

Nutritional Value and Consumption of Black Ants (*Carebara vidua* Smith) from the Lake Victoria Region in Kenya

¹M.A. Ayieko, ²J.N. Kinyuru, ³M.F. Ndong'a and ⁴G.M. Kenji

¹Bondo University College, P.O. Box: 210-40601, Bondo, Kenya,

²Jomo Kenyatta University of Agriculture and Technology, P.O. Box: 6200-00200, Nairobi, Kenya,

³Maseno University, Box 333-40105, Maseno, Kenya,

⁴Jomo Kenyatta University of Agriculture and Technology, P.O. Box: 6200-00200, Nairobi, Kenya

Abstract: The edible insects of the Lake Victoria region which provided food and medicine, have suffered the effects of mismanaged environment. Our case study of *Carebara vidua* Smith (black ant) which is an endangered insect currently threatened with extinction due to human's activities, have provided unique source of protein and medicinal value. *C. vidua* is an endangered species of Hymenoptera. This paper discusses the nutritional value and medicinal potential of the black ant. It is one of the most sought after edible insects because of its nutritional and medicinal value. The samples were collected from Kisumu and Siaya counties along the Lake Victoria region. Standard nutrient analysis methods were used to determine the nutritional value. The insect has between 39.79 to 44.64% protein and about 42.07 to 49.77% fat content depending on the body part. The insect is also rich in iron, zinc, magnesium, potassium and phosphorus. From the fatty acid profile, the edible insects recorded high content of Palmitic, Oleic and Linoleic acids. No Linolenic acid was found in the samples analysed. The elderly Luos of Kenya collect and consume the black ants to manage several body ailments probably due to the essential nutrients found in the insect. *C. vidua* Smith is fairly similar to *Polyrhachis vicina* Roger in China which has been processed and commercialised as medicinal to manage several chronic diseases. Further research is needed to highlight the potential medicinal value of *C. vidua* Smith in Kenya and to save the insect from total disappearance.

Key words: Black ants, *Carebara vidua*, edible insects, ethnomedicine, nutritional value

INTRODUCTION

The increasing human population, climate change, and inadequate world food production and distribution are indeed a global concern. The rapid growth of the world population requires commensurate increases in food production and distribution. The food situation is a pointer towards increased food production and conservation particularly to the underutilised resources. There is evidence that some food resources which were neglected are re-emerging and information about their nutritive values is being explored with positive results. Sustainable human food production and distribution require increasing the diversity of plant and animal genetic resources that are used for food production. Africa is poised for severe food shortage given the low levels of agricultural production and the observed impact of climate change on plants and animals, and the decreased consumption of indigenous food items branded unconventional to current eating patterns. It is interesting to note that households are fast changing their food and eating habits to be consistent with

the western cultures. Many families are consciously changing to western new food culture which is heavily dependent on processed foods and high animal protein, oblivious of consequences. In the efforts to produce food and shelter, the very environment that supports the activities is destroyed. Nevertheless, few consumers are conscious of food nutrients, medicinal values, and impact of food production on environment. As such a lot of attention is given to natural food sources from edible weeds, fruits and insects, and foods which were recently given less attention.

There are several species of *Hymenoptera* identified in the world. Within the Lake Victoria basin, it is estimated that there are over 200 species of black ants, of which only two (bumble bees-*Apis mellifera* L. and black ant-*Carebara vidua* Smith) are known as edible in the community. Bumble bees are normally sought for honey and wax while *C. vidua* is collected for whole insect eating. Few people would rather eat the swollen abdomen and discard the thorax not knowing that the whole insect is valuable as demonstrated in this study. This study

discusses the nutritional value of the black ant-*Carebara vidua* Smith, known as *Onyoso* in Luo and *Luhya* ethnic languages in Kenya. This is one of the nutritious edible insects which are facing danger of extinction due to human activity on their natural habitat to produce crops and domestic animals, and build shelter for increasing number of families and households in the Lake Victoria region.

