protein digestibility of insects

Proximate composition, energy value and *in vitro* protein digestibility of *Syntermes* soldiers, *Macrotermes bellicosus* and *Brachytrupes* spp. are presented in Table 1. Crude protein quantity in *Brachytrupes* spp and *Syntermes* soldiers (65.35% and 64.72%) were significantly higher ($p<0.05$) than *Macrotermes bellicosus* (40.72%). Significant difference ($p<0.05$) were recorded in the *in vitro* protein digestibility; 31.39%, 44.39% and 50.22% in *Syntermes* soldiers, *Macrotermes bellicosus* and *Brachytrupes* spp. respectively. Crude fat and energy

Table 1. Proximate composition and *in vitro* protein digestibility of *Syntermes* soldiers, *Macrotermes bellicosus* and *Brachytrupes* spp

Nutrient (g/100g)	*Syntermes* soldiers	*Macrotermes* bellicosus	*Brachytrupes* spp	p-values
Moisture	2.55 ± 0.30[a]	2.31± 0.54[a]	2.22 ± 0.41[a]	0.1700
Crude protein	64.72 ±0.75[a]	40.72± 0.26[b]	65.35 ± 0.36[a]	0.0011
Crude fat	3.05± 1.33 [c]	44.84 ± 0.35 [a]	11.76 ± 0.63 [b]	0.0063
Dietary fibre	23.03 ± 0.05 [a]	5.27± 0.51 [c]	13.29± 1.61 [b]	0.0018
Ash	4.19 ± 0.12 [a]	4.96 ± 0.07 [a]	4.88 ± 0.23 [a]	0.2009
Available carbohydrate	2.46 ± 1.40 [a]	2.16 ± 0.62 [a]	2.5 ± 0.85 [a]	0.1604
Energy (Kcal/100g)	502.86 ± 2.65[c]	696.10± 0.30[a]	536.42 ± 0.47[b]	0.0012
Protein digestibility	31.39 ± 0.99 [c]	44.39 ± 1.90 [b]	50.22 ± 0.38 [a]	0.0014

Result is mean triplicate determination ± S.D. Mean values with different superscripts along each row differ significantly ($p< 0.05$).

Table 2. Mineral and Vitamin A contents of *Syntermes* soldiers, *Macrotermes bellicosus* and *Brachytrupes* spp on dry basis

Elements (mg/100g)	*Syntermes* soldiers	*Macrotermes* bellicosus	*Brachytrupes* spp	P-values
Macro minerals				
Potassium (K)	897.15 ± 0.00[a]	676.96 ± 60.82[b]	877.26 ± 41.39[a]	0.0242
Sodium (Na)	115.75 ± 3.89 [a]	110.94 ± 1.03 [a]	150.22 ± 28.23 [a]	0.1700
Calcium (Ca)	4.16 ± 0.00 [b]	9.34 ± 2.04 [a]	4.98 ± 0.58 [b]	0.0451
Phosphorous (p)	36.75 ± 0.07 [b]	49.55 ± 0.07 [a]	38.15 ± 1.91 [b]	0.0025
Micro minerals				
Iron (Fe)	32.50 ± 3.54 [b]	42.71 ± 0.60 [a]	33.60 ± 3.23[ab]	0.0681
Zinc (Zn)	17.64 ± 0.00 [b]	16.90 ± 1.47 [b]	23.02 ± 0.06 [a]	0.0007
				0.0001

Results are means of triplicate determination ± S.D. Values with different superscripts along the row differ significantly ($p< 0.05$).

value varied significantly ($p<0.05$) in *Macrotermes bellicosus* (44.84% and 696.10 Kcal/100 g) and *Syntermes* soldiers (3.05% and 502.86 kcal/100 g) respectively. Dietary fibre was high in *Syntermes* soldiers (23.03%) and *Brachytrupes* spp. (13.29%). Total ash was not significantly different ($p>0.05$).

