International Journal of Zoology Research
ISSN : 2231-3516 & E-ISSN : 2231-3524, Volume 4, Issue 1, 2014, pp.-082-087.
Available online at http://www.bioinfopublication.org/jouarchive.php?opt=&jouid=BPJ0000254

INSECTS USED AS FOOD WITH EMPHASIS TO ACRIDID CULTURE, BIOMASS PRODUCTION AND SCOPE OF APPLICATION

DAS A.*

Department of Zoology, University of Calcutta, Kolkata- 700 017, WB, India.
*Corresponding Author: Email- dasamlan@yahoo.co.in

Received: November 16, 2013; Accepted: April 24, 2014

Abstract- This paper deals with a new approach of entomology with an economic outlook. Acridid (Orthoptera) biomass by means of its mass culture could be utilized as a non-conventional source of protein-rich feed supplement to chick rations and fisheries. Moreover, it could be encouraged for anthropogenic consumption as well. This paper advocates miscellaneous uses of insects, particularly grasshoppers, as feed ingredient and food source. The Acridid mass rearing, culture and management towards biomass production can establish economically. The mass culture procedure of Acridid is short-sketched with relevant information.

Keywords- Acridid mass culture, rearing, biomass production, protein-source, feed supplement, entomophagism

Citation: Das A. (2014) Insects Used as Food with Emphasis to Acridid Culture, Biomass Production and Scope of Application. International Journal of Zoology Research, ISSN : 2231-3516 & E-ISSN : 2231-3524, Volume 4, Issue 1, pp.-082-087.

Introduction

Economic entomology provides us many untapped natural gifts which were under revealed in the past. Sericulture, apiculture and lac culture are three such well-established sciences in the world today under this economic branch of science. Still there exist many possibilities that insects can enrich us economically by its scientific and integrated approach of utilisation. Although insects are one of the major components of natural food chain, they have seldom been seriously considered as a possible nutrient source for animal husbandry or for human consumption. Some species of grasshoppers and locusts (Orthoptera : Acridoidea) have some properties such as rapid lifecycle, high reproductive potential, gregariousness in habit, high protein content in tissues etc. and that properties are helpful towards faming and culture of those acridid species. The present paper advocates about the process of acridid culture and management towards its high biomass production. The usefulness of acridid biomass for present and future purposes is also illustrated.

The Usefulness of Insects

Insects, as a major group of fauna in the kingdom of Animalia, possess enormous biodiversity. The colossal biomass of insects in nature they have played important part in the history of human nutrition in Africa, Asia and Latin America [1]. Some comprehensive information about human use of insects as food and as animal feed has been listed up by several authors at different times [2-9]. The usefulness of insects, so far literature surveyed, can broadly be classified under the following two heads:

Insects as Feedstuff

Several investigations have been reported on utilization of insect meal in maintenance of livestock, particularly for poultry birds and fisheries. Beside Orthopteran insects in most of the instances house fly (*Musca domestica* Lin.) pupae or maggot meal [10-13], face fly (*Musca autumnalis* De Geer) pupae meal [14-15], soldier fly (*Hermetia illucens* Lin.) larvae meal [16-18] or silk worm pupae meal [19-23] were used as supplementary feed ingredients.

Among Orthopteran insects grasshopper meal has high proportion of crude protein and fat and is therefore it could be a probable protein source for poultry feed supplement [24-25]. Working with poultry birds scientists suggested that grasshopper meal can replace significant quantity of fish meal in broiler ration upon a result that grasshopper meal facilitates rapid weight gain to poultry birds [26]. It was also advocated that grasshopper meal do not hamper productive performance in broilers and therefore, their production and utilization in feed formulation could be encouraged [27-28]. On a similar investigation it was reported that grasshopper meal could replace control diet of broiler chicks without any adverse affects on weight gain or feed intake [29]. In a comprehensive study, on using of grasshopper feed meal to chick rations, it was strongly supported that being high nutritional, minerals and calorie values, they could be use as alternative animal feed supplement to chick rations [30]. Beside the above information, time and again several authors advocated about the usefulness of grasshopper meals to chick rations and fisheries. All of them mainly furnished about the quantity of protein, fat and minerals and quality of amino acid present in grasshoppers and how that grasshopper, as meals, could be incorporated in chick or fish rations [31-36].

