Nutrient Composition and Protein Quality of Four Species of the Curcubitaceae Family

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Abstract: The kernels of most Curcubitaceae species have tremendous food value in Africa where protein-energy malnutrition is high but they are not widely used in food preparations. This study assessed the nutritional composition and protein quality of four species of Curcubitaceae seeds using laboratory rats. Moisture, ash, fibre, minerals and protein of the Curcubitaceae seeds were determined. Rats were randomly assigned to seven groups of five and were fed for four weeks on the following diets: the four species of the Curcubitaceae seed meal and control diets of Soya Bean Meal (SBM), protein free diet and normal rat chow respectively. Their urine and faeces were collected for analysis and feed intakes determined. After four weeks feeding, the rats were weighed, lyophilized and protein utilization determined. The moisture, crude protein, fat and ash content of the seeds were 5.44-6.66, 30-36, 44-58 and 3.18-4.90%, respectively. Crude fibre was less than 2.5%. The Curcubitaceae seeds contained high amounts of: Zn (5.0-7.1 mg/100 g), Cu (1.4-7.9 mg/100 g) and Fe (5.6-8.5 mg/100 g). All the seeds had good protein quality as judged by the PER (0.75-1.36) and (NPU) (46.10-69.10). The four Curcubitaceae seeds have good protein quality, fat and minerals which may help reduce under nutrition. These are important food resources and thus their consumption should be promoted.

Keywords: Curcubitaceae seeds, mineral, net protein utilization, protein efficiency ratio, protein quality

INTRODUCTION

Protein Energy Malnutrition (PEM) is by far the most ruinous form of malnutrition, with children being the most visible casualties (WHO, 2010). Hence the search for alternative protein food source, especially for developing countries, is of utmost importance, particularly because of the high cost of animal protein sources and the high levels of poverty (Fasuyi, 2007). Nonetheless, most plant source foods have received much less attention in the scientific arena (Vodouhé and Capo-Chichi, 1998). This has restricted their cultivation to certain areas where other essential ones are still wild (Mnzava et al., 1999); most of which contain proteins and other nutritionally important components that could be harnessed as alternatives for human diet (Achigan-Dako et al., 2008; Mabalaha et al., 2007). Hence a persuasive way to draw attention to local crops is to create awareness of their nutrient composition and protein quality for reducing PEM.

The discovery of protein and its effect on body metabolism (Cox and Nelson, 2001; Berg et al., 2002), the higher commercial value placed on the product due to its necessity (Carpenter, 2003a, b and c) and the associated role it plays in preventing and/or solving malnutrition especially Protein Energy Malnutrition (WHO, 2010; Wardlaw, 2000) has for a long time triggered research into alternative sources and the various properties it possesses. Food has been enriched both consciously and unconsciously to raise the protein status of protein deficient individuals via the use of scientifically approved methods especially relying on the complementarily of proteins from different sources, or the reliance on good traditionally adopted food preparation methods probably not with the real intention of improving the nutritional profile of the foods but to enhance the taste of food through harnessing available food stuffs (Ponka et al., 2005).

Soybean, Peanuts, cowpea and different Curcubitaceae seeds have been used in different ways to ameliorate PEM. Some studies have also investigated the nutritional value, antinutrient constituents as well as the effect of processing on the anti-nutrient quantities of Curcubitaceae seeds in many part of West Africa (Fokou et al., 2004; Onyeike and Acheru, 2002; Badifu, 2001). The seeds of most species of Curcubitaceae have tremendous food value in Africa (Badifu and Ogunsua, 1991), but information on biological utilization of its nutrients is scanty. Also, there are limited studies on the use of laboratory animals to clearly determine the bioavailability of the nutrients in the processed kernels of the different varieties of the Curcubitaceae. In Ghana four species of the Curcubitaceae namely: Cucumoperispis mannnii, Citrullus lanatus (Thumb) Matsum and Nakai var. citroides, Cucumis melo linn and Cucurbita pepo linn seeds are available but utilization is very low. To promote
utilization and consumption, particularly in complementary and/or supplementary feeding to help reduce the high rates of growth faltering in the country. It is important to know the nutrient profile as well as the biological utilization of the seeds in order to understand its fullest nutritional benefits. This study therefore determined the proximate composition, mineral content and the protein quality of seeds using laboratory rats.