Mineral composition of insects

Minerals composition of *Syntermes* soldiers, *Macrotermes bellicosus* and *Brachytrupes* spp. are presented in Table 2. Potassium levels were highest of all the macro minerals in *Syntermes* soldiers (897.15 mg/100 g), *Brachytrupes* spp (877.26 mg/100 g) and *Macrotermes bellicosus* (676.96 mg/100 g) respectively. Levels of Potassium, Sodium and Phosphorus varied significantly ($p<0.05$) in *Macrotermes bellicosus* as compared to *Syntermes* soldiers and *Brachytrupes* spp. *Macrotermes bellicosus* had higher levels of calcium and iron compared to *Syntermes* soldiers and *Brachytrupes* spp. Levels of Zinc were significantly higher ($p<0.05$) in *Brachytrupes* spp. compared to *Syntermes* soldiers and *Macrotermes* bellicosus.

Fatty acid composition of insects

Table 3 Show the fatty acid profile of edible insects analyzed. By and large, the insects had higher unsaturated (57.25 to 63.92%) fatty acid contents. Oleic acid was the most abundant fatty acid in the insects, being significantly higher in *Macrotermes bellicosus* (47.73%) compared to *Brachytrupes* spp (38.27%) and *Syntermes* soldiers (37.64%). Linoleic acid was the most abundant polyunsaturated fatty acid, with the levels varying significantly ($p<0.05$) among the insects. Total polyunsaturated fatty acid was significantly high ($p<0.05$) in *Brachytrupes* spp. (24.68%) and low in *Macrotermes bellicosus* (9.55%). Ratios of TPUFA to TSFA varied significantly ($p<0.05$) among the insects.

Table 3. Fatty acid composition (%) of *Syntermes* soldiers, *Macrotermes bellicosus* and *Brachytrupes* spp on "as is basis"

Fatty Acid (%)	*Syntermes* soldiers	*Macrotermes* bellicosus	*Brachytrupes* spp	p-values
Myristic acid (14:0)	0.00 ± 0.00[c]	0.75 ± 0.01[b]	0.96 ± 0.01[a]	0.0000
Palmitic acid (16:0)	5.66± 0.05[c]	27.71 ± 1.58[a]	21.31 ± 0.49[b]	0.0004
Palmitoleic acid (16:1n7)	0.00 ± 0.00[b]	2.20 ± 0.34[a]	0.96 ± 0.01[b]	0.0035
Stearic acid (18:0)	9.18 ± 0.67[a]	11.59 ± 0.70[a]	12.24 ± 0.24[a]	0.0258
Oleic acid (18:1n9)	37.64 ± 1.93[b]	47.73 ± 0.55[a]	38.27 ± 0.67[b]	0.0062
Linoleic acid (18: 2n6)	16.74 ± 0.38[b]	8.92 ± 0.23[c]	22.14 ± 0.59[a]	0.0002
Linolenic acid (18:3n3)	2.88 ± 0.00[a]	0.63 ± 0.00[b]	2.55 ± 0.18[a]	0.0004
Arachidic (20:0)	0.00 ± 0.00[b]	0.00 ± 0.00[b]	0.49 ± 0.007[a]	0.0000
Unknown	28.93 ± 0.43[a]	0.00 ± 0.00[b]	0.00 ± 0.00[b]	0.0000
TSFA	14.83 ± 0.62[c]	40.06 ± 0.88[a]	34.99 ± 0.24[b]	0.0001
TUSFA	57.25 ± 2.32[a]	59.48 ± 0.66[a]	63.92 ± 0.12[a]	0.0377
TMUFA	37.64 ± 1.93[b]	49.93 ± 0.88[a]	39.23 ± 0.66[b]	0.0044
TPUFA	19.62 ± 0.38[b]	9.55 ± 0.23[c]	24.68 ± 0.77[a]	0.0002
TPUFA/TSFA	1.32 ± 0.03[a]	0.24 ± 0.01[c]	0.71 ± 0.02[b]	0.0000

Result is mean triplicate determination ± S.D. Mean value with different superscripts along each row differ significantly ($p<0.05$). TSFA= Total saturated fatty acid. TUSFA= Total unsaturated fatty acid, TMUFA= Total mono unsaturated fatty acid, TPUFA= Total poly unsaturated fatty acid