In the lake region, many households depend on fish for more than 50% of their animal protein. However, the high demand for fish for human and livestock feeding has contributed to shortage and rocketing prices in the fish market for the low and medium income households. The shifts in demands have created shortage of protein supply, particularly in the urban areas where food production and supply is not comparable to the population increase. The high demand for fish is not only felt in the urban areas but the rural families are having their share of inadequate supply of the commodity. Edible insects have been proved viable to provide alternative rich source of protein for human feeding. The concern of FAO for world food is to promote the use of edible insects as alternative rich source of food nutrients which are easily assimilated by human body. Edible insects, as mini-livestock, are being recommended for increased utilization for food security because they have high food conversion ratio and do not have to be fed on grains as livestock do and are environment friendly (Ooninx *et al.*, 2010).

Among the rural Luo communities, *C. vidua* Smith have been the most sought after edible insects among those who practise entomophagy. The insect is a favourite because of its nutritional value and medicinal potentials. Its conspicuously oily abdomen gives it a unique rich flavour. *C. vidua* is an endangered species of *Hemiptera*. The elderly Luos collect and consume the black ant to manage several body ailments including sexuality. As observed by Posey (1988), almost 90% of the world germ plasma and indigenous knowledge including traditions and beliefs about food and medicinal items in some aspects of human lives are kept by different ethnic groups in the world. They claim that the insect does not compare to any other edible insect they know of in the community. *C. vidua* is considered a rare relative to the edible lake flies, termites and grass hoppers which are found in plenty in western Kenya. Due to exploitation and unsustainable use of the ecosystem, the *onyoso* is facing extinction.

The secretive emergence of *C. vidua* Smith makes it mysterious to the Luos. The insect is also revered for its shiny black colour appreciated in black magic. Indeed, *C. vidua* is secretive in its emergence and not easy to detect when and where it will emerge. They build mounds underground, under rocks and buildings. Their emergence is preceded by tiny little workers and soldiers, not easily noticeable on the ground. Often, the insects emerge from the holes on the ground and quickly fly away unnoticed because they look just like other black ants of less value.

The Luos have been collecting this insect for their own personal consumption and rarely sell it in open markets. The insects are never taken to the market probably because the catch is normally small not worthy of selling compared to lake flies and the elate termites which are collected in the region in large amounts. Due to its purported medicinal value, the collectors normally consume the small portions of the catch rather than sell for few shillings in the market. The argument is that the opportunity cost of selling *C. vidua* is too high. This main objective of this study to analyse the nutritional components of the edible insects to highlight the unique food value that probably has made *C. vidua* so valuable to be the most sought after edible insects in the Luo community; and to draw attention to the looming extinction of the valuable insect.

Classification of the edible black ant: The black ant, *Carebara vidua* Smith, also called *onyoso* by Luo living around the Kenyan Lake Victoria basin is an insect belonging to the Order *Hymenoptera* and Family *Formicidae* in the Subfamily *Formicinae*. This ant was described by Smith and placed in the subfamily *Formicidae* by Ward in 2007 (Bolton, 2010). Classification of this species places it in the Order *Hymenoptera* which includes the ants, bees and the wasps (Borror *et al.*, 1989). The authors comment that the family *Formicidae* is known for their characteristic stinging habit. In Kenya, a survey of ants from Kakamega forest identified 500 species in 63 genera from 12 ant subfamilies including subfamily *Formicinae*. The subfamily *Formicinae* has 75 species consisting of 12 genera that have been identified so far (Gracia *et al.*, 2010).

C. vidua is a traditionally edible insect species among the Luo and the *Abaluhya* of Kenya. Elsewhere, ants play important roles in having medicinal properties leading to their conservation (Rajan *et al.*, 2005). Kuria (2007) found that ants played a significantly important ecological role in the structuring of the insect communities in the canopy of *Senegalia drepanolobium* near Laikipia in Kenya. Ants species such as *Crematogaster sjostedti* exhibited very close association with Hemipteran species from which they obtained some food which is a case of symbiotic relationship.