MATERIALS AND METHODS

Sample and sample preparation: Matured, sun-dried seed samples were obtained from three regions of Ghana where the seeds are popularly cultivated. *Curcumeropsis mannii*, *Citrus lanatus* (Thumb.) Matsum. and Nakai var. *Citroides* and Soy beans were obtained from Northern region; *Cucumis melo* linnaeus, obtained from Brong-Ahafo and *Cucurbita pepo* linnaeus obtained from Brong-Ahafo and Western regions. The seeds were transported in polyethylene bags to the laboratory and authenticated at the Department of Botany, University of Ghana, Legon. The samples were dehulled manually and winnowed to remove all debris. The kernels obtained were ground in an electric grinder to fine powder, placed in air-tight containers and stored in the desiccator prior to further analysis.

Proximate analyses: The chemical composition of the *Cucurbitaceae* seeds were determined using standard methods after AOAC (1990). For moisture, Two grams of each of the samples was weighed and dried to constant weight at a temperature of 105°C to obtain the moisture content. Protein content was assessed using 0.2 g of samples which were digested using ammonium salts with concentrated H₂SO₄ at a high temperature. The mixture was cool ed and 50% NaOH added. The resulting ammonia was distilled into a known volume of standard boric acid with indicator. The distillate was then titrated with 0.1N HCl. The calculated amount of nitrogen obtained was multiplied by 6.25 to give the quantity of protein present in each of the samples.

Fat content was determined by the Soxhlet method as described by the American Oil Chemists’ Society (1997) Crude fiber was calculated as the loss on ignition of dried residue remaining after digestion of sample with 1.25% H₂SO₄ and 1.25% NaOH solutions. The ash content was calculated as ash formed per the amount of sample used after 2 g of the samples were weighed into crucibles and heated to constant weight at a temperature of 550°C.

Determination of minerals: About 0.1 g of each of the prepared *Cucurbitaceae* seeds samples were wet digested with nitric acid and perchloric acid; the filtrates obtained were analyzed for Fe, Zn, Cu, Ca, Mn and Mg using the atomic absorption spectrophotometer (AOAC, 1990).

**Biological utilization of proteins:** To evaluate the protein quality of the seeds in terms of their biological utilization, animal modules were employed. To do this, the seeds were prepared and diets formulated as required by the nutrients needs of rats. Soy beans were used for control diet. The Net Protein Utilisation (NPU) and Protein Efficiency Ratio (PER) were obtained.

**Seed cake preparation:** Samples were roasted separately in oven at 100°C for 20 min, cooled and ground into powder with a laboratory mill (Size 8 inch laboratory mill, Christy and Norris limited, Chelmsford, England) and then passed through 1.0 mm sieve. Distilled water was mixed with the powder and filtered through 500 microns Impact Laboratory test sieve. The filtrates were boiled at 98°C for 20 min to further reduce the anti-nutrients in the anticipated seed meal to be prepared (Badifu, 2001). They were allowed to cool, freeze dried and defatted with the Soxhlet method of fat extraction using n-hexane as the extracting solvent (AOAC, 1990). The defatted samples were dried in an air oven at 60°C for 24 h to remove all traces of solvent. The seed cakes prepared which served as the protein source for the seed meal preparations were packed in air-tight plastic containers and refrigerated at 4°C. It is important to note that half the quantity of *C. mannii* was not roasted but taken through the subsequent processes as the other samples because it is not roasted when it is use in the preparation of stews such as palaver sauce.

**Formulation of animal meal:** The diets were prepared based on the formulation of the AOAC (1984) as shown in Table 1. All experimental diets were hand-mixed, with initial minute components of the ingredients to ensure uniformity and proper blending (Fasuyi, 2007). A separate Nitrogen free diet was made without any nitrogen source as an ingredient. Soy bean meal was prepared with the same procedure and served as the control diet. The protein content of the diet was 10%. The protein concentrated seed cakes of defatted soy bean as well as the *Cucurbitaceae* varieties to be evaluated were added to corn starch (BDH Limited Poole England) to give approximately 10% crude protein on a dry matter basis. Proximate composition of the diets used in the study was performed to ascertain and authenticate the proximate constituents of the diet. They were thereafter put into different well-sealed plastic containers, labelled and stored at 4°C prior to use.

