International Journal of Entomology Research
www.entomologyjournals.com
ISSN: 2455-4758
Received: 29-04-2021, Accepted: 14-05-2021, Published: 31-05-2021
Volume 6, Issue 3, 2021, Page No. 109-114

Distribution and nutritional worth of orthopteran insects: A review

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Abstract
Edible orthopteran insects are a potential source of nutrition as food and feed for humans and livestock with a great promise of food security. Worldwide, consumption of insects belonging the order Orthoptera is known since prehistoric time, but lack of knowledge of their nutritional quality and occurrence limit their utilization for consumption or inclusion into other food sources. Orthopteran insects are well distributed all over the world due to the frequent acquiescence in the terrestrial environment. Owing to orthopteran's large size and easy rearing process contribute their essence in a nutritional means for both humans as well as other animals. The family Acrididae plays an incredibly key role in orthopteran entomophagy having elevated variations in grasshopper and locust species and their well distribution in all type of the habitats. This review aims to provide the database of the distribution of edible orthopteran insects in different geographic regions (Nearctic, Neotropical, Palearctic, Oriental, African and Australian) of the world and their nutritional contents based on the published literature. The information on the distribution, nutritional advantage and food security of various edible orthopteran species for the future generation is very well highlighted. The paper explored the use of individuals of the order Orthoptera for livestock feed, contribution to economic development and livelihood improvement.

Keywords: *Acrididae, Edible orthoptera, entomophagy, Grasshopper, Locust, Nutrition*

Introduction

In ancient times insects were used as food for human consumption mostly during starvation and drought. The consumption of insects remained a long practice that started above 7000 years ago [14]. The practice to eat insects is known as entomophagy and kept going on throughout the area of the world for decades particularly in developing countries. Insects have been known as significant foodstuffs in prehistoric eastern civilizations, specifically in China, as far back as several centuries BC [39]. However, the ingestion of specific insects and their products (locusts and honey) were documented in the earlier civilizations of various parts of the world. Traditionally, entomophagy was principal practiced in tropical and subtropical areas of the world [38]. In that time, insects were simply consumed as delicacies or occasionally during starvation. Traditionally, several advanced countries have been used a huge number of insect species for dietary components and therapeutic uses [13]. In the major parts of Asia and Africa and South America, indigenous human populations have used insects in a huge number of dishes [14]. Europe and parts of North America are two exceptions, where entomophagy is not familiar. Aldovandi was an Italian entomologist is known for the modern-day study of edible insects. Currently, 2 billion people on the earth, consume more than 2500 insect species belonging to 18 orders in their daily diet, primarily in Asian, African, and Latin American states [38]. Besides, there is an intensifying curiosity for entomophagy in the western world. Particularly as aquafeed, the demand for insects is high. In the western world, several approaches to promote the significant usage of insects have been reported [39].

Edible insects are considered to be sustainable food sources with negligible negative impacts on the environment. Recently, these are preferred for the security of food, nutrition, and economic business practice for present and future generations. Sustainable insect diets or we can say insect consumption protect the biodiversity in the ecosystem by avoiding the sacrification of other animals to eat. Insects are culturally acceptable, available, commercially equitable and reasonable, nutritionally sufficient, and healthy food resources [4]. Insects are rich components of nutrients which are quite similar to those of traditional animal food and have been reported for its consumption in 130 nations. They have vast potential nutrient contents and bioactive compounds for human as well as live stock, poultry too. Insect protein is a well-known substitute of protein and will be studied as a promising source of mutton, chicken, and beef substitute in the future [14]. Insects have been using as an analog of protein in the African, Asian, and American continents [33]. Instead of other species, insects provide a hopeful alternative feed to mammals, fishes and other livestock. Insects can be reared with fewer resources like soil or land, water, electricity, and feed rather than other animals for the supply of more nutrients. They have less contribution to climate change by producing lower emissions of gases of green-house and lesser contaminants like ammonia [15]. Insects have antioxidants that tend to suppress different diseases. There is an urgent demand for alternative to protein products. Therefore insects are considered to be one of the best choices for the future supply of safe food material [5]. Owing to the fact, increasing demand for rich food, attention is being paid towards insect utilization, farming, and processing at the commercial level. However, interest all over side still need to be developed for insect consumption.