Physical characteristics of the insect: *Carebara Vidua* Smith female is a large (20-25 mm long) black and winged insect with large round abdomen (6-6.2 mm diameter) and a narrow gaster with one nodule. The abdomen is filled with eggs and some fatty substances. Possibly the fat body serves for the nourishment of the developing eggs and for sustenance during the nuptial flight, oviposition and starting a new colony as suggested by Borror *et al.* (1989). The worker caste of this ant is small (3-5 mm long) and has a sting which is an important morphological characteristic for predatory species since

they have to kill their prey and consume it or take it to the nest. The males are almost half the size of the female and also winged with white abdomen which is 10 mm long. Being hymenopterous, the head is orthognathous (mouth facing downward) with three simple eyes (ocelli), and one pair of well developed compound eyes. Antennae are other specialized scape and pedicel, and multi-segmented flagellum compared with those of the other species of other subfamilies in the same order. Mouthparts are chewing type of mandibulate (Ross, 1965).

The thorax is short and segments are closely attached to each other. The first segment (prothorax) is relatively inconspicuous. But the middle one (mesothorax) constitutes a large part of the thorax and contains the major flight muscles. Dorsally the mesothorax is covered by mesonotum which is divided into a scutum and a scutellum. The first abdominal segment firmly fuses with the mesothoracic segment to form the *gaster* or a petiole or stalk and bears no dorsal projection or node. The gaster has a transverse flexible suture across mesothoracic scutum. This region forms a deep constriction between first and second abdominal segments both dorsally and ventrally. The adults have two pairs of well developed, transparent wings which are similar in texture and without scales. At the base of the wing is a small oval sclerite known as tegulae. The fore-wings are larger than the hind wings in both female and males. It has fore wings with closed anal cells. The tibial spur formula 1:2:2 is as in all members of the sub order *Apocrita* with ovipositor retracted (Ross, 1965).

Ecology of the black ant: The edible black ants live in holes of a large constructed subterranean colony interspersed with a complex system of galleries and chambers within which the members of the colony store food and their larval stages (Ross, 1965; Borror *et al.*, 2009). Similar habitat has been described by Deyrup and Cover (2004) for the species *Odontomachus relictus* in the subfamily *Ponerinae*. *C. vidua* colony consists of winged adult males and females and non-reproductive wingless workers which are smaller in size compared to the reproductive males and females. The workers perform the duties of constructing the nest by excavating the subterranean chambers and galleries, and foraging for food that all the members of the colony consume (Ross, 1965). These ants are omnivores, feeding on living and dead animals including insects, vegetable matter and sweet sugary exudates, nectar and glandular products from plants, flowers and honey dew from aphids and scales. They feed on smaller insects such as the small lepidopteran larvae and worms.

Life history: The reproductive males and females undertake nuptial flights periodically once a year during the long rains. They often emerge from the exit holes at around 11:00 A.M-3:00 P.M. During swarming they pair up, mate and the male dies while the female seeks out a

suitable nesting site in the ground. This becomes its first chamber in which it lays her first brood of eggs. Due to the shallowness of the chamber the eggs receive sufficient warmth and hatch after 5-7 days. This species colony can survive for many years depending on the level of habitat disturbance (Ross, 1965; Borror *et al.*, 1989). The frequency of swarming may remain the same i.e. once in a year but the quantity that emerges from the colony reduces. Each reproductive adult is picked as it emerges from the hole.

MATERIALS AND METHODS

In order to collect the insects, word was sent out within the Lake Victoria *Luo* ethnic villagers. The community was chosen because the villagers are familiar with the insects. Selected villagers who showed interest in hunting for the insects were instructed on how to identify the emergence holes and trained on safe collection and handling of the insects. Safe handling instructions included sanitation aspects of the collectors' hands, clean bowls with cover to prevent the insects from flying out after collection, and safe storage for overnight delivery in case of afternoon collection. The collectors were instructed to deliver the insects to the research laboratory the next morning or on the same day if possible. This ensured that the insects were delivered alive for quality inspection. The collectors were offered an attractive price per weight delivered alive. The reward for live delivery was attractive to encourage fresh and clean insects and to ensure that adequate amount was collected for the study. Arrangement was made to have the insect species confirmed by an entomologist at the National Museums of Kenya, Nairobi.

The study was done in the western region of the Lake Victoria region in Kisumu Country in 2009 during the onset of the long rains. It took the field assistants 2 years to eventually locate and collect the black ants because they are rarely found. After two months of onset of long April rainy season in 2009, about one kilogram of fresh collection was delivered by only two collectors. The insects were collected from *Karateng* location, *Maseno* division of *Kisumu* County. The second collection was obtained from *Alego* location, *Siaya* County. Both collections were made in the same week, three days apart. Both male and female insects were collected because they emerge from the same hole at the same time. Care was taken to separate the males from the females for analysis based on their morphological differences. The insects were then washed to remove any sand, soil or foreign bodies before freezing for storage. The body parts were then separated into thorax and abdomen for analysis.