Insects as Foodstuff

Insects are intentionally eaten in many parts of the world. They are consumed in an immature or in adult form, cooked or raw, in whole or in part. In most instances the insects are gathered from the wild while in a few countries they are reared commercially. Older literature contains numerous accounts provided by explorers, naturalists, anthropologists and assorted travellers describing the use of insects as food by the indigenous people of most of the world. In a comprehensive review of early literature more than twenty references about edible insects and their consumption pattern throughout the world have been cited [1]. In another incident nearly thirty edible insects that are commonly consumed by mankind in different parts of the world have been advocated [37]. Among Orthopteroid insects some species of grasshoppers and locusts *viz. Patanga succincta* Linn. and *Schistocerca gregaria* Forks. are taken as food on account of their large size and frequent availability in considerable numbers since very early times; they are roasted and eaten in Africa, Arabia, Thailand and in India and among crickets, *Gryllus testaceous* Walck., *Brachytrypes portentosus* Licht. and *Liogryllus bimaculatus* de Geer are also roasted and eaten in various parts of the world [37]. Detailed information regarding diversity, mode of consumption and economic values of the edible insects in all tropical and subtropical regions of the world has been compiled in a nearly recent publication [38].

The *Pedi* of South Africa prefer certain insects to meat [39] as do the *Yukpa* of Colombia and Venezuela [40]. It was recognized the quantitative importance of insects to indigenous diets in Peru [41] and in Zimbabwe [42]. Insect consumption credits as averting many potential cases of *Kwashiorkor* among the young of rural areas of Zimbabwe [42]. During studies with *Yukpa* in Colombia and Venezuela it was reported that people eat insects as either a curiosity or a relic of barbarism [40]. In a comparative study of food habits among three ethnic groups of *Melanesians* of Papua New Guinea it was reported that coastal people know well which insects are edible; and they were seen indulging especially frequently in the yellow leaf ant, *Oecophylla smaragdina* F. (Hymenoptera: Formicidae) [43]. In search of animal protein in *Kipushi* territory of Zaire caterpillars were indisputably the first supplement chosen, where in South Africa the caterpillars of saturniid moth (*Gonimbrasia belina* Westwood), known as '*masonja*', are very favourite with beef [44]. In Petersburg, Russia also it was reported that Mopanie caterpillars were economically profitable [45]. In Southern Mexico food insects are not only prominent in the market places of rural towns and villages, but some are sold in the finest restaurants in the largest cities and exported abroad to Europe and United States [46-48]. In India it was reported that insects represent the cheapest source of animal protein in Manipur, their consumption should be encouraged because many of the people cannot afford fish or animal flesh [49]. The wide spread practice of entomophagy warrants further attention in any evaluation of availability of protein sources in the Amazonian ecosystem. In a case study of Tukanoan Indians in the northwest Amazon, it was described the insect fauna that was included in their diet, sometimes in large amounts, with a purpose to define the characteristics of their predictability as food resources in the environment and to evaluate the dietary significance of entomophagy for this population [50].

The *Kiriwinians* who live in the Trobriand Islands eat a wide variety of insects, not because they have to, but because they like them [40]. According to the author [40], 'insects are widely consumed in Asia; despite great modernization and the like they are widely appreciated in Japan, particularly in rural areas. Insect consumption rates are high in Southeast Asia, particularly among the Thais, Laotians, Burmese and Kampucheans because of a wide variety of insects are available in these areas. Insects can make a potentially enormous contribution to solving problems of human nutrition'. It was considered attempting to produce insects as low-cost feed for pond fishes as small farms [2]. Dried caterpillars of saturniid moths are sold in the local market in Zimbabwe and the consumptions of termites, locusts and tettigoniids by the vast majority of the population continues in spite of presence of western cultures. The cone-headed grasshopper referred to is probably *Ruspolia* (=*Homorocoryphus*) *nitidula* Scopoli (Tettigoniidae) and winged termites are eaten in great delicacies among many tribes in Uganda and other eastern and central African countries [21]. Locusts or grasshoppers, or both are included in diet of almost every country for which any published record exists. The desert locust, *Schistocerca gregaria* Forks. (Orthoptera: Acridoidea), well known as a destroyer of crops, was itself treated as a major source of food in Northern Africa and in Middle East at earlier times. Although few insects other than this locust were used as food in Northern Africa and hundreds of species have been used in Central and Southern Africa, Asia, Australia and Latin America. The reported total approximates 500 species in more than 260 genera and 70 families of insects are used for anthropogenic consumption. The actual numbers are probably far greater than the numbers reported towards the idea of insects as food [9, 21, 51-52]. A perusal of assorted literature has revealed variety of information about entomophagy by different ethnic people around the world. In this regard, the works of eminent researchers are worth mentioning [1, 4, 7, 42, 49, 50, 53-66). It was reported that there were approximately 250 edible insect species in sub-Saharan Africa that were high in nutritive value [9]. Over 1,500 species of edible insects have been recorded in another report [67] in 300 ethnic groups of the world from 113 countries. Around the world, in some ethnic groups insects provide 5-10% of annual protein input as well as fats, calories, vitamins and minerals [67]. On an account of anthro-entomophagy it was advocated that 'edible insects are a natural renewal resource that merit deep study in order to deliver more food and especially proteins to people with poor nutrition and it is also necessary to cultivate some species to continue to sustain them' [8].

