Emirates Journal of Food and Agriculture. 2018. 30(5): 389-395
doi: 10.9755/ejfa.2018.v30.i5.1682
http://www.ejfa.me/

REGULAR ARTICLE

Nutritional characterization of fatty acids and minerals in *Brachystola magna* (Girard) during their development

José Gabriel Monter-Miranda[1], Paul Baruk Zamudio-Flores[1,*], Juan Manuel Tirado-Gallegos[1], Francisco Javier Molina-Corral[1], Emilio Ochoa-Reyes[1], Claudio Rios-Velasco[1], María Hernández-González[2], Francisco Hernández-Centeno[2], Haydee Yajaira López de la Peña[2]

[1]Centro de Investigación en Alimentación y Desarrollo (CIAD), A.C., Unidad Cuauhtémoc, Av. Río Conchos S/N Parque Industrial, Apdo. Postal 781. Cd. Cuauhtémoc, Chihuahua, C.P. 31570, México, [2]Departamento de Ciencia y Tecnología de Alimentos, División de Ciencia Animal, Universidad Autónoma Agraria Antonio Narro, Calzada Antonio Narro1923, Buenavista, Saltillo Coahuila 2315, México

ABSTRACT

Due to the growing demand for food sources, it is increasingly common to opt for entomophagy, in addition to contributing to the control of grasshopper *Brachystola magna* (Girard) insect considered a harmful pest for agriculture in the regions where it lives. In this study, a nutritional characterization on the grasshopper *B. magna* in four different stages of its biological cycle (egg, nymph 3, nymph 4 and adult) was performed. In the adult stage, values of protein and lipid content of 64.7 and 8.2%, respectively, were obtained through proximal chemical analysis. For the determination of fatty acids and minerals the techniques of gas chromatography and atomic absorption spectroscopy were used. The results of fatty acids and minerals indicated a high content of both, unsaturated fatty acids of eighteen carbons, especially oleic, and the minerals K^{+1}, Mg^{+2} and Ca^{+2} with a relatively low presence of Na^{+1} due to its peculiar source of feed (bean). The results suggest that *Brachystola magna* (Girard) could be a potential source of consumption for healthy people and people with specific needs (people with cardiovascular problems of high protein requirements, such as caloric-protein malnutrition and bodybuilding).

Keywords: Edible insects; Nutritional characterization; Unsaturated fatty acids; Proteins; Minerals

INTRODUCTION

The *Orthoptera* order is one of the most common insect groups (more than 20,000 species) in the world. The populations of some of the species classified in this order can reach extremely large numbers of individuals and cause economic failures in areas of agricultural crops (Antonatos et al., 2014; Erdogan and Kaya, 2016). In this order, the grasshopper is one of the insects recommended as an excellent alternative food, due to its high nutritional value (mainly for its high protein content) (Ramos-Elorduy et al., 1998; Ramos-Elorduy et al., 2012; Melo Ruiz et al., 2015). Grasshopper´s biological cycle is annual, although in laboratory conditions it may last a minimum of 230 days and a maximum of 350 days. Mating occurs in the months of August and September lasting 7 h as maximum. Egg laying occurs four to five days later, at the borders of the plots, roads, ditches, etc., incubating in the soil at a depth of 1.5 to 5 cm and at a temperature of 30 ºC, during eight to nine months (Uribe-González and Santiago-Basilio, 2012).

Approximately 920 species of the *Orthoptera´*s order grasshoppers are known in Mexico. Pest species are few, taking into account the number of these that inhabit the ecosystem. The grasshoppers (*Orthoptera*: *acrididae*) cause large losses in agriculture, especially in crops of beans and maizes as well as in natural pastures in states whose altitude is over 2,000 meters above sea level, such as Chihuahua, Durango, Zacatecas, San Luis Potosi, Aguascalientes, Hidalgo Mexico, Michoacán, Puebla, Tlaxcala and Guanajuato, where the genera *Melanoplus*, *Boopedum*, *Mermiria*, *Sphenarium* and *Brachystola* have been recorded (García-Gutiérrez and González-Maldonado, 2009; Uribe-González and Santiago-Basilio, 2012). A number of alternatives have been developed to reduce the problems caused by grasshoppers in crops. One of them is to avoid their propagation by chemical methods, such as the use of