Analysis of proximate composition: The frozen insect samples were sent to the food laboratory. The samples were analyzed for moisture content by drying method, crude fat by Soxhlet method, crude protein by semi-

micro-kjeldhal method, crude ash by incinerating in a muffle furnace at 550°C and crude fibre determined by Hennenberg-Stohman method (AOAC, 1996).

Determination of mineral composition: The quantification of iron, zinc, calcium, magnesium, potassium, phosphorous, sodium, copper and manganese was done by atomic absorption spectrometry using AAS (Shimadzu AA-6200) according to AOAC methods (AOAC, 1996).

Determination of fatty acid composition: The fatty acid profile was determined by gas chromatography. The extraction of the lipids was done by a modification of the Bligh and Dyer (1959). Samples of 1.0 g each were crushed and placed in a glass stoppered centrifuge tube and denatured at 100°C for 3 min. Then 2 mL of water and 7.5 mL of methanol-chloroform (2:1 v/v) added and the mixture shaken overnight at room temperature. The samples were then centrifuged, the supernatant decanted and the residue resuspended in 9.5 mL of methanol-chloroform-water (2:1:0.8), the homogenate was centrifuged. Then 7.5 mL each of chloroform and water was added to the supernatant and the mixture centrifuged. The chloroform phase was extracted and dried in a vacuum rotary evaporator at 40°C. The residue was completely dried in a dessicator over KOH pellets. Then the lipid methylated by placing 2 mg of the sample in a flask and refluxing with 2 mL of 95% methanol-HCl for 1 h. The methyl esters was extracted with 3 portions of hexane (1 mL) and then washed with distilled water (3 mL). The hexane layer dried in vacuum rotary evaporator and the residue redissolved in a small drop of hexane. Then 0.2 µL was injected into the GC comprising of a capillary column, supelcowax 30×0.53 mm; injection/detection temperature, 220°C under a flame ionization detector. Identification of the fatty acid methyl esters was by comparison of retention times with standards.

Determination of fat soluble vitamins: Retinol and α -tocopherol were analyzed by HPLC using a modification of the method of Barker *et al.* (1998). Duplicate tissue samples (2.0 g) were homogenized with 4 mL of 95% ethanol and 1 mL of 50% KOH. The mixtures were saponified by heating in a 70°C water bath for 15 min and then cooled in an ice bath. Fat-soluble vitamins were extracted with 1 mL hexane containing 0.2% BHT, and a 1 mL aliquot of the hexane layer was evaporated under nitrogen. Saponification, extraction, and evaporation procedures were performed under yellow light. Samples were then reconstituted with 0.25 mL ethanol containing 0.1% BHT. A Perkin Elmer (PE) series 400 liquid chromatograph equipped with a 250×4.0 mm stainless steel ODS reversed-phase column was used to quantify α -tocopherols, and retinol as measures of vitamins E and A, respectively. The mobile phase was 96:4 methanol: water

for tocopherol detection, and 90:10 methanol: water for retinol separation at a flow rate of 1 mL/min. The α -tocopherol was monitored at 285 nm wavelength and retinol at 325 nm on a UV detector. External standards were compared to sample extracts for determination of vitamin concentrations.