Insect Farming

A few instances of actual rearing of insects for human consumption were referred by authors at few occasions [68]. It was suggested that Mormon cricket (*Anabrus simplex* Haldeman) might be possible to develop management systems in which harvest would be a viable alternative to chemical control [52]. Insect farming will be a part of new agricultural system based on symbiotic relationships with species, which are presently not used as food. It would be possible to construct insect farms that are physically quite small but having a high volumetric rate. A high population density will be possible to produce fresh animal protein without a complicated transportation and storage system [69].

Coleopteran and Lepidopteran larval stages are often long in propagation to that of adult and therefore offer a greater harvesting opportunity; colonies of ants of the genus *Atta* and termites of the genus *Syntermes* are long lived and the soldiers could be harvested repeatedly throughout the year [50]. A research output on insect farming indicates that it should be economically feasible to harvest the biomass of aquatic insects [70-71]. The Food Insects Research and Development Project (FIRDP), University of Wisconsin, Madison, USA (1986) advocated that food insect harvest would be a part of pest management program and thus would help to reduce the need for insecticides for crop protection. Insect farming could be called as production of minilivestock. And the scientific method of any insect faming for commercial use is still lacking. On an article [72] “minilivestock: production from gathering to controlled”, it was opined that people in tropical and developing countries could start producing meat by minilivestocks, through a new approach based on sustainability, on protection of the environment, on rational use of local species and on high demand. On a comprehensive compilation of world edible insects some valuable comments were made that, “before insects can make a greater contribution to human nutrition, research is needed to ensure more dependable supplies through development of economically feasible methods of mass-rearing edible species and development of more and better management programmes for efficiently harvesting wild populations” [73]. Therefore, in concrete, research projects on edible insects should be done on 1) background information on existing processing technologies of selected edible insects, 2) studies of the chemical composition and nutritional value of selected edible insects, 3) developing storage and packaging procedures, 4) improving the technology presently available and developing training programs in the production of new insect foods and 5) studies of probability of insect farming as a means of increasing production [74].

Biomass Production

Literatures on insect biomass production are very insufficient. However, a few of them describe a little on biomass production on some insects including grasshoppers and locusts [75-77]. In some findings seasonal changes in number and biomass of arthropods in herbaceous layer of Savannas have been studied [78] and in some other findings seasonal changes in the arthropods biomass in ‘burnt’ and ‘unburnt’ Savannas was also given [79]. It was reported that among grasshoppers (Acridoidea), efficiencies of food utilisation, biomass and energy budgets have been studied in only about twenty five species worldwide [80]. Some authors [81] studied biomass production of *Melanoplus sanguinipes* fed on different diets. On a somewhat similar study of fall army worm *Spodoptera litura* (F.) larvae, it was reported that biomass production depends on host plants they consumed [82]. The knowledge of biomass production of insects has great importance for rearing and mass culture of the species.

Considering all of the above criteria on edible insects, a framework of Acridid biomass production method has been tried to establish. The culture procedure is very simple, inexpensive without any recurring expenditure and easy to understand. Hence, small farmers and rural people, especially the weaker women section of villages, can adopt it very quickly to improve their economic condition.