Orthopterans play an important role in grassland ecosystems because they constitute a large percentage of arthropod biomass. The order Orthoptera worldwide constitutes about 10% of the entire world insect species containing over 20,000 species [4]. Their widespread abundance and

availability, well adaptation in various habitats, life history, and body mass have made them an ideal group for the research [20]. An orthopteran insect comprises katydids, locusts, and grasshoppers, crickets that represent a broad range of ecological, morphological, and behavioural variation. These species are diversified very well in the desert, grassland, alpine, tropical forest, and semi-aquatic environment where the temperature remains warm for their fast development. Among orthopterans, the family "Acrididae" is dominant including more than 6,700 valid species scattering worldwide [23]. Despite providing nourishment to animals (invertebrates and vertebrates), they assist potential biological processes in the ecosystem [41]. Orthopterans are primarily herbivores and play a key function in food chain and transferring energy.

Earlier, feeding of some species of kosher locusts was generally known. In the 18th century BC, the workers in the Palace of Asurbanipal (Ninivé) were thought to have brought locusts arranged on sticks to eat. In the 2nd century BC, Diodorus of Sicily termed Ethiopian Acridophagi or "people who eat locusts and grasshoppers" (Acrididae: Orthoptera) [38]. In 1978, in Thailand, a locust (*Patanga succineta*) was highly used as food in epidemic conditions of the country by the government to drive and encourage the edibility of the locust. They have become a healthy "quick bite" as they are no more a crop pest. And, their marketplace price means that some farmers now explicitly grow crops to give them proper nourish meals [18].

Orthopteran role in entomophagy

Worldwide, edible Orthopteran species (grasshoppers, locusts, crickets, and katydids) are well distributed in Australia, North America, South America, Asia, African continents and consumed as food and feed in human's society [9]. Orthoptera plays a 13% role in entomophagy among all insects. Around the world, eighty species of grasshopper are eaten, and a huge number of grasshopper species are edible. During swarms, locusts emerge that making them easy to collect or directly use for food and feed. In temperate areas, insect harvesting is mainly carried out by family-run businesses to rear the insects like crickets, grasshoppers, and mealworms, mainly for zoo animals and pets feed [38]. Another important aspect to harvest Orthopteran insects is, these insects can easily rearable with low negative impact on the environment and the production rate is huge and rapid [14]. Insect culture practices would be able to save the land, water, resources, and feed directly and indirectly, and achieve high output with economic advantages for farms over traditional food producers [15].

The insects of the order Orthoptera are enough large to facilitate harvest and farmed at a large scale. The nutritional value of the orthopterans is excellent and may be influenced by the stage of development, sex, ecological factor, and feed at which they developed. The family Acrididae and pyrgomorphidae are mainly consumed for both adult and nymph stages, while others are eaten for adults or nymphs only [11]. Moreover, the composition of nutrients varies according to the species of Orthoptera or within the same species. The acridids have higher protein content in comparison to the locally available conventional soybean and fishmeal [24]. The orthopteran insects represent the amount of crude protein about 40-75% based on the dry weight of the insect body and amino acids composition is usually analogous to conventional meat [42]. Edible orthopterans are found to have protein 12.10% - 77.13%, fat 2.49% - 53.05%, and fiber 1.01% - 22.08% as nutritional contents range [33]. The nutritional profile of orthopteran insect based on the dry matter from published literature is represented in Table-1.

In the house cricket *(Acheta domesticus)* various fatty acids were extracted from different developmental stages [42]. According to a review, the members of the Acridids, *Zonocerus variegatus* (Linnaeus, 1758) [28], *Locusta migratoria* (Linnaeus, 1758) [28], *Schistocerca gregaria* (Forskål, 1775), *Cyrtacanthacris aeruginosus unicolor* (Stoll, 1813), *Acanthacris ruficornis citrina* (Serville, 1839), *Anacridium melanorhodon* (Walker, 1870) and *Kraussaria angulifera* (Krauss, 1877), have reported having high protein content with wealthy amino acids. They also have a rich amount of vitamins, fatty acids (saturated and non-saturated), and minerals. Vitamin B_{12} exists only in the food of animal origin, which is also well expressed in *Acheta domesticus* [25]. Protein-energy malnutrition (PEM) leads to around 50 percent of the deaths of children under the age of five in developing nations, as per the National Health Commission Study [9]. Therefore, acridians can play a key role in the battle toward malnutrition and starvation too [23]. The role of edible orthopteran is important not only for humans but also for the other animals to carry out the experiments in the laboratories. Acridid grasshopper, *Zonocerus variegatus* is utilized for the feed to experimental albino rats in the laboratory as potential protein substitutes. In another study essential fatty acids at the maximum level can be obtained by rearing *Ruspolia differens* [34]. *Oxya fuscovittata* and *Spathosternum prasiniferum prasiniferum* play a key role in animal food. Easily captured and reared insects like *Locusta* and *Oxya* have high potential elements to provide the basic nutrition in the form of fat, protein, and carbohydrate [16, 28]. Several studies concluded that the genus *Schistocerca* is highly enriched with protein content [31, 45].