Determination of water-soluble vitamins: The vitamins were determined according to the method by Ekinici and Kadakal (2005). The sample was prepared using solid-phase extraction, SPE in order to remove components that may cause interference with vitamins. For this reason the sample treatment proposed consists of SPE with sep-pak C₁₈ (500 mg) cartridges that enable separation of water-soluble vitamins and remove most of interfering components. Twenty gram of deionised water were added into 5 g. The mixture was homogenized using a homogenizer at medium speed for 1 min. The homogenized samples were centrifuged for 10 min at 14×10³ RPM. The stationary phase was flushed with 10 mL methanol and 10 mL water adjusted to pH 4.2 to activate the stationary phase. Homogenization and centrifuged samples (10 mL) was then loaded. The sample was eluted with 5 mL water (pH 4.2) then 10 mL methanol at a flow rate of 1 mL/min. The effluent was collected in a bottle and evaporated to dryness. The residue was dissolved in mobile phase. Before HPLC analysis all samples were filtered through 0.45 µm pore size. Samples (20 µL) of solutions of the water-soluble vitamins were injected into the HPLC column. The column eluate was monitored with a photodiode-array detector at 265 nm for ascorbic acid, 234 nm for thiamine, 266 nm for riboflavin, 234 for pyridoxine, 282 nm for folic acid and 261 nm for niacin. The mobile phase was filtered through a 0.45 µm membrane and degassed by sonication before use. The mobile phase was 0.1 mol/L KH₂PO₄ (pH 7): methanol (90:10) and reverse phase C-18 column. The flow rate was 0.7/min at room temperature (25°C). Identification of compounds was achieved by comparing their retention times with standards and concentrations calculated from integrated areas of the sample and the corresponding standards.

RESULTS

As shown in Table 1 to 4, *Carebara Vidua* Smith is rich in many key nutrients.

As indicated on Table 1, the whole body of the insect is rich in protein with the abdomen containing up to 44.64% protein content. The table also shows a fairly high level of fat content, probably one of the reasons why the insect is a favourite of many in the community. The abdomen, which the villagers prefer is approximately 50% fat content. From the visual appearance of the insect, one would not expect so much of fat content from the head or the thorax. But examination revealed equally plenty of fat from both head and thorax compared to the abdomen. It

Table 1: Proximate composition of female *carebara vidua* smith distributed by body parts

Body part	Moisture (%)	Protein (%)	Fat (%)	Ash (%)	Fibre (%)
Thorax	3.69	39.79	42.07	2.07	10.09
Abdomen	4.36	44.64	49.77	0.95	4.31
Whole	3.93	40.83	47.51	1.55	6.91

Table 2: Mineral content (mg/100 g) of female *carebara vidua* smith distributed by body parts and compared to recommended daily intake for a healthy body of an adult

Body parts	Fe	Zn	Mg	Ca	Na	K	P
Thorax	9.74	5.51	10.50	13.17	30.28	70.40	106.91
Abdomen	2.71	6.65	10.93	26.10	21.19	46.37	105.85
Whole	10.69	5.69	10.41	22.23	26.23	51.73	106.04
RDI*	12-15	11-15	400	1000	2400	3500	1000
	mg	mg	mg	mg	mg	mg	mg

*: Required Daily Intake RDI in mg/day

Table 3: Vitamin content of whole female *carebara vidua* smith

Vitamin	Common names	Concentration mg/100g	SD
Retinol	A	0.767	0.069
α-Tocopherol	E	0.593	0.058
Riboflavin	B	20.262	0.021
Niacin	B3	0.280	0.003
Thiamin	B1	0.457	0.000
Folic acid	Folic acid	0.451	0.032
Ascorbic acid	C	0.026	0.001

SD: Standard deviation

Table 4: Percent distribution of fatty acids in *carebara vidua* smith by sex and body parts

Fatty acid (%)	Female thorax	Female abdomen	Male abdomen
Lauric	0.48	2.20	1.72
Myristic	1.06	1.83	1.38
Palmitic	27.06	28.75	25.94
Palmitoleic	1.86	2.93	3.31
Stearic	4.82	5.94	5.78
Oleic	51.44	46.78	51.26
Linoleic	12.19	10.20	10.61
Linolenic	nd	nd	nd
Arachidic	1.11	1.36	nd

nd: not detected

was also observed that the abdomen which physically tends to contain mainly fat, has plenty of protein content (44.64%) as well.

Minerals are among the most important components of edible insects because they are always available in plenty relative to most other foods. Table 2 indicates that the insect is specifically rich in iron and zinc, minerals that are often deficient in many vulnerable groups such as children, elderly and nursing women. About 100 g of the insect is able to provide a reasonable amount of iron, and zinc for these vulnerable groups. The table shows that the insect is able to provide a sizeable amount of daily intake of zinc according to the standards published by the American Zinc Association (2010).