Mass Culture of Acridids

In laboratory, mass culture of acridids (Orthoptera: Acridoidea) may be done following a series of rearing set-up, specially designed for this purpose. And for this some commonly occurred grasshopper species (one or more species together) from the culture area could be selected. For better yielding of biomass throughout the year selection of multivoltine species are ideal. Upon a preliminary filed survey at the culture area, the frequently occurred (abundant) species (with considerable weight) could be marked and catch (by net sweeping) from the field to maintain a primary ‘mother-stock’. Subsequently, the following seven steps may be followed for their mass culture. In our laboratory we followed this procedure using four acridid species viz., *Oxya fuscovittata* (Marschall), *Acrida exaltata* (Walker), *Hieroglyphus banian* (Fab.) and *Spathosternum prasiniferum prasiniferum* (Walker) and got valuable responses.

Step-1: Preparation and maintenance of mother stock for egg production

Step-2: Collection of egg pods

Step-3: Incubation of eggs and allowed to hatching

Step-4: Nymphal rearing up to fledgling stage (0-day adult)

Step-5: Adult rearing for breeding

Step-6: Quantitative estimation of biomass

Step-7: Qualitative test of biomass

Step-1: Preparation and Maintenance of Mother Stock for Egg Production

Acridids may be collected from nearby agricultural or grassland fields by sweeping using conventional insect nets of 30 cm diameter. The collected nymphs and adults can be acclimatized in specially designed cages for the purpose of rearing at natural condition. Each cage was made of nylon net gauge on a wooden frame measured 4'x3.5'x3'. The floor of the cage was also wooden and at the floor centre there was an outlet measuring 5x5 cm with a valve for cleaning the faecal matters from the cage. Fine fresh washed (by running tap water) and sterilized (by boiled water) sand in small glass/plastic $cups_1$ (300 ml) were placed on the floor of the cages in porcelain tray for oviposition. Four $cups_1$ in a tray and five such trays were placed on cage floor in an orientation of four at the four corners and one at the middle. A few drops of water can be added daily to keep the sand moist. Green shoots of fresh mixed commonly occurred grasses might be provided in cage as their food in small water filled containers (100ml). As most of the grasshoppers prefer plants to families Poaceae and Cyperaceae, hence, plants from these two families would be effective for their culture in addition to other plants. In our case we used equally mixed proportion of *Cynodon dactylon* (Poaceae) and *Cyperus kyllingia* (Cyperaceae). The collected adult individuals were then allowed to copulate and oviposit. In mother stock at 3:1 ratio of male to female would be ideal for copulation and oviposition.

Step-2: Collection of Egg Pods

From glass $cups_1$ oviposited egg pods should be collected by hand picking and transferred to another sets of glass/plastic $cups_2$ (300 ml) filled with sterilized sand. In $cups_2$ egg pods should be placed up to 1-2" depth in sand and 1-2" space of $cups_2$ should be kept free from sand surface (after nymphal emergence, the new-borns will take their position at the free space of covered $cups_2$). 4-5 egg pods may be placed in one cup_2 based on the pod size. A few drops of water should be added daily in cup_2 to keep the sand moist. The mouths of $cups_2$ should be covered by fine nylon net using rubber bands.

Step-3: Incubation of Eggs and Hatching

$Cups_2$ with egg pods should be then placed at BOD incubator under controlled 35ºC temperature for egg incubation. The incubating temperature may be calibrated manually @ 1 to 2ºC deviating from 35ºC to make sure maximum hatching. After 2 to 3 trials, the incubating temperature for a particular species could be fixed (based on maximum hatchlings). Day to day observation should be done to notice the hatchlings, if emerged in $cups_2$. By noticing first emergence of mymph, the incubating period could be recorded for future trials. In absence of incubator (and electricity), $cups_2$ (with moist sand) can be placed under open sunlight until sand dries, then a few drops of water should be added on dried sand again to keep it moist. The alternate moistening and drying up may be continued daily till emergence of nymphs.

