# EXPLORING THE FOOD AND NUTRITIONAL POTENTIAL OF THREE EDIBLES AMAZONIAN ARTHROPODS

**Richard Jesús Cedeño Giron [1], Glida Gisela Hidalgo [1], Jesús Eribert Bravo Garcia [1], Enrique Pino Hernández [2], Pedro Manuel Villa [3,4,*]**

[1] Servicio Autónomo Centro Amazónico para Investigación y Control de Enfermedades Tropicales Simón Bolívar, Avenida Perimetral, Cerro Orinoco, Edificio CAICET, Puerto Ayacucho, Estado Amazonas, Venezuela.
[2] Universidad de Minho, Departamento de Ciencia y Tecnología de Alimentos y Nutrición, Minho, Portugal
[3] Universidade Federal de Viçosa, Departamento de Engenharia Florestal, Laboratório de Restauração Florestal, CEP 36570900, Viçosa, Minas Gerais, Brasil.
[4] Fundación para la Conservación de la Biodiversidad, 7101, Puerto Ayacucho, estado Amazonas, Venezuela.

* Correo: pedro.villa@ufv.br

ABSTRACT

Ensuring food supply and availability, and consequently food safety, on a global scale represents one of the most important challenges of this century. The exploitation of local resources such as invertebrates has been extremely relevant to contribute to food security. However, most research has focused on evaluating the nutritional potential of insects, with very few studies approaching other invertebrate groups. Three types of edible arthropods, the palm weevil larva (*Rhynchophorus palmarum*), the leaf-cutter ant (*Atta laevigata*), and the Goliath bird-eating spider (*Theraphosa blondi*) were studied in the Northern Amazon basin. Eight composite samples of each arthropod were collected and chemically analyzed following the procedures of the Associations of Official Analytical Chemists. Proximate composition analysis was performed to quantify moisture, crude fiber, protein, crude fat, and ash. The energy content was calculated by multiplying the mean values of crude protein by the Atwater factors. All three analyzed arthropod species have high nutritional potential compared with different types of insects and other invertebrates worldwide. Results of nutritional analysis on the three arthropods selected for this study revealed statistically significant differences in their chemical composition. Such values are similar to those of insects from orders Coleoptera and Hymenoptera, with variations of 13–77% in protein amounts, 10–66% in lipid amounts, and 90–500 kcal/100 g in energy content per unit dry weight. We recommend that future research not only demonstrates the nutritional potential of edible arthropods, but also assesses the impact they have on food security.

KEYWORDS: ecosystem goods, edible invertebrates, entomophagy, traditional diets

## EXPLORANDO EL POTENCIAL ALIMENTICIO Y NUTRICIONAL DE TRES ARTRÓPODOS AMAZÓNICOS COMESTIBLES

RESUMEN

La disponibilidad de alimentos para garantizar la seguridad alimentaria a escala global, representa uno de los desafíos más importantes del presente siglo. Los recursos locales, como el aprovechamiento de invertebrados, han sido de mucha relevancia para contribuir con la seguridad alimentaria. Sin embargo, la mayoría de los estudios ha sido para evaluar el potencial alimentario de los insectos, y muy poco sobre otros grupos de invertebrados. Se estudiaron tres tipos de artrópodos comestibles, larvas de picudo de palma (*Rhynchophorus palmarum*), hormigas cortadoras de hojas (*Atta laevigata*) y arañas Goliat come pájaros (*Theraphosa blondi*) en el norte de la Amazonía. Se colectaron ocho muestras compuestas de cada tipo de artrópodo, y cada muestra se analizó químicamente de acuerdo con los procedimientos de la *Associations of Official Analytical Chemists*. En el análisis nutricional se determinó el contenido de agua, fibra bruta, proteína, grasa bruta y cenizas. El contenido energético se calculó


Fecha de recepción: 22-01-2017 • Fecha de aceptación: 05-03-2017

multiplicando los valores medios de la proteína bruta. Las tres especies de artrópodos analizadas en este estudio tienen un alto potencial nutricional, en comparación con diferentes tipos de insectos y otros invertebrados en todo el mundo. Los resultados de los análisis nutricionales de los tres artrópodos seleccionados para este estudio revelaron diferencias estadísticamente significativas en su composición química. Tales valores son similares a los de los insectos de los órdenes Coleoptera e Hymenoptera, con variaciones de 13-77% en las cantidades de proteínas, 10-66% en las cantidades de lípidos, y 90-500 kcal / 100 g en el contenido de energía por unidad de peso seco. Recomendamos que las investigaciones futuras no sólo demuestren el potencial nutricional de los artrópodos comestibles, sino que también evalúen el impacto que tienen en la seguridad alimentaria.