***Corresponding author:**
Paul Baruk Zamudio Flores, Ph.D. in Biotics Products, Research Center for Food and Development, Laboratory of Carbohydrates, Packaging and Functional Foods, Av. Río Conchos S/N Parque Industrial, Apdo. Postal 781. Cd. Cuauhtemoc, Chihuahua, C.P. 31570, Mexico. Tel.: +52 625 581-29-20, Fax: +52 625 581-29-70, Ext. 111, E-mail: pzamudio@ciad.mx

Received: 19 November 2017; **Accepted:** 12 May 2018

1% cypermethrin (a systemic insecticide) and biological methods, which include the use of entomopathogenic fungi, for instance *Beauveria* spp., which digests the insect, and other is *Metarhizium* spp., which attacks the insect by contact. They all have advantages and limitations (Rios-Velasco et al., 2014). But why spend so much and waste a possible source of income and food? The irony of eliminating a source with a higher nutritional quality to preserve a lower quality one is nutritionally absurd, in addition to doing so it would represent a considerable saving in terms of the decrease of supplies used in its control (Premalatha et al., 2011).

However, in several parts of the world, as in Mexico, the interest in using insects as a source of food has promoted their nutritional study in diverse stages of their biological cycle, as in *Thasus gigas*, for sauces production (Mendoza et al., 2009). In this context, it is important to analyze the nutritional content of this type of insects and to evaluate their feasible nutritional changes as a function of insect development. Recently, our research group reported the extraction and characterization of the physicochemical, morphological and structural properties of chitin chitosan from the insect *Brachystola magna* (Girard) (Monter-Miranda et al., 2016). However, edible insects provide satisfactorily with energy and protein, meet amino acid requirements for humans, are high in monounsaturated and/or polyunstaunsaturated fatty acids, and rich in several micronutrients such as copper, iron, magnesium, manganese, phosphorous, selenium, and zinc as well as riboflavin, pantothenic acid, biotin, and in some cases folic acid (Rumpold et al., 2013). Therefore, the objective of this study was to perform a qualitative and quantitative determination of nutrient components (protein, fatty acid and mineral content) in four stages (egg, nymph 3, nymph 4 and adult) of the development of the grasshopper *Brachystola Magna* (Girard).

MATERIALS AND METHODS

Materials

The reagents used for the proximal chemical analysis were of analytical grade. The chemical reagents and reference standards used for analysis of the fatty acid profile and purity grade for the analytical techniques of gas chromatography and atomic absorption spectroscopy were HPLC grade. These reagents were 1 N hydrochloric acid, 70% nitric acid, 94% sulfuric acid, 1 M and 40% sodium hydroxide, 2% acetic acid, 1: 2 chloroform/methanol and sodium borohydrate to 0.25 mg/300 mL, which were purchased from Sigma-Aldrich, Co. (Toluca, State of Mexico, Mexico). The reference standards used for the minerals determination were K^{+1}, Na^{+1}, Fe^{+3}, Zn^{+2}, Mg^{+2}, Cu^{+2}, Ca^{+3}, and the mixture of methylated fatty acids C8-C24 and methyl undecanoate for atomic absorption and gas chromatography, respectively.

Insects, *B. magna* were obtained from the surrounding region of Cuauhtemoc, Chihuahua (Nuevo Zaragoza, colony Alvaro Obregon, Municipality of Cuauhtemoc, and in the municipality of Guerrero) in bean cultivars and fodders. Harvesting was performed at early hours of the day (before 7 am), because the grasshoppers, at this time are at rest, facilitating their capture. Once collected, they were washed with distilled water for the removal of external contaminants and regurgitation of the insect. Subsequently, a second wash was performed and then they were ultra frozen at -65 °C, to finally been lyophilized (Labconco 77540-00, MO, USA). In order to obtain the eggs (ootheques), nurseries were established in 15 × 20 × 15 cm plastic containers with previously sterilized soil (121 ºC/15 min/120 psi) in rations of ≈ 8 kg, using a total of 2 ton of soil mixed with sand in a ratio of 2: 1 (w/w). Pairs of grasshoppers were placed in each of the boxes and maintained with artificial diet until their death. Samplings were used in the stages of ootheca (egg), nymph 3, nymph 4 and adult.

Obtaining of grasshopper flour

After cleaning previously described, grasshoppers were lyophilized at a temperature of -40°C and -133 mbar vacuum with a lyophilizer (Labconco 77540-00, MO, USA). The lyophilized grasshoppers were milled and sieved (425 µm Retsch, number 40, Haan, Germany) to standardize the particle size. Once milled, the powder obtained was stored in sealed bags (Ziploc®, Johnson and Sons, Inc., Racine, WI, USA) in a dry, light-free environment until further analysis.