Table 3 shows that the insects can supply a reasonable amount of the B vitamins which are not normally available in many animal proteins. Nevertheless,

the edible insect is not adequate for vitamin supply compared with insects such as lake flies, termites, crickets or grasshoppers (Ayieko and Oriaro, 2008; Kinyuri *et al.*, 2009; Kinyuru *et al.*, 2010).

C. vidua Smith is richly endowed with essential fatty acids as shown in Table 4. Content of palmitic and oleic acids stands out to be significant even in males. Linoleic acid was not detected. Males and females showed similarities in fatty acid composition. Also all the body parts (Thorax, abdomen) are fairly similar in values with minor differences except for females where lauric and palmitoleic acids were lower than in males. Arachidic acid was detected in females but not in males albeit in small amounts.

DISCUSSION

The insect, *C. vidua* Smith, is not exceptionally rich in many vitamins as thought of by many elderly villagers in the Luo ethnic group. Nevertheless, the demonstrated nutrients which are key to healthy human body confirm that the Luo's appreciation of the insect for management of several health conditions is well founded. A similar black ant (*Polyrhachis vicina* Roger) has been used as a nutritional ingredient and processed into tonics or health foods in China (Tang *et al.*, 1995; Shen *et al.*, 2006). What comes out clearly from the analysis of body parts is that the whole insect is rich in essential nutrients. This outcome dispels the thought that only the abdomen of the insect is valuable than other parts. It has been reported by villagers that birds catch the insects but only eat the abdomen. They discard the thorax and the thorax because these parts are less valuable. In the same token human beings take the cue and eat the abdomen only. This study confirms that all the body parts of the insect are equally nutritious and should be eaten.

In general, most *C. vidua* consumers collect both male and females for human consumption. Contrary to what Christensen *et al.* (2006) report, both males and females are rich in the identified nutrients and are thus fit for human consumption. Informal conversation with the Luo elders in the region confirmed that the majority of the villagers consume the whole male and females as a source of protein. However, few would rather take only the females' abdomen because they believe it is the most concentrated part with the healing power due to the fat content therein.

The use of edible insects as food and medicine in Africa is much more than simply a tradition or folklore for tourists as was earlier reported by several writers. Paoletti (2005) states that millions of people live on biodiversity from the wild and on bush foods. Particularly people in the rural areas depend on their biodiversity for food and medicines. Such resources are means of survival that is unknown to outsiders; at best, are perceived as unpleasant to people living in large urbanised communities.

Since the insect is well endowed with essential zinc, it has several health benefits to human body. Zinc is important in regulating immune system, relaxing fatigue and anti-aging as alluded to by Shen *et al.* (2006) and Tang *et al.* (1995). The American Zinc Association reports that high concentration of zinc is in the prostate gland and semen. As such the mineral is important in treating and managing prostate cancer (American Zinc Association, 2010). The association also asserts that zinc is effective in managing the immune system. Of course there is evidence that insects' chitin can significantly reduce serum cholesterol levels and can provide antibacterial and antiviral effect (Goodman, 1989; Tang *et al.*, 1995; Shen *et al.*, 2006). The availability of the key food nutrients in the insect justifies the folk tales and high demand for the endangered insects. As has been reported by Yamakawa (1998), several insects are regarded as a source for development of drugs. *Onyoso* falls in this category and is worth investigating further for its medicinal value as practised by the *Luo*.

CONCLUSION

C. vidua is rich in essential minerals, fatty acids, protein and few vitamins such as the B complex. *C. vidua* should be explored further for its commercial value in medicine and its habitat should be protected to save it from extinction.

ACKNOWLEDGMENT

This research is part of an ongoing project funded by the Inter University Council of East Africa-VicRes. We are grateful for the continuous support.

REFERENCES

American Zinc Association, 2010. <http://www.zinc-health.org/2010>.
AOAC, (1996). Official methods of analysis of the Association of Official Analytical Chemists, 16th Edn., Association of Official Analytical Chemists, Washington D.C., pp:
Ayieko, M.A. and V. Oriaro, (2008). Consumption, indigenous knowledge and cultural values of lake flies species within the Lake Victoria region. *Afr. J. Environ. Technol.*, 2(10): 282-286.
Barker, D., M.P. Fitzpatrick and E.S. Dierenfeld, (1998). Nutrient composition of selected whole invertebrates. *Zoo Biol.*, 17: 123-134.
Bligh, E.G. and N.J. Dyer, (1959). A rapid method for total lipid extraction and Purification. *Can. J. Biochem. Physiol.*, 37: 911-917.
Bolton, B., (2010). Taxonomic History. <http://www.antweb.org> 2010.