**Experimental animals:** Forty clinically healthy weanling male albino rats (Sprague-Dawley), 24±2 days old were obtained from the clinical rat colony of the Centre for Scientific Research into Plant Medicine, Mampong-Akuapem, Ghana. The rats were randomly divided into 7 groups of 5 rats each on the basis of
initial weight and litter origin. They were housed individually in plastic metabolic cages to facilitate separate faecal and urinary collection in a room maintained at 18-26°C with a 12 h light/dark cycle and 40-70% relative humidity. They were fed commercial laboratory rat chow diet ad libitum. The rats were acclimatized for 5 days before they were placed on their respective diets for 4 weeks. After feeding for four weeks, the rats were humanely sacrificed with chloroform. The carcasses were frozen, lyophilized and the net protein content of defatted sample was assessed using the Kjeldahl method (AOAC, 1990).

### RESULTS AND DISCUSSION

The carbohydrates content in the *Cucurbitaceae* seeds studied were lower than the other macronutrients in the seeds. The seeds of *C. melo* (lawn), *C. pepo* (lawn) and *C. lanatus* exhibited similarities in their carbohydrate contents which ranged from 3.11±0.74-4.28±1.64% as shown in Table 2. This suggests that the seeds may have some resemblance in their genetic composition that is not affected by changes in climatic conditions (Achu et al., 2005). The *C. manii* was observed to be an ideal source of carbohydrate among the four *Cucurbitaceae* seeds species studied. The carbohydrate of *C. manii* was found to be similar to the 7.11% found by Achu et al. (2005). On the contrary, the carbohydrates content of the *C. manii* was lower than the 12.55% for the same variety that Abiodum and Odeke (2010) reported. This implies that the *Cucurbitaceae* seeds studied may not serve as a good source of carbohydrates.

The lipid extracted from *C. manii*, *C. lanatus* and *C. melo* lawn were pale yellow in colour while those from *C. pepo* lawn seeds were green, similar to what Achu et al. (2005) detected. They were all fluid at room temperature. This suggests that they may have higher quantities of unsaturated fatty acids (Glew et al., 2006; Giwa et al., 2010; Oluba et al., 2008; Uruakpa and Aluko, 2004). Glew et al. (2006) reported that the fatty acid: oleic, linoleic and stearic composition in *Cucurbita* sp., were: 45.4, 31.0 and 7.8%, respectively. Achu et al. (2008) also reported similar results when they analyzed the fatty acid composition of the oil of five different *Cucurbitaceae* species. These finding suggests that the *Cucurbitaceae* varieties investigated could provide the fatty acids for the synthesis of other fatty acid derivatives which could be harnessed for the growth and development of consumers especially children (Williams, 2005; Wardlaw, 2000; Anthony, 2000).

### Table 1: Composition of animal meal

| Ingredients          | Concentration (g/Kg) | Soybean (control) | Protein free diet | C. manii (raw) | C. manii (roasted) | C. pepo | Cucumis melo | *C. lanatus* |
|----------------------|----------------------|-------------------|-------------------|----------------|--------------------|---------|--------------|--------------|
| Corn starch          | 549.9                | 760               | 603.0             | 603.0          | 608.6              | 614.6   | 611.6        |              |
| Defatted sample*     | 211.0                | 0.0               | 157.0             | 157.0          | 151.4              | 145.8   | 148.4        |              |
| Soybean oil          | 80.0                 | 80.0              | 80.0              | 80.0           | 80.0               | 80.0    | 80.0         |              |
| Fibre content of defatted sample | 8.0  | 0.0             | 5.2               | 5.2            | 4.7                | 4.3     | 4.5          |              |
| Cellulose            | 2.0                  | 10.0              | 4.8               | 4.8            | 5.3                | 5.7     | 5.5          |              |
| Sucrose              | 100.0                | 100               | 100.0             | 100.0          | 100.0              | 100.0   | 100.0        |              |
| Ash content of defatted sample | 13.8 | 0.0           | 10.5              | 10.5           | 13.0               | 9.9     | 10.1         |              |
| Mineral mix          | 26.2                 | 40.0              | 29.5              | 29.5           | 27.0               | 30.1    | 29.9         |              |
| Total min. content   | 40.0                 | 40.0              | 40.0              | 40.0           | 40.0               | 40.0    | 40.0         |              |
| Vitamin mix          | 10.0                 | 10.0              | 10.0              | 10.0           | 10.0               | 10.0    | 10.0         |              |