Proximal chemical analysis

Proximal chemical analysis was performed on lyophilized grasshoppers flour and consisted in the determination of proteins, lipids and ashes according to the AOAC (2002) official methods 928.08, 991.36 and 942.05.

Lipidic profile

a) Lipids extraction

For lipid extraction, the methodology proposed by Bligh and Dyer (1959) with some modifications was used. 0.1 g of lyophilized sample (Egg, Nymph 3, Nymph 4 and Adult) were placed, adding 1.5 mL of chloroform-methanol (1:2, v/v), and shaking vigorously for 2 min (Thermolyne, Maxi mix II, Iowa, USA). Then 0.5 mL of chloroform was incorporated by stirring for 30 s, followed by 0.5 mL of distilled water for 30 s, and finally 0.5 mL of chloroform stirring for 30 s, and centrifuging at 1400 × *g* for 3 min at 25 °C (Beckman Allegra 64-R, Indianapolis, USA).

The supernatant was removed (supernatant 1), and the precipitate was re-suspended in 0.5 mL of chloroform-methanol (1:2, v/v), making a second extraction similarly (supernatant 2), both supernatants were combined in a 10 mL tube adding 0.5 mL of distilled water to allow phase separation. The upper phase (alcohol phase) was discarded and the organic phase was evaporated with nitrogen stream, then the precipitate was re-suspended in 1 mL of chloroform (Sigma-Aldrich, Toluca, Estado de Mexico, Mexico), evaporating again with Nitrogen stream to obtain the final dry extract to which 50 µl of methyl undecanoate (50 ppm) was added as an internal standard.

b) Esterification

The dry extract was re-suspended in 1 mL of toluene (Sigma-Aldrich, Toluca, State of Mexico, Mexico), shaking for 10 s, then adding 2 mL of 0.5 M methanolic base (Sigma-Aldrich, Toluca, Mexico, Mexico), and mixing for 10 s. The mixture was heated at 70-80 °C for 17 ± 1 min in a solid heating block (Thermolyne, USA), then the mixture was allowed to cool at room temperature and 1 mL of distilled water and 1 mL of hexane were added, mixing again. Subsequently, the sample was allowed to stand for phase separation, recovering the organic phase (top) in a 2 mL vial adding 200 mg of anhydrous sodium sulfate (JTBaker, Mexico), finally freezing the sample at -20 °C until further analysis.

c) Identification and quantification of fatty acids

Identification of the fatty acids in the esterified samples was performed on a gas chromatograph equipped with a mass detector (Varian Saturn 2100D, Palo Alto, California, USA). The compounds in the samples were identified by comparison of the respective mass spectra against those of the NIST 2008 database, and against those of high purity reference standards (Sigma-Aldrich, Mexico). The quantification of the fatty acid content was carried out on a gas chromatograph (Agilent 7820A, China), equipped with a flame ionization detector. A 60-m DB-Wax (Agilent Technologies, USA) column, 0.250 mm internal diameter and 0.25 µm film thickness were used in both gas chromatographs under the following chromatographic conditions: 1 µl sample, Injector temperature of 240 °C (in 1:5 divided mode), initial column temperature of 100 °C, heating at 200 °C to 25 °C min-1, and finally at 230 °C at 3 °C min- 1, using helium as carrier gas with a flow of 1.5 mL min

d) Mineral quantification

1 g of lyophilized sample (egg, N3, N4 and Ad) was placed in a 50 mL volumetric flask, with 15 mL of 70% nitric acid and 7.5 mL of 94% sulfuric acid (Sigma Aldrich, Toluca, Mexico state). This solution was heated in plate at 100 °C for 5 h until the cessation of orange fumes. Finally, the samples were cooled at room temperature (25 °C), deforesting with deionized water (Solution A). The samples (Solution A) were diluted 1:2, 1:10 and 1: 100 with deionized water to be analyzed by atomic absorption spectroscopy using the flame ionization (AAS-flame) technique. The studied minerals were Na (λ = 589 nm), K (λ = 769.9 nm), Ca (λ = 422.7 nm), Zn (λ = 213.9 nm), Fe) and Cu (λ = 328.8 nm), and high purity reference standards (Sigma-Aldrich, Mexico) were used to compare analyzing according to the equipment manufacturer's recommendations (AAnalyst 700, Perkin-Elmer, USA).