**PALABRAS CLAVE:** Bienes ecosistémicos, invertebrados comestibles, entomofagia, dietas tradicionales

## INTRODUCTION

Ensuring food supply and availability, and consequently food safety, of current and future human generations represents one of the most important challenges of this century (FAO, 2016). With the current trend of rampant growth in human population, food demand will increase at the expense of the exploitation of several environmental assets, like watercourses and croplands (Godfray *et al*., 2010a; Godfray *et al*., 2010b). In that sense, traditional food systems are extremely relevant, as they depend on resources that are culturally accepted on a local basis (Mintz and Du Bois, 2002; Kuhnlein, 2003).

Usually, these food systems are part of the subsistence strategies of several indigenous peoples, mainly through agriculture and harvest (Kuhnlein, 2003; Wahlqvist and Lee, 2007). In view of this scenario of overexploitation of ecosystem goods and services, which leads to a major degradation of food production systems, the harvesting and use of invertebrates as food represents a valuable alternative contributing to food security (Mintz and Du Bois, 2002; Paoletti and Dreon, 2005). In view of that, rescuing and conserving indigenous traditional knowledge within ancestral cultures that use this alternative food source is fundamental (Paoletti, 2005). However, most research in the field has focused on evaluating the nutritional potential of insects, with very few studies approaching other invertebrate groups.

Edible invertebrates represent an important dietary component of several indigenous communities and rural settlements, especially in the tropics, where there is a high potentially edible biological diversity (Paoletti, 2005). In most of these autochthonous societies, insects contribute significantly to food security and subsistence means (van Huis *et al*., 2013). For that reason, with more than 2000 insect species being considered edible worldwide (Jongema, 2012), entomophagy has become an alternative to increase food security in the more than 113 countries where it occurs (Ramos-Elorduy and Pino, 1990; MacEvilly, 2000). Edible insects have a highly variable nutritional value, although in general they are very nutrient-rich, especially due to their high contents of proteins, fats, and minerals (Ramos-Elorduy *et al*., 1997; Rumpold and Schlüter, 2013a; Kouřimská and Adámková, 2016). In Northwestern Amazon, for instance, insects provide ca. 5% to 7% of the total protein intake of local peoples during the year (Costa-Neto, 2016).

Lastly, it has been discussed that the selection of invertebrates as well as the mode of their consumption by each indigenous tribe depends mainly on eating habits and on the availability of such resources in the ecosystem (Paoletti and Dufour, 2005; Costa-Neto, 2016). It is worth noting, however, that most research has centered on evaluating food availability, while studies that analyze their nutritional potential remain scarce.

Out of the remarkable report of more than 209 invertebrates that are considered important sources of food for several indigenous communities in the Amazon basin, insects represent the major source among those invertebrates in the region (Paoletti and Dufour, 2005). Yet, the relative importance that such food sources have on food security remains unknown. The highly nutritional palm weevil larva (*Rhynchophorus palmarum*) is one of the most consumed species in different localities of the Amazon basin (Cerda *et al*., 2001; Choo *et al*., 2009; Sancho *et al*., 2015), similarly to other *Rhynchophorus* species which are consumed in several other tropical ecosystems (van Huis *et al*., 2013). As food resources, palm weevil larvae are available in a predictable manner, since Indians have learned how to control their supply in a way that can be considered semi-harvesting (Choo *et al*., 2009; van Itterbeeck and van Huis, 2012). On the other hand, little is still known on the chemical composition of representatives from other arthropod groups that are used as food in the Amazon, like the leaf-cutter ant (*Atta laevigata*) and the Goliath bird-eting spider (*Theraphosa blondi*). Thus, we aimed to evaluate the nutritional potential of three arthropods from the Northern Amazon basin. These three species were selected for being traditionally consumed by locals.