* 10% protein level; a: Mineral mix (g/Kg diet), CoCl2 6H2O (0.001), CuSO4 5H2O (0.07), MnSO4 (0.178), KI (0.032), KH2PO4 (40.0), CaSO4 (15.25), NaCl (5.573), ZnCO3 (1.6), FeSO4 7H2O (1.078), MgSO4 7H2O (2.292); b: Vitamin mix (per Kg of diet): Thiamin hydrochloride = 7 mg; nicotinic acid = 30 mg; folic acid = 2 mg; calcium pantothenate = 16 mg; biotin = 0.2 mg; cyanocobalamin = 0.01 mg; retinol palmitate = 1000 IU; α-tocopherol acetate = 50 IU; menadione = 0.05 mg; chlorin chloride = 2 g
Table 2: Nutritive content of four Cucurbitaceae species

| Nutrient | C. manni | C. melo linn | C. pepo linn | C. lanatus |
|----------|----------|--------------|--------------|------------|
| Protein  | 36.00±0.24\(^a\) | 35.00±0.39\(^a\) | 36.00±0.94\(^d\) | 30.00±0.39\(^d\) |
| Fats     | 44.00±0.58\(^b\) | 50.00±0.37\(^b\) | 46.00±0.57\(^b\) | 56.00±0.29\(^b\) |
| Moisture | 6.64±0.09\(^a\)  | 6.34±0.17\(^a\)  | 6.66±0.25\(^a\)  | 5.44±0.14\(^a\)  |
| CHO      | 7.65±0.29\(^a\)  | 3.11±0.74\(^a\)  | 4.28±1.64\(^a\)  | 4.13±0.71\(^a\)  |
| Fibre    | 2.00±0.31\(^a\)  | 2.00±0.33\(^a\)  | 2.40±0.48\(^a\)  | 1.90±0.39\(^a\)  |
| Ash      | 3.91±0.03\(^a\)  | 3.56±0.06\(^a\)  | 4.90±0.08\(^a\)  | 3.18±0.06\(^a\)  |

C. lanatus is Citrullus lanatus (Thumb.) Matsum. and Nakai var. citroides; \(^a\): Carbohydrate; \(^\ast\): Values within a row with the same superscript means that there are no significant differences but those with different superscript show significant differences (p<0.05) by the Tukey’s multiple comparison test; S.D.: Standard deviation

The fat (lipid) contents of C. manni, C. melo linn, C. Pepo linn and C. lanatus were 44.00±0.58, 50.00±0.37, 46.00±0.57\(^b\), 56.00±0.29\(^b\), respectively (Table 2). The lipid content of C. lanatus was similar to the 56.67±4.90\(^b\) obtained by Loukou et al. (2007). C. manni lipid content obtained was also comparable to what was obtained by Loukou et al. (2007) and Anhwange et al. (2010). It was however, higher than the 42.29\(^b\) obtained by Abiodun and Adeleke (2010). The quantity of lipid obtained from the C. pepo linn assessed was also higher than that obtained by Nyam et al. (2009). This may be due to the method used in the sample preparation stage. It was not stated by Nyam et al. (2009) whether they dehulled the seeds used for their lipid quantification. If they did not dehull the seeds prior to their use, the testa of the seeds might have absorbed some of the lipid that would have been measured. The higher lipid content we obtained might also be attributed to the genetic makeup or environmental conditions that might have favored higher lipid synthesis by the seeds (Achu et al., 2005).