Statistical analysis

For each determination, a minimum size of three replicates (n > 3) was used in all samples. For analysis of results a one-way analysis of variance (ANOVA, $P < 0.05$) was applied using the MiniTab statistical software, version 17 (Minitab Inc., State College, Pennsylvania, USA). Differences between treatments/samples were determined by Tukey test (Walpole et al., 1999).

RESULTS AND DISCUSSION

Proximal chemical analysis

There were significant differences ($P < 0.05$) between the different stages of the insect in the content of proteins, lipids, ashes and carbohydrates, except for the egg stage since its analysis was not carried out due to shortage of sample collected. Table 1, presents these results. It is important to mention that the egg sample would be unlikely to be used as food because of the difficulty of its production.

Regarding to the proximal content and in agreement with other studies performed in insects as *Chondacris rosea, Brachytrupes orientalis*, *Sphenarium magnum*, *Sphenarium borrei*, *Acheta domestica*, *Periplaneta americana* among others, a similar trend has been observed in such proximal determinations; this tendency has been attributed in the case of proteins, lipids and moisture, to the development of the insect through its life cycle (Ramos-Elorduy et al., 2012; Chakravorty et al., 2014). Variations in the proximal lipid and protein content for the different stages of the

Table 1: Proximal analysis of lyophilized grasshopper (*B. magna*) g/100 g[1]

Sample	Proteins	Lipids	Ash	CHO[2]
Egg	Nd	Nd	Nd	Nd
Nymph 3	62.64±0.30^{b}	2.88±0.22^{c}	8.25±0.31^{a}	26.23±0.68^{b}
Nymph 4	62.46±0.48^{b}	3.32±0.19^{b}	6.44±0.08^{b}	27.79±0.89^{a}
Adult	64.70±0.44^{a}	8.24±0.23^{a}	4.76±0.07^{c}	22.30±0.51^{c}

Arithmetic mean of at least three replicates±standard error. Averages with different lowercase letters in the same column show significant differences in Tukey's parametric test ($P \leq 0.05$). [1]Analysis on insect dry basis, [2]CHO=Carbohydrates obtained by difference. Nd=Not determined

insect can be attributed to the development of taxonomic structures rich in lipids during the insect's growth (Chapman et al., 1995; Banjo et al., 2006). According to Mendoza et al. (2009), the variation in the ash content (minerals) in the nymphal stages is due to the fact that in these stages the insects tend to store larger amounts of minerals in their body.

Protein content was relatively higher compared to other insects, even in nymphal instars. The results of the protein content are higher than those reported by Kinyuru et al. (2010) for grasshoppers *Ruspolia differens* (≈ 43 %) but similar to the studies performed by Banjo et al. (2006) in grasshopper *Zonocerus variegatus* (≈ 63.2 %) and to the value reported for the grasshopper *Chondacris rosea* (≈ 68.9 %) (Chakravorty et al., 2014). This latter result is possibly related to the own taxonomic of *Brachystola magna* or because of its diet. National wide, studies have been carried out where high values have been reported in protein content in various species of grasshopper. To mention some, Ramos-Elorduy et al. (2012) analyzed 25 species of grasshoppers, obtaining a variation of 43.9% (for the lowest) up to 77.1% (for the highest), being the grasshoppers one of the insects with the greatest content of proteins. In previous years, this same research group carried out a larger study (considering 78 species) observing a similar tendency (Ramos-Elorduy et al., 1997).

Although it can be seen that there was differences in the proximal content of the results presented in the current research, with those reported in other studies, even in insects of the same order, it is not possible to attribute the cause only to insect habitat and feeding (Ramos-Elorduy et al., 1998; Ramos-Elorduy, 2009; Ramos-Elorduy et al., 2012). Genetic variation could be another variable to consider for the differences found, which are mostly perceptible in carbohydrate content; However, in the case of lipids, the variation between species is not as determinant, since habitat has been reported as the main factor, because at extreme temperatures (which can occur from one region to another) the insect tends to adapt physiologically to preserve its body hydration (Chapman et al., 1995).