## MATERIAL AND METHODS

**Sampling area and arthropod collection.** Three edible arthropods, namely the palm weevil larva (*Rhynchophorus palmarum*), the leaf-cutter ant (*Atta laevigata*), and the Goliath bird-eating spider (*Theraphosa blondi*), were collected in the forest surrounding an area of shifting cultivation at the Samaria community (5°34'26.8" N, 67°27'38.7" W), a traditional village of the ethnic group Piaroa, whose population ranges around 360. The village is located 24 km south of Puerto Ayacucho city, Amazonas State, Venezuela. Eight composite samples of each arthropod were collected. The palm weevil larvae were collected at late developmental stages from the "cucurito" palm tree (*Maximiliana regia*) by handpicking. The leaf-cutter ant and the spider were also collected manually, but in their respective belowground holes. The arthropods were killed by asphyxiation in a deep freezer for 48 h. From the spiders, only edible parts (legs and thorax) were collected for analysis. Samples were dried separately at 60°C in a Gallenkamp oven until constant weight. The oil extracted during drying was collected in a bottle and stored in the laboratory until analysis. Dried samples were ground using a laboratory pestle and mortar, and were then stored in containers until analysis.

Arthropods were collected throughout three months (March through May 2015) with the assistance of the Piaroa people, during their traditional activities of food harvest in the forest. The Piaroa usually collect between 10 and 15 Goliath bird-eating spiders a day, normally at every two to three months. According to the Piaroa traditional knowledge, up to six medium- to large-sized spiders can be found in each ground hole. Palm weevil larvae were collected from naturally fallen palms; approximately 150 to 200 larvae were collected from each tree. The frequency of larvae consumption is variable, being related not to climate variations, yet to the availability of fallen trees. Finally, leaf-cutter ants are much more abundant, being found in the surroundings of the Samaria community as well as across the entire Cataniapo river basin. Ants were captured by introducing small sticks into their nests, waiting until the largest number of ants possible climbed the sticks, and then placing them in a container with water.

**Proximate composition and statistical analysis.** Samples from each arthropod were chemically analyzed following the procedures of the Association of Official Analytical Chemists (AOAC), using three 250 g subsamples for each analysis. The proximate composition (moisture, protein, crude fat, and ash) was performed according to the AOAC procedures (AOAC, 2005); the carbohydrate value is considered as the diference between 100 and the sum of the percentages of water, protein, ash, and total fat. The energy was calculated by multiplying the mean values of fat, protein, and carbohydrates content by their respective caloric values: 9.0 Kcal/g, 4.0 Kcal/g, and 4.0 Kcal/g respectively (Atwater´s conversion factors). The energy values were expressed in kcal per 100 g of sample (AOAC, 2005). Data was statistically analyzed by one-way ANOVA and Tukey's multiple comparison tests at the 95% confidence level ($p < 0.05$) using software R version 2. 3.2.4 (R Core Team, 2016).

## RESULTS AND DISCUSSION

All three arthropod species analyzed in this study have high nutritional potential (Table 1) compared with different types of insects and other invertebrates all over the world (Paoletti and Dreon, 2005; Kouřimská and Adámková, 2016). The studied species are therefore justifiably used as a complementary source of food by the Piaroa in the Samaria community region.

According to previous studies conducted in the Amazon, most indigenous groups have a special preference for palm larvae (Curculionidae, Rhynchophorinae), such as those of the species *R. palmarum*, which are consumed by the Yanomamis from Alto Orinoco (Cerda *et al*., 2005) and by the Hoti from Sierra de Maigualida (Choo, 2008). Analogously, other *Rhynchophorus* species have been reported to be consumed by ethnic groups from several other localities in the tropics (van Huis *et al*., 2013): *R. palmarum* in all South America (Paoletti and Dufour, 2005; Schabel, 2010), *R. phoenicis* in West and Central Africa (Schabel, 2010; Kelemu *et al*., 2015), *R. bilineatus* in Papua New Guinea and Indonesia (Schabel, 2010; Ramandey and Mastrigt, 2010; Yen, 2015), and *R. ferrugineus* in Java and Borneo (Chung, 2010; Lukiwati, 2010). All these species are highly appreciated by locals. However, published research has focused majorly on the descriptive analysis of the food potential of edible *Rhynchophorus* species, yet with no investigation on either their true nutritional potential or their implication for food security on a local scale.