Table 1: *Nutritio*nal value of *Orthoptera*

Insect Name	Protein	Fat	Carbohydrate	References
Aceta domestica	65.04 %	22.96 %	_	Rumpold and Schleuter, 2013
Brachytrupes orientalis	65.74%	6.33%	15.18%	Chakravorty *et al.*, 2014
Chondracris rosea (De Geer)	24.6 gm/100gm	_	_	Das, 2018
Choroedocus robustus (Serville)	18.4 gm/100gm	_	_	Das, 2018
Chorthippus parallelus	_	13%	_	Paul *et al.*, 2017
Conocephalus discolor	_	10%	_	Paul *et al.*, 2017
Eupreponotus inflatus (Uvrov)	16.9 gm/100gm	_	_	Das, 2018
Gryllotalpa africana (Beauvois)	14.8 gm/100gm	_	_	Das, 2018
Gryllus bimaculatus (De Geer)	58.32 gm/100gm	11.88 gm/100gm	_	Ghosh *et al.*, 2017
Gryllus campestris	13.08 gm/100gm	_	_	Das, 2018
Gryllus testaceus	58.3%	_	_	Wang *et al*., 2005

Heiroglyphus banian	19.2 gm/100gm	_	_	Das, 2018
Locusta migratoria	50.42 ± 2%	19.62±0.8 %	4.78±0.7%	Mohamed, 2015
Manis religiosa	8.2 gm/100gm	_	_	Das, 2018
Mecopoda elongate elongate	19.8 gm/100gm	_	_	Das, 2018
Oxya hyla hyla	64.67%	2.18%	28.17%	Ganguly *et al*., 2013
Ruspolia baileyi	22.4 gm/100gm	67%	_	Womeni *et al*., 2009; Das, 2018
Ruspolia differens	44.3 %	46.2%	_	Rumpold and Schl€uter, 2013
Schistocerca gregaria (Forsk.)	76 gm/100gm	12.97 gm/100gm	_	Zielińska *et al*., 2015
Schistocerca piceifrons piceifrons (Walker)	80.26 gm/100gm	6.21 gm/100gm	_	Pérez-Ramírez *et al.*, 2019
Schistocerca sp.	61.05%	17%	_	Pérez-Ramírez *et al.*, 2019
Sphenarium purpuracens	61.33%	11.7%	_	Rumpold and Schl€uter, 2013
Sphenarium purpurascens (Charp.)	65.2 gm/100gm	10.8 gm/100gm	_	Blásquez *et al.*, 2012
Taeniopoda auricornis (Walker)	63 gm/100gm	10.2 gm/100gm	_	Blásquez *et al.*, 2012
Tarbinskiellus portentosus	21.6gm/100gm	_	_	Das, 2018
Teleogryllus emma (Ohmachi and Matsuura)	55.65 gm/100gm	25.14 gm/100gm	_	Ghosh *et al.*, 2017
Zonocerus variegates	_	9%	_	Womeni *et al*., 2009.
Zonocerus variegatus (L.)	17.2 gm/100gm	1.18 gm/100gm	_	Ademolu *et al*., 2017

Distribution of edible orthopterans

In Africa, South America and Asia continents locusts, grasshoppers, crickets, and katydids are eaten as human food [11]. Grasshoppers and locusts have been used for poultry feeding too. Edible orthopteran belonging to the family Acrididae, Tettigonidae, and Pyrgomorphidae are mostly reported. Their consumption mainly depends on the distribution, availability, and cultural practices. Consumption of orthopterans is found to be more in developing countries as novel property to mitigate food scarcity and malnutrition. Orthopterans are highly consumed in African cities with maximum numbers of acrididae members followed by pyrgomorphidae and tettigonidae family [11]. In Madagascar, Orthoptera is consumed both as a snack and as a component of the regular meal. Grasshoppers are boiled, fried, steamed, or sun-dried for consumption [2, 38]. In East Africa, *Ruspolia diferens* is a highly nutritional and economically important edible insect [26].