Step-4: Nymphal Rearing up to Fledgling Stage

Newly hatched nymphs (0-day, Ist instar hatchling) should transfer immediately to nymphal rearing chamber whenever they popped up from sand and see through from $cups_2$ nylon net. During hatchling transfer the mouth-cover-nylon-net of $cups_2$ should unwrap only after keeping the $cups_2$ in nymphal rearing chamber. Thus, hatchlings can easily be transferred into the nymphal rearing chamber without any contact injury. Hatchlings should be reared in the nymphal rearing chamber up to fledgling stage (0-day adult). The structural design of nymphal rearing chamber was similar to mother stock chamber. Here also four small moist sand filled trays (6"x4"x3") were placed at four corners of the chamber floor. Sand should keep moist by watering daily. Fresh green grasses preferably from families Poaceae and Cyperaceae in water filled containers should be provided as food to nymphs. Faecal discharge should also clean daily through the central outlet of rearing chamber. To keep the rearing chamber moist 5-6 wet cotton balls can be placed in chamber. We used four-tired nymphal rearing chamber (four boxes stacked one by one) as a single unit to keep maximum individuals at a time using the same ground space.

Step-5: Adult Rearing for Breeding

The structural design of adult rearing chamber was also same as mother stock chamber but its size may be altered according to population number. Food and other environmental conditions were also same as mother stock rearing. Another set of ovipositing glass/ plastic $cups_3$ filled with moist sand were placed here for oviposition. Both male and female fledglings (0-day adult) obtained from nymphal rearing chamber should transfer to the adult rearing chamber carefully for their copulation and oviposition. Here also 3:1 male female ration would be ideal for culture.

Thus rearing cycle may be completed in five steps initially, but subsequently culture procedure would be completed in four steps as because after one generation adult stock could serve as mother stock for the next generations.

Step-6: Quantitative Estimation of Biomass and its Qualitative Test

To estimate the amount of biomass production/year of a species the following factors should be taken under consideration as they play the key role in biomass production. The factors are:

- Fertility of that species
- Nymphal mortality during culture
- Sex ratio among males and females
- Calculation of mean wet weight of male individual
- Calculation of mean wet weight of female individual and
- Voltine nature of the species

In biomass estimation one or many gravid female individual(s) may consider initially. Thereafter biomass in subsequent generations per year, obtained either from one female or females considered initially, might be estimated using the following particulars.

- Only the viable (on basis of fertility) offspring (nymphs) emerged out from only one gravid female individual in her life span may be considered initially.
- According to the sex ratio the viable nymphs may be grouped into males and females separately.
- By deducting total nymphal mortality from both male and female nymphs, the survived male and female adult individuals should be calculated. To calculate nymphal mortality dead nymphs of both sexes should be counted accordingly after completion of each instar stage.
- By multiplying the mean weight (wet) of a male to total male individuals of that population, the total ‘male biomass’ (wet weight) may be estimated. And similarly, by multiplying the mean weight (wet) of a female individual to total female individuals of that population, the total ‘female biomass’ (wet weight) may also be estimated.
- Survived female individuals from first generation may be multiplied further to its fertility number to estimate its offspring for the next generation (i.e, IInd generation).
- In generation II also offspring may be separated according to its sex ratio as earlier.
- Nymphal mortality may be then deducted from male and female offspring as earlier.
- The survived adult male and female adult individuals then may be multiplied by their mean weight (wet) again to estimate the male and female biomasses.
- The total biomass (wet weight) may be then calculated by summation of male and female biomass together.

Dry biomass may be calculated by deducting the water content (%) from their fresh (wet) values. To calculate water content insects can be placed in micro-oven under 60ºC for one hour or more depending upon the size of the insect. From fresh wet weight dried weight may be deducted and then calculate the water content accordingly.

Here it can be noted that initially (up to IInd and IIIrd instar stage) the nymphal sex may not be recognized; and if so, calculation can be progressed whenever sex would be understandable.

Step-7: Estimation of Nutritional Value of Biomass

Tissue constituents like total crude protein [83], total soluble carbohydrates [84], total fat [85] and total ash contents [86] may be estimated in both adult males and females using standard methods.

Scope of Application

The commonly used fish meal (fresh or sea water origin) to poultry and fish rations contains 13.7-20.2% protein, 0.5-4.4% carbohydrates and 0.8-2.6% fat, where the meat meal or ‘meat tankage’ contains 15-26% protein and 1.2-6.7% fat [86-87]. The acridid biomass, can be named as ‘acridid feed stuff’, is at per with, or even some time superior to any kind of commonly used animal protein supplementary feedstuffs concerning protein (15.07-16.69%), carbohydrates (7.11-8.11%) or fat (5.46-6.49%) [88]. In preparation of poultry feed it is reported that fish meals are used @ 5-10% as animal protein supplement diet ingredient and among other protein supplementary meals, meat meals are used @ 7.5-10% [86]. These fish meals or meat meals can be replaced from the standard commonly used poultry feed by ‘acridid meal’.