There was also observed a tendency to increase the content of proteins and lipids, and to decrease the ash content as the insect developed. The variation in the content of the nutrients mentioned above during the biological cycle of some insects has already been reported in similar studies, for example in bedbugs (*Thasus gigas*) (Mendoza et al., 2009). The results of the high protein content are suggestive that this type of insects can be a potential food source of great value, both for man and for animal feed. This is relevant in terms of human nutrition, as they represent an important protein resource, and could potentially replace animal protein obtained from traditional food sources (such as cattle, sheep, porcine, among others) that are usually absent in the diet of the rural population and in the areas of low economic resources in developing countries (Banjo et al., 2006).

Besides the previous information (high protein content), these results exhibit a moderate carbohydrate content (which most of them are not digestible) and low lipid content, which may reinforce the idea that this type of insects can be recommended to substitute food from animal origin. This would provide an additional benefit (as reported in diets with these characteristics), in terms of reduction of cardiovascular diseases, control of lipid profile, and weight loss due to moderate ketosis (Kappagoda et al., 2004).

Lipidic profile

It is important to mention that the lipidic profile was determined by breaking the glycerol linkages with the fatty acid units by methylation process. This produces methylated fatty acids for further analysis, to avoid the losses caused by exposure to light and/or oxygen. The fatty acid composition presented significant differences ($P < 0.05$) for the different stages of life or development of the insect (Table 2). At the egg sample, decanoic and lauric fatty acids were present, which were not found in samples

Table 2: Determination of fatty acids in grasshopper (*B. magna*) samples[1]

Fatty acid	Sample			
	Egg	Nymph 3	Nymph 4	Adult
Decanoic	0.040±0.006[a]	Nd	Nd	Nd
Lauric	0.048±0.001[a]	Nd	Nd	Nd
Tetradecanoic	0.274±0.007[b]	0.217±0.002[d]	0.316±0.009[a]	0.233±0.003[c]
Palmitoleic	0.183±0.005[a]	0.133±0.001[b]	0.136±0.001[b]	0.135±0.002[b]
Oleic	5.435±0.076[a]	0.337±0.012[c]	0.880±0.101[b]	0.319±0.015[c]
Arachidonic	0.048±0.000[c]	0.038±0.000[d]	0.127±0.003[a]	0.092±0.013[b]
Docosanoic	0.039±0.001[a]	0.025±0.001[b]	0.035±0.003[a]	0.025±0.000[b]
Erucanoic	0.008±0.002[a]	Nd	0.011±0.001	Nd

Arithmetic mean of at least three determinations±standard error. Averages with different letters in the same row show significant differences in Tukey's parametric test ($P \leq 0.05$). [1]Value obtained based on the percentage of g/100 g of the lipids extracted from the dry matter. Nd=not detected.

from the other stages of the insect. Also, the erucanoic acid was only observed in the samples corresponding to the stages of egg and nymph 4.

In general, the lipid composition of the insect indicated that the unsaturated fatty acids present in the samples were hydrocarbon structures of eighteen units with one, two and three double bonds, oleic, linoleic and linolenic respectively (Chapman et al., 1995; Barker et al., 1998; Banjo et al., 2006; Golębiowski et al., 2007; Fontaneto et al., 2011; Chakravorty et al., 2014). Insects, as has been reported in some studies, were being recognized for their high content of unsaturated fatty acids, especially polyunsaturated, such as oleic, linoleic and linolenic; they may be potential substitutes for vegetable oils, as was observed in the study carried out by Longvah et al. (2012), where they analyzed the content of α-linoleic in the insect of the silkworm *Bombyx mori* and found a higher content of it, whereas the traditional oil of sunflower did not present it.

Several studies have reported that the content of unsaturated fatty acids is high in insects *Blissus leucopterus leucopterus* y *B. iowensis*; regardless of whether they are aquatic or terrestrial, especially in those of 16 and 18 carbons, these being palmitoleic, oleic, linoleic and linolenic acid (C16:1; C18:1; C18:2 y C18:3, respectively) (Spike et al., 1991; Fontaneto et al., 2011). Although insects are an important source of fatty acids, which has been found that among them (especially in insects of different order) there is particularity in the presence of some of them; however, the most predominant (in relation to their chemical composition) are the two homologous series of the saturated (C14:0; C16:0 and C18:0) and long chain unsaturated (C16:1 y C18:1) among others (Golębiowski et al., 2007; Raksakantong et al., 2010; Fontaneto et al., 2011). In spec ies of the *Orthoptera* order, there are also differences in the content of these compounds in the distribution and presence of some fatty acids; however, the trend in distribution is similar for all cases, with only variations in the quantities (Raksakantong et al., 2010; Chakravorty et al., 2014).