More than 40% of the content of the seeds of the studied Cucurbitaceae species being lipid is indicative of their prolific lipid content. The lipid content shows that they, (especially C. lanatus) could be alternative to soy bean which has been reported by USDA (2010) to have 20%. The quantities of lipid in the seeds provides a vital evidence that they could also be considered for use in the formulation of lipid based nutrient supplementation products particularly due to their added high protein content. The Cucurbitaceae seeds investigated have high economic potential as commercial lipid seeds. This advantage could be harnessed to improve the financial well-being of impoverished rural people who are mostly the growers of these Cucurbitaceae seeds.

The quantity and quality of protein in the seeds were assessed in order to ascertain the amount of this nutrient these plant species could contribute to the diet of consumers as well as their prolificacy as a source of protein in the industrial and research setting. The protein contents of all the Cucurbitaceae varieties studied were above 30% indicating that they are rich sources of proteins. C. manni, C. melo linn, C. pepo linn and C. lanatus had protein content of 36.00±0.24, 35.00±0.39, 36.00±0.94 and 30.00±0.39\(^d\), respectively (Table 2). The protein content of C. lanatus was comparable to what was obtained by Loukou et al. (2007) but lower than another variety of C. lanatus (watermelon) that El-Adawy and Taha (2001) investigated. The protein content of C. pepo linn was higher than that obtained by Nyam et al. (2009), but comparable to the result of El-Adawy and Taha (2001). It was however; lower than the result obtained by Younis et al. (2000). Likewise, the protein content of C. melo linn obtained in this study was found to be significantly (p<0.05) higher than the 29.55\(^b\) obtained in C. melo var. agrestis (Loukou et al., 2007). However that of the C. manni was similar to the 36.1%, obtained by Badifu and Ogunsua (1991), as well as the 34.64 to 41.18% in C. manni grown in the high savanna region of Cameroon, but lower than the 43.38 and 41.75% in the same species cultivated in the rain and swamp forests respectively grown in the same country (Achu et al., 2005). This suggest that the variability observed could be attributed to intra-species and interspecies differences or seed drying procedures (Bankole et al., 2005) as well as the different climatic conditions.

The protein content of all the Cucurbitaceae varieties studied were found to be higher than those of other lipid seeds such as cashew nuts (22.8%), cottonseed (21.9%) and sesame (18.7%) (FAO, 1982). It is worth noting that C. manni, C. melo linn and C. pepo linn could provide consumers proteins in quantities comparable to the 36.49\(^a\) of soy bean (USDA, 2010). About 55 g of the Cucurbitaceae seeds studied could provide the Recommended Dietary Intake (RDI) of 19 g needed by children at age 5 (Institute of Medicine, 2001). These species may therefore be able to provide enough proteins for the nutritionally vulnerable, especially children, pregnant and lactating mothers, as well as old people who need adequate proteins in their diet for proper growth, maintenance and repair of worn out tissues (Williams, 2005). It also suggests that the Cucurbitaceae varieties studied are capable of providing enough proteins that could be added to staples that are poor in proteins and/or some of the amino acids to provide a very good diet for children especially during complementary feeding (Asiedu et al., 1994) to help solve the increasing demand of proteins for children especially in developing countries.

The fraction of the proteins consumed which is absorbed by the body cells (net protein) and used to
synthesizes new cells for growth and repair of worn out tissues is of immense benefit. Net Protein Utilization (NPU) is therefore used as a means of predicting the quality (biological value) of a protein (Rasco, 2001). The NPU for the Cucurbitaceae varieties studied ranged from 46.10±1.62-61.00±1.64 (Table 3). The NPU for soy bean (67.70±1.53) as shown in Table 3 was higher than all the Cucurbitaceae species investigated but C. pepo linn had the highest NPU among all the Cucurbitaceae varieties. The C. pepo linn could thus be regarded as the best protein source among the Cucurbitaceae species for providing much essential amino acids for the growth and maintenance of consumers especially vulnerable people like: children, pregnant women, the elderly and the sick (Williams, 2005; Wardlaw, 2000). The NPU for C. melo linn and C. pepo linn were higher than all the NPU for the various processed C. vulgaris schrad obtained by Oyenuga and Fetuga (1975). On the other hand, there was no significant difference between the NPU for C. mannii (raw) and C. mannii (roasted) and the 50.12 for Fried Defatted Meal (FDM) made from C. vulgaris schrad that Oyenuga and Fetuga (1975) found. The NPU for C. lanatus was lower than the Fried Defatted Meal (FDM) and the Raw Defatted Meal (RDM); but higher than the NPU for the Fried Undefatted Meal (FUM) and the Raw Undefatted Meal (RUM) from the same seed variety. This indicates that the pre-treatment method employed impacted significantly on the NPU of the studied seeds.