The recommended formula patterns for all-mash poultry rations [86] give a picture that to produce 1 ton feed 23-45 kg animal protein supplements are to be required for chick starter, 14-36 kg for grower and 23-45 kg for breeder (average- 31 kg for starter/grower/breeder). The biomass obtained from a single female individual of *Oxya fuscovittata* Marschall (Acridoidea: Orthoptera) [from starting generation (Ist) and along with its subsequent IInd, IIIrd and IVth generations that completed in a year], can be able to produce 3058.71 kg poultry feeds [88]. And noteworthy to say that a huge amount of biomass as well as its chick feed would be produced if more than one female individual may consider at starting generation!

Cited with several references it has already been stated that not only in underdeveloped or developing countries but also in developed countries entomophagism took attention to the people. And thus, it would not be surprising in near future if cooked or fried grasshoppers were widely served in delicious dishes in a roadside café, pub, motel or restaurants, though, presently, it is not a rare picture in civilised society.

Acknowledgement: SERB (SR/FT/LS-174/2012), Govt. of India, Department of Zoology, Visva Bharati, Santiniketan and Department of Zoology, Dinabandhu Mahavidyalaya, Bongaon, WB.

References

[1] Bodenheimer F.S. (1951) *Insects as Human Food.* Dr. W. Junk Publications, Hague, The Netherlands, 352.

[2] DeFoliart G.R. (1989) *Bull. of the Entomol. Soc. Am. Spring*., 22 -35.

[3] DeFoliart G.R. (1992) *Crop Protect*., 11, 395-399.

[4] DeFoliart G.R. (1999) *Annu. Rev. Entomol*., 44, 21-50.

[5] DeFoliart G.R. (2003) *Encyclopaedia of Insects*, Academic Press, 431-437.

[6] Ramos-Elorduy J., Morenoa J.M.P., Pradob E.E., Perezb M.A., Oteroc J.L. & de Guevarad O.L. (1997) *Journal of Food Composition and Analysis*, 10(2), 142-157.

[7] Ramos-Elorduy J. (1997) *J. Ecol. Food Nut*., 36, 247-276.

[8] Ramos-Elorduy J. (2009) *Entomological Research*, 39(5), 271-288.

[9] Van Huis A.V. (2003) *Insect Sci. Applic.*, 23(3), 163-185.

[10] Calvert C.C., Martin R.D. & Morgan N.O. (1969) *J. Economic Entomology*, 62(4), 938-939.

[11] Teotia J.S. & Miller B.F. (1974) *Brit. Poultry Sci*., 15, 177-182.

[12] Fasakin E.A., Balogun A.M. & Ajayi O.O. (2003) *Aquaculture Research*, 9(34), 733-738.

[13] Teguia A. & Beynen A.C. (2005) *Livestock Research for Rural Development*, 17(3), 1-11.

[14] Dashefsky H.S., Anderson D.L., Tobin E.N. & Peters T.M. (1976) *Environmental Entomology*, 5, 680-682.

[15] Koo S.I., Currian T.A., Johnson M.G., King E.W. & Turk D.E., (1980) *Poultry Science*, 59, 2514-2518.

[16] Bondari K.& Sheppard D.C. (1981) *Aquaculture*, 24, 103-109.

[17] Bondari K. & Sheppard D.C. (1987) *Aquaculture and Fisheries Managemen,* 18, 209-220.

[18] St-Hilaire S., Cranfill K., McGuire M.A., Mosley E.E., Tomberlin J.K., Newton L., Sealey W., Sheppard C. & Irving S. (2007). *Journal of the World Aquaculture Society*, 38 (2), 309-313.

[19] Bora L.R. & Sharma P.K. (1965) *Indian Vet. J.*, 42, 354-359.

[20] Ichhponani J.S. & Malik N.S. (1971) *Br. Poult. Sci*., 12, 231-234.

[21] DeFoliart G.R. (1989) *Bull. of the Entomol. Soc. America*, Spring, 22-35

[22] Khatun R., Howlider M.A.R., Rahman M.M. & Hasanuzzaman M. (2003). *Pakistan J. Biol. Sci.,* 6 (11), 955-958.