The results obtained in the analysis of fatty acids present in *Brachystola magna* and in the values reported for other species of the same insect´s order, such as those obtained in the grasshoppers *Chondacris rosea* (Chakravorty et al., 2014), *Chondracris roseapbrunner* (Yang et al., 2006), *Ruspolia differens* (Kinyuru et al., 2010), have shown that they can contribute great health benefits because of their high content of polyunsaturated compounds, since it has been found that the intake of them may reduce the risk of cardiovascular diseases (Ferrucci et al., 2006). For this reason, it is important to consider that this type of insects can be an alternative source for human consumption and as such, need to be promoted for their daily intake, especially in areas with high rates of cardiovascular diseases.

Minerals quantification

Mineral content (K^{+1}, Ca^{+2}, Mg^{+2}, Fe^{+3}, Cu^{+2}, Zn^{+2} y Na^{+1}) evidenced significant differences ($P < 0.05$) during the different life cycles of the grasshoppers (Table 3). In the egg sample, a smaller quantity was observed as compared with the nymph 3, nymph 4 and adult stages (in the majority of the determined minerals), showing to be significantly smaller ($P<0.05$) with the exception of Cu^{+2}, which proved to be greater. There were significant differences ($P<0.05$) in the results of the minerals Zn^{+2}, Na^{+1} and Mg^{+2} at different nymphal stages, except for the mineral Mg^{+2}, in which there was no significant difference ($P > 0.05$) between nymph instars egg, nymph 3 and nymph 4. These results indicated that the amount of mineral Mg^{+2} present in the adult of grasshopper was significantly higher ($P < 0.05$) as compared with the other stages of development.

It is important to mention that in addition to the large amount of the mineral Ca^{+2}, in the adult of grasshopper, which was also determined a greater quantity of two minerals (Mg^{+2} y K^{+1}). In particular it could be inferred that three (Ca^{+2}, Mg^{+2} y K^{+1}) of the seven minerals determined were found in greater proportion, which was similar to the behavior shown in other samples of insects of the same order in their adult stage, such as those analyzed by Chakravorty et al. (2014). These researchers analyzed two insects of the order *Orthoptera* (the grasshopper *Chondacris rosea* and the cricket *Brachytrupes orientalis*). Compared with

Table 3: Content of mineral elements in *B. magna* at different stages (mg/100 g)[1]

Minerals	Egg	Nymph 3	Nymph 4	Adult
Fe+3	2.68±0.68^{b}	44.64±12.75^{a}	22.07±9.00^{ab}	20.07±9.34^{ab}
Cu+2	6.96±2.91^{a}	3.80±0.78^{b}	1.45±0.31^{b}	2.33±0.30^{b}
Zn+2	8.11±0.01^{b}	9.30±0.01^{a}	6.90±0.00^{d}	7.11±0.00^{c}
Na+1	33.29±0.00^{d}	48.07±0.02^{a}	34.99±0.01^{c}	41.37±0.01^{b}
Ca+2	37.25±5.45^{b}	117.00±13.50^{b}	115.05±10.25^{b}	142.55±14.85^{a}
Mg+2	87.75±0.05^{b}	147.00±0.06^{b}	157.75±0.11^{b}	237.00±0.12^{a}
K+1	264.00±51.50^{b}	1533.50±12.50^{a}	1495.00±14.50^{b}	1200.50±11.50^{b}

Arithmetic mean of at least three determinations±standard error. Values with different letters in the same row show significant differences in the Tukeyx's parametric test ($P \leq 0.05$). [1]Values obtained in dry extract.

previous studies, the results showed a higher content of K^{+1} y Mg^{+2}, followed byFe^{+3} in the *B. magna* (Fig. 1).

Chapman et al. (1995) determined that insect feed did not significantly modify their lipid composition; however, for the mineral content was the opposite side, since it has been reported that insects tend to store minerals from the tissues they consumed, especially in their nymphal stages (Mendoza et al., 2009). Therefore, the content of each mineral found in the sample depends to a great extent on the type and quantity of food that the insect has consumed. According to data published by the USDA (2015), the mineral composition of pinto bean (*Phaseolus vulgaris*) L. (Fabales: Fabaceae) was high (in the raw state) and it was estimated to vary in the following amounts 100 g) for Ca: 113 mg, Mg: 176 mg, K: 1393 mg; having relatively low Fe content: 5 mg, Na: 12 mg, Zn: 2 mg. This justifies the high contents of these minerals present in *B. magna*, since despite being polyphagous, this insect has preference for this crop, so it is also known as "chapulín frijolero" (Mena-Covarrubias, 2009). A relevant fact that agrees with that published by Mendoza et al. (2009), is that until the insect begins to accumulate the minerals product of its ingestion, these later do not increase, which is congruent with the results found in the present study for the grasshopper. Therefore, a smaller difference was observed in the content of the minerals K^{+1}, Mg^{+2}, Ca^{+3} y Fe^{+3} of the egg compared to other stages.