The quantity of tissue developed which provide the platform for growth out of the protein consumed as proposed by Osborne et al. (1919) has been used as a method for assessing protein quality. Protein Efficiency Ratio (PER) of the Cucurbitaceae seeds varied from 1.36±0.01 for C. pepo linn to 0.75±0.03 for C. Lanatus (Table 3). The PER of 1.36 recorded for the C. pepo linn was higher than the 1.01 recorded by Zdunczyk et al. (1999) and Oyenuga and Fetuga (1975) for other varieties of Cucurbitaceae investigated. Some changes in processing the test diet or differences in the genetic makeup of the C. pepo from different parts of the world might have contributed to the changes in the PER (Achu et al., 2005). The PERs for all the seeds obtained were however lower than the PER of the 10% content of germinated fluted pumpkin (Telfairia occidentalis Hook) concentrates in cookies that Giami and Barber (2004) reported. The lowest PER of 0.75 obtained for the C. lanatus indicates that the proteins from other plant sources have to be added to augment the essential amino acids to be consumed. As Zdunczyk et al. (1999) did, the addition of soy bean to C. pepo at the ratio of 1:1 raised the PER of the product to 1.43 which was higher than the PER obtained for soy bean or C. pepo alone. The PER obtained for C. lanatus tallies with its level of coagulation observed during the processing of the various seed meal. It appeared to have the least level of coagulation. It may be having low levels of soluble proteins like albumins and globulins that were utilized by the rats used in the bioassay.

Similarity in PER was observed in the PERs of C. mannii both raw and roasted and C. melo linn. This indicates that these protein sources have similar protein characteristics that were utilized by the rats (Giami and Barber, 2004). They could therefore be harnessed interchangeably as a source of protein in any protein based diet. The absence of significant difference in the PER of the C. mannii (raw) and C. mannii (roasted) also suggests that boiling alone or roasting before boiling that most Ghanaians incorporate in the cooking of these Cucurbitaceae varieties do not produce any differences in the biological utilization of the proteins in them. According to Badifu (2001), roasting alone is capable of reducing 22-44% saponin and 24-54% total phenol contents of Cucurbitaceae kernels; whereas boiling can also appreciably reduce all anti-nutrients by about 40-81%, with phenols having the greatest reduction. Thus, the processing method involving roasting before boiling might have been expected to further reduce substantially the amounts of anti-nutrients to bring about an increase in the bioavailability of the proteins in the seed cake used. The roasting done before boiling might have been added by users to improve the organoleptic properties of the outcome-usually the soup. There was a lower PER value of the proteins of the seeds of the Cucurbitaceae varieties as compared to that of the soy bean (1.87±0.04) based on the method employed. It suggests that the essential amino acids and/or the bioavailability of the proteins of the soy bean may be superior to that of the seeds of the Cucurbitaceae varieties studied. However, different procedures like the inclusion of germination in the processing of seeds before formulation of the test diet could have had a positive influence on the PER (Giami and Barber, 2004; Asiedu et al., 1994). Hence different methods of processing need to be investigated to determine the most appropriate method of making the proteins in the Cucurbitaceae seeds more bio-available.

The search for good iron sources is relevant due to the increasing levels of Iron deficiency anaemia in Africa. The iron content of C. mannii, C. melo linn, C. Pepo linn and C. lanatus were 7.10±0.00, 8.50±0.01,

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**Table 3:** Protein Efficiency Ratio (PER) and Net Protein Utilization (NPU) of the proteins in the seed cakes of four Cucurbitaceae species and soybean

| Feed type       | PER±S.D.       | NPU±S.D.       |
|-----------------|----------------|----------------|
| C. melo linn    | 1.25±0.00     | 54.40±1.60     |
| 1 C. mannii (raw) | 1.17±0.07    | 51.00±1.32     |
| Soya bean       | 1.87±0.04     | 67.70±1.53     |
| C. lanatus      | 0.75±0.03     | 46.10±1.62     |
| C. pepo linn    | 1.36±0.01     | 61.00±1.64     |
| 2 C. mannii (roasted) | 1.25±0.06 | 53.70±2.11     |