However, the family Acrididae, Pyrgomorphidae, Romaleidae is dominant in the South and American continents [11]. *Sphenarium purpurascens*, an alfalfa pest, is a common edible insect in Mexico. In the certain Chinese food markets, they are served on skewers as well. In Latin America, the grasshopper chapuline (*Sphenarium purpurascens*) is best known to feed. Similarly, in Mexico and Asia, *Gryllus bimaculatus*, *Acheta domesticus*, *Teleogryllus occipitalis*, and *T. Mitratus*, are commonly used edible species [5, 44]. In various countries like Thailand, the crops are grown to feed the insects for harvesting, not for the crop selling [18]. In Nigeria, grasshoppers fed with bran having essential fatty acids have a protein content that is almost twice as large as those fed on maize [1]. In Southeast Asia, commercial farming of locusts, grasshopper, and crickets is growing for foodstuffs whrereas in Japan, China, and Korea, rice field grasshoppers are harvested for food [20]. People prefer female grasshoppers more in food rather than males because they have more fat in their bodies [24]. Cricket flour is used for many purposes [25]. According to Das, Orthopterans are feed as boiled, fried, roasted, vegetable paste, and chutney [9]. Before boiling, frying, or roasting the intestine, wings, legs, and head are removed from the insect body [40].

Edible orthopterans are distributed all over the Indian subcontinent. In Shri Lanka, species of three families Acrididae, Gryllotalpidae, and Tettigoniidae are well distributed [29]. Around five orthopteran species contributed to feeding and medicinal purposes in Bangladesh, in which, *Oxya sp., Lethocerus indicus* and *Brachytrupes sp.* were more preferred by all ethnic groups taken together [12]. Around 50 insects are reported from Pakistan, among them few species are used for animal food too [14]. In the Indian subcontinent maximum edible insects are reported from eastern and north-eastern India. In India, more than 225 insect species are used for both therapeutic and feeding purposes by ethnic tribes. Among them, entomophagy is more common in Northeast Indian states [6]. Edible orthopteran families distribution all over the world in different geographic regions is presented in the Table-2.

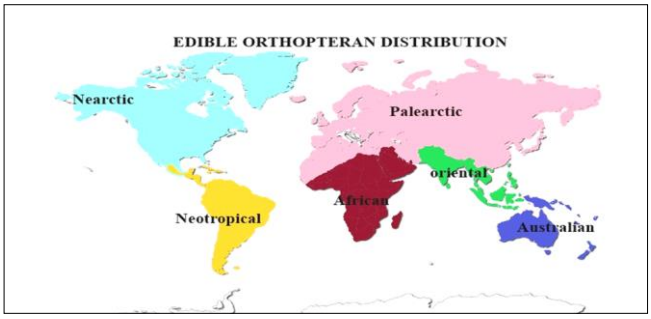

Fig 1: A world map showing various geographic regions where edible orthopteran distribution is documented.

Nearctic region- North America (highlands of Maxico, Greenland); Neotropical region- South America (Central America and the Carrabian; Palearctic region- Europe, Asia (Northen part of Himalayan foothills, Northern Africa, Central and Northen part of Arabian peninsula); Oriental region- Southeast Asia (Taiwan, India, Shri Lanka, Pakistan and China); African region- Africa (Sahara desert, Arabian Peninsula, Southern Iran, Southwestern Pakistan and Madagaskar); Australian region- Australia

Table 2: Major edible families of Orthoptera

S.No.	Family	Regions	References
1.	Acrididae	Australia (Papua New Guinea) Nearctic (North America, USA, Canada) Neotropical (Colombia, Mexico, Venezuela, Brazil, South America, West	Bodenheimer, 1951; DeFoliart, 2002; Yhoung-Aree *et al.*, 2005; Singh and Chakravorty, 2008; Siriamornpun and