***Tabla 1.*** Proximate analysis on selected edible arthropods (g/100 g dry weight): palm weevil larva (*Rynchophorus palmarum*), leaf-cutter ant (*Atta laevigata*), and spider Goliath bird-eting (*Theraphosa blondi*). Mean values ± SE (n = 8).

| Analysis | *R. palmarum* | *A. laevigata* | *T. blondi* |
|---|---|---|---|
| Moisture (g/100 g) | 69.36 ± 0.03 [c] | 71.05 ± 0.34 [a] | 70.28 ± 0.08 [b] |
| Energy (Kcal/100 g) | 187.79 ± 0.05 [a] | 140.10 ± 0.07 [b] | 109.68 ± 0.12 [c] |
| Carbohydrates (g/100 g) | 18.04 ± 1.02 [c] | 20.24 ± 0.34 [b] | 22.01 ± 0.28 [a] |
| Protein (g/100 g) | 4.45 ± 0.15 [a] | 3.58 ± 0.46 [b] | 2.62 ± 0.46 [c] |
| Fat (g/100 g) | 10.87 ± 0.26 [a] | 4.98 ± 0.83 [b] | 1.24 ± 0.19 [c] |
| Ash (g/100 g) | 1.04 ± 0.44 [c] | 2.26 ± 0.21 [b] | 5.26 ± 0.07 [a] |

Means followed by different letters in a same row differ significantly by Tukey's test ($p > 0.05$).

Ants from the *Atta* genus also represent an important food source in the tropics (Choo, 2008). The ethnicities Curripaco, Piaroa, and Guajibo, all of which live near Puerto Ayacucho, use the species *Atta cephalotes* to prepare other supplementary foods, like the spicy sauce 'catara' (Paoletti and Dufour, 2005). However, the potentialities of *A. laevigata* in human nutrition remain unknown.

On the other hand, in our study we show, for the first time, the importance of the spider *T. blondi* as potential food and source of nutrients for the Piaroa Amazonian community. This species has also been reported to be an important part of the Yanomami diet, but its relative contribution to the diet of both these ethnicities remains unknown. In contrast, the Yekuana do not consume spiders; instead, they prefer oligochaetes as protein source, especially the species *Andiorrhinus motto* (Araujo and Becerra, 2007).

Thus, ethnic groups may have differing preferences regarding the selection of foods to integrate their diets, which is why not all types of insects or arthropods are always consumed. For instance, the Yukpa and the Guajibos consume grasshoppers, while other indigenous groups that live near Puerto Ayacucho (e.g., the Piaroa, Curripaco, Ye'kuanas, and Yanomami) do not (Paoletti and Dufour, 2005). Probably, the immigration of these indigenous groups to territories with higher influence of western culture, like the areas near the capital of the Venezuelan state of Amazonas, has also influenced the exchange of eating standards, enabling the development of a higher dependence on foreign foods.

In this work, we present, for the first time, the results on the proximate composition of *T. blondi* and *A laevigata*. It should be noted that most studies have so far mainly focused on evaluating the food and nutritional potentials of insects (Kouř imská and Adámková, 2016), while few studies have investigated the same properties in other terrestrial invertebrate groups, like arthropods, mollusks, and annelids. In that sense, the results of nutritional analyses on the three arthropods selected for this study revealed statistically significant differences in their chemical composition (Table 1). Numerically, however, the values found were overall not strikingly different among the species. On the other hand, such values are similar to those of insects from orders Coleoptera and Hymenoptera, with variations of 13–77% in protein amounts, 10–66% in lipid amounts, and 90-500 kcal/100 g in energy content per unit dry weight (Kouř imská and Adámková, 2016).

Proportional values have been reported to *Rhynchophorus* spp. that are diferent to the ones we found in this study, like the energy one, in the order of 580 kcal/100 g in *R. palmarum* (Cerda et al. 2005) as opposed to the ones in the order of 425 to 480 kcal/100 g in *R. phoenicis* (Onyeike *et al*., 2005; Rumpold and Schlüter, 2013b). The protein contents in *R. palmarum* and *R. phoenicis* range around 7 and 36 g/100 g, respectively (van Huis *et al*., 2013). On the other hand, the nutritional potential of the *Atta* genus has been less evaluated than that of *Rhynchophorus*, although there are some reports of similar energy and lipid content values between these genera. In *A. mexicana* and *A. cephalotes*, studies have reported energy values ranging between 400 and 550 kcal/100 g, respectively (Ramos-Elorduy *et al*., 1997; Rumpold and Schlüter, 2013b; van Huis *et al*., 2013; Kouř imská and Adámková, 2016). In this sense, the energy contents of edible insects varies according to the species and region found, and the Coleopteran and Lepidopteran species provide more energy (Ramos-Elorduy, 2008).