*a-f: Values within a column with the same superscript means that there are no significant differences but those with different superscript show significant differences (p<0.05) by the Tukey’s multiple comparison test; S.D.: Standard deviation*
6.50±0.00 and 5.60±0.00 mg/100g, respectively (Table 4). The iron content in C. pepo linn studied was found to be lower than the 10.9 mg/100 g as well as the 106 µg/g observed by El-Adawy and Taha (2001) and Glew et al. (2006) respectively. C. mannii was observed to contain lower iron content than the 117 ppm reported by Badifu and Ogunsua (1991). According to American Academy of Pediatrics (1993), the Recommended Daily Intake (RDI) for iron for infant between the ages 6 to 12 months of weight 9 kg is 7 mg. The result suggests that C. mannii and C. melo linn may be capable of providing more than 100% of the recommended daily iron intake if these seeds could constitute 100 g of the total food consumed per day. C. pepo linn and C. lanatus could contribute 93 and 80%, respectively. All the seeds with the exception of C. lanatus could provide all the daily iron needed by children between 1 and 3 years and weights between 11 and 14 kg. However, only C. melo linn could provide the RDI for children at their fifth year. C. mannii, C. pepo linn and C. lanatus may be capable of providing 89, 81 and 70% RDI, respectively of iron for children at age five.

Conversely, since the absorption of iron from plant food sources is low, there is the need to consume alongside these iron rich sources some iron absorption enhancers like vitamin C-a cheaper enhancer than meat to augment the absorption of the iron. The substantial iron content in the studied Cucurbitaceae species coupled with its high protein contents could go a long way in the synthesis of iron containing compounds like haemoglobin, myoglobin and cytochromes that play pivotal role in energy metabolism (Cox and Nelson, 2001). Increased consumption of these Cucurbitaceae as part of the meal could also increase work efficiency among men and women in their productive ages. This will increase their income levels that would also help raise their living condition which has been seen to have influence on the nutritional status of their families.

Abundance of physiological energy in children especially would also enhance their growth and development necessary in their critical stage of development due to the rapid rate of growth and differentiation of cells of the children. These Cucurbitaceae seed varieties could also be used to curtail iron deficiency anaemia among women of child-bearing age and during pregnancy; because of increased iron needed to supply the expanding blood volume of the mother, rapidly growing foetus and placenta (Adom et al., 2010; Bowman and Russell, 2001). These rich iron sources could also help to reduce the prevalence of associated effects like low birth weight mainly in the form of intrauterine growth retardation, preterm delivery and foetal death partly due to iron deficiency anaemia in pregnant women especially in developing countries (Centres for Disease Control and Prevention, 1998).

Research into the benefits of zinc to plants and animals has received tremendous attention since 1926. The zinc content in C. mannii, C. melo linn, C. pepo linn and C. lanatus were 5.00±0.07, 5.80±0.03, 7.10±0.04 and 5.10±0.02 mg/100 g, respectively (Table 4). The zinc content in C. pepo linn studied was found to be lower than the 8.2 mg/100 g as well as the 113 µg/g reported by El-Adawy and Taha (2001) and Glew et al. (2006), respectively. All the seeds could also provide more than 100% of RDI for zinc for children at age 5 years (American Academy of Pediatrics, 1993; Institute of Medicine, 2001).

The studied Cucurbitaceae could be promising in the provision of zinc to consumers especially children because zinc functions in the synthesis of both deoxyribonucleic and ribonucleic acids that play vital roles in cellular growth and differentiation. Besides these nucleic acids have influence on tissues with rapid cell turnover, especially the immune system which requires rapid expansion of immune cells including natural killer cells and phagocytic polymorphonuclear leukocytes (Bowman and Russell, 2001). The intake of these good zinc sources could also enhance the growth, the sexual wellbeing, vision and the social comfort of the consumers. Among the pregnant, it could help prevent prolonged labor, intrauterine growth retardation, teratogenesis and foetal death. It could also help raise the zinc status of lactating mothers especially at their early weeks of postpartum which have been known to pose a significant threat to maternal zinc status (Krebs, 1998).