		Indies) Oriental (Thailand, India, Laos, Malaysia, Indonesia, Philippines, Vietnam) Palearctic (Korea, China, Kuwait, Saudi Arabia, Morocco, Netherlands, Libya, Japan, Pan-regional, S.W. Asia, North Africa, UK) Africa (Zimbabwe, Congo, Niger, Zambia, Malawi, Sahel, D.R. Congo, South Africa, Cameroun, Burkina Faso, Mali, Togo, Benin, Sudan, South Sudan, CAR, Cameroun, Malawi, Uganda, Eastern Africa. Botswana, Nigeria, Mozambique, Ethiopia, Kenya, Sierra Leone, North benin)	Thammapat, 2008; Chen *et al.*, 2009; Hanboonsong, 2010; Riggi *et al.*, 2013; Meyer-Rochow, 2013; Rumpold, and Schlüter, 2013; Van Huis, 2013; Kelemu *et al.*, 2015; Yen, 2015; Jongema, 2017; Hongbété and Kindossi, 2017; Das, 2018
2.	Gryllidae	Nearctic (North America) Neotropical (Mexico) Oriental (Laos, Thailand, India, Indonesia, Myanmar) Palearctic (Japan, China) Africa (Botswana, Zambia, Zimbabwe, Kenya, Tanzania, D.R. Congo, CAR, North benin, G. Bissau, Sierra Leone, Guinée, Liberia, Benin, Togo, Nigeria, D.R. Congo, Kenya, South Sudan, East, Central and Southern Africa, Cameroun, Burkina Faso, Angola, Togo)	Bodenheimer, 1951; DeFoliart, 2002; Yhoung-Aree *et al.*, 2005; Singh and Chakravorty, 2008; Siriamornpun and Thammapat, 2008; Yen 2015; Kelemu *et al.*, 2015; Jongema, 2017; Hongbété and Kindossi, 2017; Hazarika, 2018; Das *et al.*, 2019
3.	Gryllotalpidae	Australia (Papua New Guinea) Neotropical (Mexico) Oriental (Thailand, India, Indonesia, Philippines, Vietnam, Laos, Malaysia, Sabah) Palearctic (Japan,china) Africa (Zambia, Uganda)	Bodenheimer, 1951; DeFoliart, 2002; Chung *et al.*, 2002; Yhoung-Aree *et al.*, 2005; Chen *et al.*, 2009; Jongema, 2017; Das, 2018
4.	Tettigoniidae	Australia (Papua New Guinea) Nearctic (North America) Neotropical (Colombia, Venezuela, Mexico) Oriental (Malaysia, Sabah, India, Thailand, Vietnam, Laos, Indonesia) Palearctic (Japan, Korea) Africa (CAR, Benin, Southern Africa,The whole of East, D.R. Congo, Tanzania, Zimbabwe, Zambia, Malawi, Southern Africa, Cameroun, Kenya, South Africa, Uganda, Benin, Congo, Burkina Faso, Guinée	DeFoliart, 2002; Chung *et al.*, 2002; Yhoung-Aree *et al.*, 2005; Womeni *et al.*, 2009; Hanboonsong, 2010; Blásquez *et al.*, 2012; Meyer-Rochow, 2013; Riggi *et al.*, 2013; Kelemu *et al*., 2015; Jongema, 2017
5.	Pyrgomorphidae	Neotropical (Mexico) Oriental (Malaysia, Sabah, Thailand, India) Palearctic (UK) Africa (Cameroun, CAR, Mozambique, South Africa, Nigeria, D.R. Congo, Cameroun, Congo, Côte d'Ivoire, Sao Tomé, Guinée, Ghana, Liberia, G. Bissau	DeFoliart, 2002; Chung *et al.*, 2002; Hanboonsong, 2010; Blásquez *et al*., 2012; Rumpold and Schlüter, 2013; Kelemu *et al.*, 2015
6.	Romaleidae	Neotropical (Mexico, Brazil, Colombia)	DeFoliart, 2002; Jongema, 2017

Based on online literature published documented edible orthopterans the family Acrididae is dominant regarding entomophagy followed by the Tettigoniidae, Gryllidae, and Pyrgomorphidae. The family Romaleidae, Stenopelmatidae, Catantopidae, Rhaphidophoridae, Tetrigidae, and Anostostomatidae, as well as Gryllotalpidae are edible in many parts of the world.

Conclusion

The knowledge of distribution or particularly edible orthopterans is not well known yet. Grasshoppers, locusts and crickets are recognized for rich amounts of protein, fat, carbohydrate, mineral, and energy that can be explored for sustainable consumption and mass production for future food requirements. On the whole, the orthopteran species are well distributed all over the world and safe to be consumed. Edible orthopteran distribution provides key information of the nutritional contents and distribution that could be used to extract more knowledge of their farming, consumer's choices, and other benefits of these edible insects. There is a scope to assess the knowledge of orthopterans diversity and their role in entomophagy that support humans and animals with nutritional and medicinal necessity. Easy collection in bulk and cost-effective farming of the orthopreans can be environment friendly task to produce food supplements and feed for livestock and aqua animals. There is an extension to put forth an attempt to expand their business esteem as food and feed for animals particularly chicken and accessibility on-request in a supportable way. The review gives comprehensive information on the diversity and availability of edible orthopteran insects all over the world, their nutritional worth, and their significant contribution to the employment of mankind.

Abbreviations

CAR- Central African Re public, D. R. of Congo-Democratic Republic of the Congo, G. Bissau-Guinea-Bissau, UK- United kingdom, USA- United State of America, N. Am. – North America, P.N.G.- Papua New Guinea.

Acknowledgement

The authors are indebted to everyone who published their articles which greatly enlightened this review.The first author are also thankful to the funding agency, Council of Scientific and Industrial Research (CSIR), Government of India, for providing financial support in the form of JRF (Junior Research Fellowship).

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