CONCLUSIONS

In the adult stage values of ≈ 65 and 8% were quantified for proteins and lipids, respectively and they were different from the other stages. The results of fatty acids and minerals indicated a high content of unsaturated fatty acids of eighteen carbons (especially oleic), and minerals like K^{+1}, Mg^{+2} and Ca^{+2} and relatively low in Na^{+1}. In general, nutritional results suggested that *Brachystola magna* (Girard) could be a potential source of consumption for people with specific needs (people with cardiovascular problems or high protein requirements, such as caloric-protein malnutrition and bodybuilding).

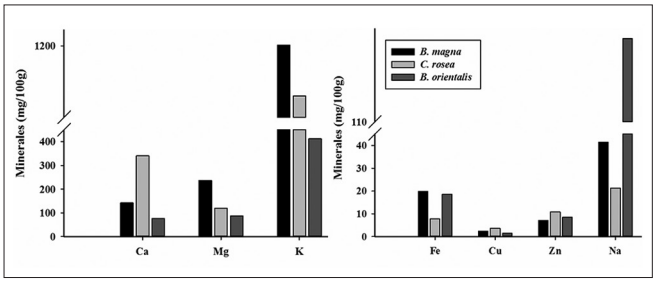

Fig 1. Comparison of the content of quantified minerals in *B. magna* (in this study) and those reported for other species of the order *Orthoptera* (*C. rosea y B. orientalis*) published by Chakravorty et al. (2014).

ACKNOWLEDGMENTS

The first author (J.G. Monter-Miranda) is grateful for the scholarship granted by the National Council of Science and Technology (CONACYT), the scholarship of the Center for Research in Food and Development (CIAD, A.C.) and the working group formed to obtain the samples. The present study is a product of the Carbohydrate, Packaging and Functional Foods Research Group (CEAF) of CIAD-Cuauhtémoc.

Authors contributions

J.G. Monter-Miranda execution of experimental work, interpretation results, and also contributed to the writing of the manuscript. P.B. Zamudio-Flores (the corresponding author) designed the research plan, organized the study, coordinated the data analysis, and contributed to the writing of the manuscript. F.J. Molina-Corral and E. Ochoa-Reyes participated in the experiments. J.M. Tirado-Gallegos and C. Rios-Velasco participated in the experimental design. H. Y. López de la Peña, F. Hernández-Centeno and M. Hernández-González performed some analysis and contributed in the translation of the manuscript.

REFERENCES

Antonatos, S., N. Emmanouel, A. Fantinou, A. Tsagkarakis, A. Anagnostopoulos and D. Ntampakis. 2014. Seasonal population fluctuation and spatial distribution of Orthoptera in two grassland areas of Attica-Greece. J. Nat. Hist.48: 661-674.

AOAC. 2002. Official Methods of Analysis. 17th ed. Association of Official Analytical Chemist, Gaithersburg, MA, EUA.

Banjo, A., O. Lawal and E. Songonuga. 2006. The nutritional value of fourteen species of edible insects in southwestern Nigeria. Afr. J. Biotechnol.5: 298-301.

Barker, D., M. P. Fitzpatrick and E. S. Dierenfeld. 1998. Nutrient composition of selected whole invertebrates. Zool. Biol.17: 123-134.

Bligh, E. G. and W. J. Dyer. 1959. A rapid method of total lipid extraction and purification. Can. J. Biochem. Physiol.37: 911-917.

Chakravorty, J., S. Ghosh, C. Jung and V. B. Meyer-Rochow. 2014. Nutritional composition of Chondacris rosea and *Brachytrupes orientalis* : Two common insects used as food by tribes of Arunachal Pradesh, India. J. Asia Pac. Entomol.17: 407-415.