There are still few studies comparing the nutritional and energetic potential among different invertebrate groups. In that sense, we recommend that future research not only demonstrates the nutritional potential of edible arthropods, but also determines the temporal variation as food resource, rescues local knowledge on their management, and assesses the impact they have on food security.

**ACKNOWLEDGMENTS**

The author would like to acknowledge to the ethnic group Piaroa of Samaria, for enabling this work to be developed.

**LITERATURE CITED**

AOAC. 2005. *Official methods of analysis of the Association of Official Analytical Chemists*. HORWITZ, W,18th ed. Arlington: AOAC Inc.

Araujo, Y. y P. Beserra. 2007. Diversidad de invertebrados consumidos por las etnias yanomami y yekuana del Alto Orinoco, Venezuela. *Interciencia 32*: 318-323.

Cerda, H., Y. Araujo, R.H. Glew, and M.G. Paoletti. 2005. Palm worm (Coleoptera, Curculionidae: *Rhynchophorus palmarum*) a traditional food: examples from Alto Orinoco, Venezuela. In M.G. Paoletti (Ed.), *Ecological implications of minilivestock: potential of insects, rodents, frogs and snails* (pp. 353-366). Enfield NH, Science Pub.

Cerda, H., R. Martinez, N. Briceno, L. Pizzoferrato, P. Manzi, M.T. Ponzetta, O. Marin and M.G. Paoletti. 2001. Palm worm: (*Rhynchophorus palmarum*) traditional food in Amazonas, Venezuela - Nutritional, composition, small scale production and tourist palatability. *Ecology of Food and Nutrition 40*: 13-32.

Choo, J. 2008. Potential ecological implications of human entomophagy by subsistence groups of the Neotropics. *Terrestrial Arthropod Reviews 1*: 81–93.

Choo, J., E.L. Zent, and B.B. Simpson. 2009. The importance of traditional ecological knowledge for palm-weevil cultivation in the Venezuelan Amazon. *Journal of Ethnobiology* 29: 113-128.

Chung, A.Y.C. 2010. Edible insects and entomophagy in Borneo. In P. B. Durst, D. V. Johnson, R. N. Leslie, and K. Shono (Eds.), *Forest insects as food: Humans bite back*. Proceedings of a workshop on Asia-Pacific resources and their potential for development. Chiang Mai, Thailand, 19–21 February, 2008 (pp. 141–150). FAO.

Costa-Neto, E.M. 2016. Edible insects in Latin America: old challenges, new opportunities. *Journal of Insects as Food and Feed 2*: 1–2.

FAO. 2016. *The state of food and agriculture: Climate change, agriculture and food security*. Rome, Italy: FAO. 214 pp.

Godfray, H.C.J., J.R. Beddington, I.R. Crute, L. Haddad, D. Lawrence, J.F. Muir, J. Pretty, S. Robinson, S. M. Thomas, and C. Toulmin. 2010a. Food Security: The Challenge of Feeding 9 Billion People. *Science* 327: 812-818.

Godfray, H.C.J., I.R. Crute, L. Haddad, D. Lawrence, J.F. Muir, N. Nisbett, J. Pretty, S. Robinson, C.Toulmin, and R. Whiteley. 2010b. The future of the global food system. *Philosophical transactions of the Royal Society of London. Series B, Biological sciences 365*(1554): 2769-77.

Jongema, Y. 2012. *List of edible insects of the world* (April 4, 2012). http://www.ent. wur.nl/UK/Edible+insects/Worldwide+species+list/

Kelemu, S., S. Niassy, B. Torto, K. Fiaboe, H. Affognon, H. Tonnang, N.K. Maniania and S. Ekesi. 2015. African edible insects for food and feed: inventory, diversity, commonalities and contribution to food security. *Journal of Insects as Food and Feed* 1(1): 1-17.

Kouřimská, L., and A. Adámková. 2016. Nutritional and sensory quality of edible insects. *NFS Journal* 4: 22-26.

Kuhnlein, H.V. 2003. Micronutrient Nutrition and Traditional Food Systems of Indigenous Peoples. *Food, Nutrition and Agriculture* 32: 33-39.

Lukiwati, D.R. 2010. Teak caterpillars and other edible insects in Java. In P. B. Durst, D. V. Johnson, R. N. Leslie, and K. Shono (Eds.), *Forest insects as food: Humans bite back*. Proceedings of a workshop on Asia-Pacific resources and their potential for development. Chiang Mai, Thailand, 19-21 February, 2008 (pp. 99-103). FAO.