The copper content of the Cucurbitaceae species ranged from 1.40±0.36-7.90±0.41 mg/100 g as shown in Table 4. Copper content in C. pepo linn studied was found to be about four times higher than the 1.7 mg/100

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Table 4: Mineral profile of the dry seeds of four Cucurbitaceae species

| Mineral | C. mannii | C. melo linn | C. pepo linn | C. lanatus |
|---------|-----------|--------------|--------------|-----------|
| Fe      | 7.10±0.00a| 8.50±0.01b   | 6.50±0.00b   | 5.60±0.06b|
| Cu      | 1.40±0.36a| 1.60±0.58b   | 7.90±0.41b   | 1.50±1.90b|
| Mn      | 4.40±0.06a| 3.40±0.00b   | 3.20±0.01b   | 2.40±0.04b|
| Zn      | 5.00±0.07a| 5.80±0.03b   | 7.10±0.04b   | 5.10±0.02b|
| Mg      | 430.00±17.00a| 430.00±34b | 530.00±35b   | 350.00±0.68c|
| K       | 620.00±1.00a| 560.00±34b | 610.00±100b  | 540.00±0.68d|
| Ca      | 44.00±23.00a| 29.00±14.00b| 31.00±3.90b  | 34.00±2.60d|
| Na      | 9.30±0.06a| 14.00±0.02b  | 8.50±0.06d   | 8.70±0.33d|

Values within a row with the same superscript means that there are no significant differences but those with different superscript show significant differences (p<0.05) by the Tukey's multiple comparison test.

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g and 15.4 µg/g that El-Adawy and Taha (2001) as well as Glew et al. (2006) respectively observed. The higher percentages of copper especially in C. pepo linn seeds taking into consideration RDI for copper may be attributed to genetic differences among the various Cucurbitaceae varieties (Achu et al., 2005). According to the recommendation of the Institute of Medicine (2001), the copper content in C. mannii, C. melo linn, C. pepo linn and C. lanatus could make available about: 636, 727, 3590 and 681%, respectively for children between 7 and 12 months; 412, 471, 2300 and 440%, respectively for children between 1 and 3 years; and 318, 364, 1795 and 341%, respectively for children between 4 and 8 years if 100 g of these Cucurbitaceae is consumed by a child and also serves as a sole provider of copper a day.

The essentiality of this transitional metal has been known for over 70 years. It is present in biological systems as either oxidised cupric ion (Cu²⁺) and the reduced cuprous (Cu⁺) ion (Williams, 2005). The homeostatic regulation of copper absorption and excretion (Bremner, 1998) as well as the impact of anti-nutrients on the absorption of this mineral (Badifu, 2001) could make the consumption of these copper rich seeds safe. The much higher content of copper in the Cucurbitaceae could be greatly harnessed by pregnant and lactating mothers who need between 1000 and 1300 µg/day (Institute of Medicine, 2001). Copper is an essential component of many proteins including several metalloenzymes like cytochromes oxidase and lysyl oxidase that are pivotal in the oxidative metabolism in the electron transport chain and the cross linking of elastin respectively. The transport of iron could also be compromised if copper is deficient in the plasma, as about 90% of copper in the plasma is bound to ceruloplasmin an important complex in iron transport and availability (Bowman and Russell, 2001).

CONCLUSION

The Cucurbitaceae seeds had low carbohydrate but high fat and protein content as compared to other plant sources. Crude protein levels were less than 2.5% in all samples. The seeds contained high amounts of Zn, Cu and Fe. All the seeds had good protein quality comparable to soy bean as judged by the PER and NPU. The research findings indicate that these under-utilized Cucurbitaceae seeds available in Ghana could be used to add value to traditional foods to combat Protein Energy Malnutrition as well as zinc and iron deficiencies.

LIMITATIONS

Even though the feed prepared were having the same energy contents, the quantity of food consumed by the rats fed the Cucurbitaceae seed meals were lower than that consumed by those fed on the soy bean meal. Further research into the fatty acid and amino acid profiles of the Cucurbitaceae seeds should be investigated since it may impact on the palatability of the seeds.

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