[23] Rangacharyulu P.V., Giri S.S., Paul B.N., Yashoda K.P., Rao R.J, Mahendrakar N.S., Mohanty S.N. & Mukhopadhyay P.K. (2003) *Bioresource Technol.*, 86(1), 29-32.

[24] Nazneen T., Isam M.A., Howlider M.A. & Hamid M.A. (1995) *Indian Veterinary Journal*, 72, 346-350.

[25] Hassan N.M.E., Hamed S.Y., Hassan A.B., Eltayab M.M. & Babiker E.E. (2008) *Pakistan Journal of Nutrition*, 7, 325-329.

[26] Hassan A.A., Sani I., Maiangwa M.W. & Rahman S.A. (2009) *J. Production Agric. Tech*., 5(1), 30-38.

[27] Ojewola G.S., Okoye F.C. & Ukoha O.A. (2005) *Int. J. Poult. Sci*., 4(7), 462-467.

[28] Ojewola G.S. & Udom S.F. (2005) *Int. J. Poult. Sci*., 4(10), 745-747.

[29] Wang D., Zhai S.W., Zhang C.X., Zhang Q. & Chen H. (2007) *Animal Feed Science and Technology*, 135(1), 66-74.

[30] Anand H., Ganguly A. & Haldar P. (2008) *Int. J. Poult. Sci*., 7(7), 722-725.

[31] Ueckert D.N., Yang S.P. & Albin R.C. (1972) *J. Eco. Entomol*., 65(5), 1286-1288.

[32] Bernays E.A. & Lee J. (1988) *Physiol. Entomol*., 13, 131-137.

[33] Ravindran V. & Blair R. (1993) *World's Poultry Science Journal*, 49, 219-235.

[34] Johnson G.D. & Boyce M.S. (1990) *J. Wildl. Manage*., 54, 89-91.

[35] Finke M.D. (2002) *Zoo Biology,* 21(3), 269-285.

[36] Ojewola G.S. & Udom S.F. (2005) *Int. J. Poult. Sci.*, 4(10), 745-747.

[37] Mathur R.N. (1954) *Indian Forester*, 427-432.

[38] DeFoliart G.R. (2002) *The Human Use of Insects as a Food Resource: a Bibliographic Account in Progress*, University of Wisconsin, 1737-1757

[39] Quin P.J. (1959) *Food and Feeding Habits of the Pedi*, Witwatersrand University Press, Johannesburg, 276.

[40] Ruddle K. (1973) *Biotropica.,* 5, 94-101.

[41] Denevan W.M. (1971) *Geogr. Rev.,* 61, 496-518.

[42] Chavunduka D.M. (1975) *Rhod. Sci. News*., 9, 217-220.

[43] Meyer-Rochow V.B. (1973) *Am. J. Clin. Nutr.,* 26, 673-677.

[44] Malaisse E. & Parent G. (1980) *Nat. Belg.,* 61, 2-24.

[45] Dreyer J.J. & Wehmeyer A.S. (1982) *S. Afr. J. Sci*., 78, 33-35.

[46] Eerde E. (1981) *Res. & Dev., Mexico,* 6-8.

[47] de Conconi J.R.E., Pino Moreno J.M., Mayaudon C., Valdez F.R., Perez M.A. & Rodriguez H.B. (1984) *J. Ethnobiol.,* 4, 61-72.

[48] Ramos-Elorduy J. (1998) *Creepy Crawly Cuisine: The Gourmet Guide to Edible Insects*, Inner Traditions International Press, USA, 160.

[49]Gope B. & Prasad B. (1983) *J. Adv. Zool.,* 4(1), 55-61.

[50]Dufour D.L. (1987) *American Anthropologist*, 89, 383-397.

[51]DeFoliart G.R. (1975) *Bull. Ent. Soc. Am.*, 21, 161-163.

[52]DeFoliart G.R., Finke M.D. & Sunde M.L. (1982) *J. Economic Entomology*, 75(5), 848-852.

[53]Sutton M.Q. (1988) *Insects as Food: Aboriginal Entomophagy in the Great Basin*, Ballena Press Anthropol, 33, 115.

[54]Mercer C.W.L. (1993) *Invertebrates (Minilivestock) Farming,* Ins. Trop. Med. Philippinesicine, Belgium, 157-162.