MacEvilly, C. 2000. Bugs in the system. *Nutrition Bulletin* 25: 267-268.

Mintz, S.W. and C.M. Du Bois. 2002. The Anthropology of Food and Eating. *Annual Review of Anthropology* 31: 99-119.

Onyeike, E.N., E.O. Ayalogu, and C.C. Okaraonye. 2005. Nutritive value of the larvae of raphia palm beetle (*Oryctes rhinoceros*) and weevil (*Rhyncophorus pheonicis*). *Journal of the Science of Food and Agriculture 85*(11): 1822–1828.

Paoletti, M.G. (ed). 2005. *Ecological implications of minilivestock*. Enfield NH, USA, Science Pub. 648 pp.

Paoletti, M.G. and A.L. Dreon. 2005. Minilivestock, Environment, Sustainability, and Local Knowledge Disappearance. In M.G. Paoletti (Ed.), *Ecological implications of minilivestock: potential of insects, rodents, frogs and snails* (pp. 1–18). Science Publishers, Enfield.

Paoletti, M.G. and D.L. Dufour. 2005. Edible invertebrates among Amazonian Indians: a critical review of disappearing knowledge. In M.G. Paoletti (Ed.), *Ecological implications of minilivestock: potential of insects, rodents, frogs and snails* (pp. 293–342).

Science Publishers, Enfield.

R Core Team (2014). R: *A language and environment for statistical computing*. R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org/

Ramandey, E. and H. van Mastrigt. 2010. Edible insects in Papua, Indonesia: From delicious snack to basic need. In P. B. Durst, D. V. Johnson, R. N. Leslie, and K. Shono (Eds.), *Forest insects as food: humans bite back.* Proceedings of a workshop on Asia-Pacific resources and their potential for development. Chiang Mai, Thailand, 19–21 February, 2008 (pp. 105–114). FAO.

Ramos-Elorduy, J. 2008. Energy supplied by edible insects from Mexico and their nutritional and ecological importance. *Ecology of Food and Nutrition* 47, 280–297.

Ramos-Elorduy, J. and J.M.M. Pino. 1990. Contenido calórico de algunos insectos comestibles de México. *Revista de la Sociedad Química de México* 34:56-68.

Ramos-Elorduy, J., Moreno, J. M. P., Prado, E. E., Perez, M. A., Otero, J. L., and O. Ladron De Guevara. 1997. Nutritional Value of Edible Insects from the State of Oaxaca, Mexico. *Journal of Food Composition and Analysis* 10: 142-157.

Rumpold, B.A. and O.K. Schlüter. 2013a. Nutritional composition and safety aspects of edible insects. *Molecular Nutrition and Food Research* 57(5): 802-823.

Rumpold, B.A. and O.K. Schlüter. 2013b. Potential and challenges of insects as an innovative source for food and feed production. *Innovative Food Science and Emerging Technologies 17*: 1-11.

Sancho, D., M. Alvarez, and L. Fernández Sánchez. 2015. Insectos y alimentación. Larvas de *Rhynchophorus palmarum* L., un alimento de los pobladores de la amazonía ecuatoriana. *Entomotropica 30*: 135–149.

Schabel, H.G. 2010. Forest insects as food: A global review. In P. B. Durst, D. V. Johnson, R. N. Leslie, and K. Shono (Eds.), *Forest insects as food: Humans bite back.* Proceedings of a workshop on Asia-Pacific resources and their potential for development. Chiang Mai, Thailand, 19-21 February, 2008 (pp. 37-64). FAO.

Van Huis, A., J. Van Itterbeeck, H. Klunder, E. Mertens, A. Halloran, G. Muir, P. Vantomme. 2013. *Edible Insects. Future Prospects for Food and Feed Security*. FAO, Rome, 2013. 201pp.

Van Itterbeeck, J. and A. van Huis. 2012. Environmental manipulation for edible insect procurement: a historical perspective. *Journal of ethnobiology and ethnomedicine 8*(3): 1–7.

Wahlqvist, M.L. and M.S. Lee. 2007. Regional Food Culture and Development. *Asia Pacific Journal of Clinical Nutrition* 16(Suppl 1): 2-7.

Yen, A.L. 2015. Insects as food and feed in the Asia Pacific region: current perspectives and future directions. *Journal of Insects as Food and Feed 1*(1): 33-55.