Discussion

Brachytrupes spp and *Syntermes* soldiers are rich in proteins; similar to reports of Oyarzun *et al*. (1996), Paoletti *et al*. (2003) and Ntukuyoh *et al*. (2012), Indeed, insects are rich in protein compared to beef (22.3%), chicken (22.25%), pork (22.0%) and lamb (19.8%) on a mass basis (Probst, 2008). Raw red muscle meat for instance contains 20-25 g protein/100 g and cooked red meat contains 28-36 g/100 g, as water content decreases and nutrients become more concentrated during cooking (Williams, 2007). Consumption of insects could contribute to the dietary protein quality, replacing higher animal protein usually deficient in diets of rural dwellers in developing countries (Banjo *et al*., 2006).

In vitro protein digestibility varied among the insects; protein quality in food is determined by amino acid profile and ability of digestive enzymes to liberate the amino acids (Gauthier *et al*., 1982). Ajayi (2012) reported higher digestibility (83.41%), for winged termites and (81.10%) in soldier termites, which could be attributed to the difference in analytical methods (multi enzyme digestion). In this study, a single enzyme digestion was used. However, the trend in the variation of digestibility was comparable. In a previous study a three enzyme (trypsin, chymotrypsin and peptidase) one-step digestion gave protein digestibility approximately 39 to 66% higher than that obtained by the two-enzyme (pepsin and pancreatin) two-step digestion method depending on type of product (Abdel-Aal, 2008). The higher protein digestibility obtained by the one-step digestion could be explained by the synergic effect of the three proteolytic enzymes used in the method. However, the two-step digestion methods were more reliable than the one-step digestion in determining differences in protein digestibility among the products.

Variations existed in fat content of winged and soldier termites; attributed to the biological role of the castes. Winged termites play a reproductive role in the colony and their body is enriched with nutrients in preparation for that purpose while the soldier termites together with workers play potential labor roles (Matthew, 2013). In the course of these activities, *Syntermes* soldiers make use of the nutrients more than others in the colony (Ajayi, 2012). Energy varied with fat content, fat is an energy dense nutrient providing more than twice the amount of energy when compared to proteins and carbohydrate (Nawar, 1996). *Macrotermes bellicosus* had the highest (696.10 kcal/100 g) calorific value. Previous studies reported 688 kcal/100 g and 529 kcal/100 g for winged and soldier termites (Oyarzun *et al*., 1996). Aware that malnutrition in developing countries is as much or more a problem of calorie deficiency as of a protein deficiency (Defoliart, 1992). These rich sources of energy could as such be used to offset energy deficiency.

The observed disparity in dietary fibre of insects was possibly due to variation in levels of chitin (main structural carbohydrates) in insects. High intake of dietary fibre has health benefits such as lowing risk of developing coronary heart disease, stroke, hypertension, diabetes, obesity and gastrointestinal diseases (Anderson *et al*., 2009). Quantity of total ash in the insects were Similar to the reports of previous studies; (3.70 to 4.50%) in soldier termites (Ntukuyoh *et al*. 2012); 5.53% for boiled tree locust (El Hassan *et al*., 2008).

Potassium was most abundant of all macro elements. However, higher values were reported for soldier termites by Paoletti *et al*. (2003) in Venezuela and *Rhychophorus phoenicis* (Elemo *et al*., 2011). Variations were attributed to disparity in environmental edaphic factors of the study sites. Potassium plays an important role in the human body and sufficient amounts in the diet protect against heart disease, hypoglycemia, diabetes, obesity and kidney disease. Consuming 100 g of the insects contributes significantly to the 4700 mg/100 g Recommended Daily Intake (RDI) of potassium for an adult (Hellwig *et al*., 2006). Iron (42.71 to 32.50 mg/100 g) and Zinc (23.2 to 17.64 mg/100 g) were higher than reported for any other conventional meat (Paoletti *et al*., 2003; Williams 2007). Iron is essential for proper functioning of immune system and production of energy and synthesis of collagen while zinc supports the immune system, reproductive functions and normal synthesis of protein (Hellwig *et al*., 2006). Consumption of 100 g of the insects meets and exceeds the Recommended Daily Intake (RDI) of iron and zinc in children, elderly and nursing and pregnant women who have very high requirements (Hellwig *et al*., 2006).