[55]Pemberton R.W. (1994) *Pan-Pacific Entomologist*, 70, 323-327.

[56]Bani G. (1995) *Food Insects Newsletter*, 8, 4-5.

[57]Mbata K.J. (1995) *Food Insects Newsletter*, 8, 5-7.

[58]Yhoung-aree J., Puwastien P.P. & Attig G.A. (1997) *Ecology of Food and Nutrition*, 36, 133-149.

[59]Luo Z.Y. (1997) *Ecology of Food and Nutrition,* 36, 201-207.

[60]Mitsuhashi J. (1997) *Ecology of Food and Nutrition*, 36, 187-199.

[61]Onore G. (1997) *Ecology of Food and Nutrition*, 36, 277-285.

[62]Tommaseo M. & Paoletti M.G. (1997) *Ecology of Food and Nutrition,* 36, 321-346.

[63]Paoletti M.G., Buscardo E. & Dufour D.L. (2000) *Environment, Development and Sustainability*, 2, 195-225.

[64]Tarunkumar S., Nabom O.S. & Chakravorty J. (2007) *Hexapoda.*, 14, 56-60.

[65]Tarunkumar S., Chakravorty J., Nabom S. & Kato D. (2007) *Journal of Nature Conservation*, 19, 169-176.

[66]Tarunkumar S., Chakravorty J. (2008) *Journal of Nature Conservation,* 19, 169-176.

[67]MacEvilly C. (2000) *Nutrition Bulletin*, 25, 267-268.

[68]Taylor R.L. (1975) *Butterflies in My Stomach*, Woodbridge Press Publishing Co. Santa Barbara., CA 224.

[69]Kok R. (1983) *Insect Food Sci. Technol. J.*, 16(1), 5-18.

[70]Schurr K. (1972) *Proc. North Cent. Branch Entomol. Soc. Am.*, 27, 135-137.

[71]Schurr K. (1976) *Proceedings Seventh Annual Workshop World Mari-culture Society*, Louisiana State University, Baton Rouge, Louisiana, 229-235.

[72]Hardouin J. (1995) *Biodiversity and Conservation*, 4, 220-232.

[73]DeFoliart G.R. (1995) *Biodiv. Conserv.*, 4, 306-21.

[74]Allotey J. & Mpuchane S.F. (2003) *Afric. J. Food Agric. Nutr. Develop.*, 2, 160-168.

[75]Soo Hoo C.F. & Fraenkel G. (1966) *J. Insect. Physiol.*, 12, 711-730.

[76]Waldbauer G.P. (1968) *Adv. Insect Physiol.*, 5, 229-269.

[77]Duodu Y.A. & Biney F.F. (1981) *Bull. Entomol. Res.*, H, 655-662.

[78]Gillon Y. & Gillon D. (1967) *Secondary Productivity of Terrestrial Ecosystems, Principles and Methods*, 2, 519-542.

[79]Gillon D. (1970) *Terre Vie.*, 124, 80-93.

[80]Köhler G., Brodhum H.P. & Schäller G. (1981) *Zool. Jb. Syst.* 108, 589-605.

[81]Hinks C.F. & Olfert O. (1999) *J. Orthoptera Res.,* 8, 237-242.

[82]Banerjee T.C. & Ray D. (1995) *Insect. Sci. Applic.*, 16 (3/4), 317-324.

[83]Lowry O.H., Rosebrough N.J., Farr A.L. & Randall R.J. (1951) *J. Biol. Chem.*, 193, 265-275.

[84]Hedge J.E. & Hofreiter B.T. (1962) *Carbohydrate Chemistry*, 17 Academic Press, New York.

[85]Association of Official Analytical Chemists (1980) *Official Methods of Analysis*, 13th ed., Washington DC, USA, 1134.

[86]Morrison F.B. (1961) *Feeds and Feeding, Abridged*, 9th ed., The Morrison Publishing Company, Clinton, Iowa, USA, 696.

[87]Lassiter J.W. & Edwards H.M.J. (1982) *Animal Nutrition*, Reston Publishing Company, INC. Reston, Virginia, USA, 451.

[88]Das A. (2002) *Strategies to yield high biomass in acridids (Orthoptera)*, PhD thesis, Visva Bharati University, Santiniketan, India, 168.