Borror, D.J., C.A. Triplehorn and N.F. Johnson, (1989). Introduction to the Study of Insects. 6th Ed., Saunders College Publishing.
Christensen, D.L., F.O. Orech, M.N. Mungai, T. Larsen, H. Friis and J. Aagaard-Hansen, (2006). Entomophagy among the Luo of Kenya: A potential mineral source? *Int. J. Food Sci. Nutr.*, 57(3/4): 198-203.
Deyrup, M. and S. Cover, (2004). A new species of *Odontomachus* ant, (Hymenoptera: Formicidae) from inland Ridges of Florida, with a key to *Odontomachus* of the United States. *Florida Entomol.*, 87(2): 136-144.
Ekinci, R. and C. Kadakal, (2005). Determination of seven water-soluble vitamins in tarhana, a traditional Turkish cereal food, by High-Performance Liquid Chromatography. *Acta Chromatographica*, 15: 289-297.
Goodman, W.G., (1989). Chitin: A magic bullet? *Food Insect Newslett.* 3: 6-9.
Gracia, F.H., G. Fisher, S. Murer and M. Peters, (2010). BIOTA East Afric Project 2006. Retrieved from: <http://www.biota-africa.org>, (Accessed on: June 12th, 2010).
Kinyuri, J.N., G.M. Kenji, S.M. Njoroge and M.A. Ayieko, (2009). Effects of processing methods on the in vitro protein digestibility and vitamin content of edible winged termites (*Macrotermes subhyalinus*) and Grasshopper (*Ruspolia differens*), *Food Bioprocess Technol.*, D01 10.1007/s11947-009-0264-1, September online publication, Springer.
Kinyuru, J.N., G.M. Kenji, S.N. Muhoho and M. Ayieko, (2010). Nutritional potential of longhorn grasshopper (*Ruspolia Differens*) consumed in Siaya district, Kenya. *J. Agric. Sci. Technol.*, 12(1): 32-46.
Kuria, K.S., (2007). The role of ants in structuring insect communities on the canopies of *Senegalia drepanolobium* near Laikipia, Kenya. Ph.D. Thesis, Rhodes University.
Oonincx, D.G.A.B., J. Itterbeeck, M.J.W. van Heetkamp, H. Brand, van den, J.J.A. Loon, van Huis, Al van, (2010). An exploration on greenhouse gas and ammonia production by insect species suitable for animal of human consumption. *Entomol. Environ.*, 5(12): e14445.
Paoletti, G.M., (2005). Ecological implications of minilivestock-Potentials of insects, rodents, frogs and snails. Science Publishers, Enfiel. USA.
Posey, D.A., (1988). The first international ethnobiology congress: A success. *Insect Food Newslett.*, 1(2): 5-5.
Rajan, D., M. Zhacharias and A. Musthak, 2005. Ants (Formicidae) of Biligiri Rangan WLS, Fauna of Biligiri Rangaswamy Temple Sanctuary, Conservation Area Series, 50:251-269.

- Ross, H.H., (1965). Textbook of entomology. 3rd Edn., John Wiley and Sons, Inc. pp 291-316.
- Shen, L., D. Li, F. Feng and Y. Ren, (2006). Nutritional composition of *Polyrhachis vicina* Roger (Edible Chinese black ant). *Songklanakarin Journal of Science and Technology*, 28(Suppl. 1), Nutraceutical and Functional Food.
- Tang, J., S. Li, E. Huang, B.Y. Zhang and Y. Chen, (1995). Economic insect fauna of China, Fase 47, Hymenoptera: Formicidae (1). Science Press, Beijing, China.
- Yamakawa, M., 1998. Insects antibacterial proteins; regulatory mechanism of their synthetic and a possibility as new antibiotics. *J. Sericult. Sci. Japan*, 67: 163-182.