Fatty acid profile varied among the insects investigated, perhaps due to environmental factors such as diet, season and living temperature. Other than biological differences such as digestibility; enzymatic activity, age, sex, and size are known to influence fatty acid composition and concentration and this could be responsible for the differences between and within species (Oranut *et al*., 2010).

By and large, the three insects had high unsaturated (57.25 to 63.92%) fatty acid contents. High level of saturated fatty acid in food is undesirable. A unique feature of saturated fatty acids is that they suppress

expression of Low density Lipoproteins (LDL) receptors, thus raising blood LDL cholesterol levels which are implicated to cause atherosclerosis (Hellwig *et al*., 2006). Similar high values of unsaturated fatty acid in edible insects especially termites and grasshoppers oils were also reported (Oyarzun *et al*., 1996; Kinyuru *et al*., 2011). Monounsaturated acid values (37.64 to 49.93%) in the analyzed insects were higher than contents in some fresh water fishes studied by Ugoala *et al*. (2008).

Oleic acid (47.73 to 37.64%) was the most predominant fatty acid in the insect oils. Presence of oleic acid in large quantities in these insects is advantageous as it can be easily converted to essential fatty acids like linoleic as studied by Yuan and Bloch (1961). Linolenic acid content in *Brachytrupes* spp (22.14%) and *Syntermes* soldiers (16.74%) were comparable to values reported for Nile perch heads (Turon *et al*., 2005). Values were also within the range (1.36 to 4.64%) indicated for Nile perch muscles (Namulawa *et al*., 2011). The low amounts of polyunsaturated fatty acids such as linoleic and linolenic acid in insect oils give them high oxidative stability. Fatty acid composition has a much higher influence on the stability of its oils than the minor components of antioxidants present in the oil (Mariod, 2013).

The presence of essential fatty acids like linoleic and Linolenic acid points to the nutritional value of the oils from insects investigated. A considerable body of evidence suggests that linoleic acid lowers total cholesterol concentrations relative to oleic acid. This differential effect may extend to all of the lipoprotein fractions (Grundy, 1997). Linoleic acid acts as a precursor for arachidonic acid, which in turn serves as the precursor for eicosanoids such as; prostaglandins, thromboxane and leukotrienes. Alpha-linolenic (a-linolenic) acid, the parent acid of the *n*-3 fatty acid series is the only *n*-3 fatty acid that is an essential fatty acid. The *n*-3 fatty acids play an important role as a structural membrane lipid, particularly in nerve tissue and retina. The *n*-3 fatty acids also compete with the *n*-6 fatty acids for enzymes responsible for production of long-chain *n*-3 fatty acids and thereby influence the balance of *n*-3 and *n*-6 fatty acid-derived eicosanoids (Hellwig *et al*., 2006).

TPUFA/TSAFA ratio of the insect oils was ranging from 1.32 to 0.24. Ratios under 0.20 have been associated with high cholesterol level and high risk of coronary heart disorders. The *n*-3/*n*-6 in *Syntermes* soldiers (1.32) and *Brachytrupes* spp (0.71) were higher than 0.10 reported for beef (Williams, 2007). Namulawa *et al*. (2011) reported *n*-3/*n*-6 of 1.2 to 1.74 for Nile perch oil. A ratio of 1:2 to1:4 are recommended for general health. On the basis of the nutrient quality, consumption of these insects needs to be recommended for heart health.

Conclusion

Insects analyzed in this paper are rich in protein, energy, essential fatty acids and minerals especially potassium, iron and zinc. Consumption of 100 g of dry insects meets the recommended daily intake for iron and zinc for individuals with high requirements such as preschool children, nursing and pregnant mothers. Consumption of these insects needs to be recommended, especially among rural communities with low animal protein intake to contribute to the dietary requirements of the essential nutrients. The available information on nutritional value of edible insect need to be properly documented, packaged and disseminated to encourage consumption. Further nutritional analysis on the insects is required to comprehend their amino acid profile, biological value and bioavailability of the insect's components.

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