Chapman, R. F., K. E. Espelie and G. A. Sword. 1995. Use of cuticular lipids in grasshopper taxonomy: A study of variation in *Schistocerca shoshone* (Thomas). Biochem. Syst. Ecol.23: 383-398.

Erdogan, S. and M. Kaya. 2016. High similarity in physicochemical properties of chitin and chitosan from nymphs and adults of a grasshopper. Int. J. Biol. Macromol.89: 118-126.

Ferrucci, L., A. Cherubini, S. Bandinelli, B. Bartali, A. Corsi, F. Lauretani, A. Martin, C. Andres-Lacueva, U. Senin and J. M. Guralnik. 2006. Relationship of plasma polyunsaturated fatty acids to circulating inflammatory markers. J. Clin. Endocrinol. Metab.91: 439-446.

Fontaneto, D., M. Tommaseo-Ponzetta, C. Galli, P. Risé, R. H. Glew

and M. G. Paoletti. 2011. Differences in fatty acid composition between aquatic and terrestrial insects used as food in human nutrition. Ecol. Food Nutr.50: 351-367.

García-Gutiérrez, C. and M. González-Maldonado. 2009. Control biológico de la plaga del chapulín (*Orthoptera: Acrididae*) en Durango, México. Vedalia.13: 79-83.

Gołębiowski, M., E. Maliński, J. Nawrot, J. Szafranek and P. Stepnowski. 2007. Identification of the cuticular lipid composition of the Western Flower Thrips *Frankliniella occidentalis*. Comp. Biochem. Physiol. B Biochem. Mol. Biol.147: 288-292.

Kappagoda, C. T., D. A. Hyson and E. A. Amsterdam. 2004. Low-carbohydrate-high-protein diets: Is there a place for them in clinical cardiology? J. Am. Coll. Cardiol.43: 725-730.

Kinyuru, J., G. Kenji, S. Muhoho and M. Ayieko. 2010. Nutritional potential of longhorn grasshopper (*Ruspolia differens*) consumed in Siaya District, Kenya. J. Agric. Sci. Tech.12: 32-46.

Longvah, T., K. Manghtya and S. S. Y. H. Qadri. 2012. Eri silkworm: A source of edible oil with a high content of α-linolenic acid and of significant nutritional value. J. Sci. Food Agric.92: 1988-1993.

Melo Ruiz, V., H. Sandoval-Trujillo, T. Quirino-Barreda, K. Sánchez-Herrera, R. Díaz-García and C. Calvo-Carrillo. 2015. Chemical composition and amino acids content of five species of edible Grasshoppers from Mexico. Emir. J. Food Agric.27: 654-658.

Mena-Covarrubias, J. 2009. Control biológico del chapulín *Brachystola* spp.(*Orthoptera: Acrididae*) con el uso del protozoario *Nosema locustae* Canning (*Microsporidia: Nosematidae*) en Zacatecas, México. Vedalia.13: 97-102.

Mendoza, M. N., L. A. Quintero, V. N. Guemes, S. S. Soto, H. G. Lopez, S. Reyes and I. Ma. 2009. Utilización de" xamui: (*Thasus gigas*) en la Lelaboración y Conservación de Una Salsa Tradicional en el Valle del Mezquital. Paper Presented at the VII Congreso Iberoamericano de Ingenieria de Alimentos CIBIA Bogotá, Colombia, Bogotá, Colombia.

Monter-Miranda, J. G., J. M. Tirado-Gallegos, P. B. Zamudio-Flores, C. Rios-Velasco, J. D. J. Ornelas-Paz, R. Salgado-Delgado, V. Espinosa-Solis and F. Hernández-Centeno. 2016. Extracción y caracterización de propiedades fisicoquímicas, morfológicas y estructurales de quitina y quitosano de *Brachystola magna* (Girard). Rev. Mex. Ing. Quim.15.

Premalatha, M., T. Abbasi, T. Abbasi and S. A. Abbasi. 2011. Energy-efficient food production to reduce global warming and ecodegradation: The use of edible insects. Renew. Sus.t Energ. Rev.15: 4357-4360.

Raksakantong, P., N. Meeso, J. Kubola and S. Siriamornpun. 2010. Fatty acids and proximate composition of eight Thai edible terricolous insects. Food Res. Int.43: 350-355.

Ramos-Elorduy, J. 2009. Anthropo-entomophagy: Cultures, evolution and sustainability. Entomol. Res.39: 271-288.

Ramos-Elorduy, J., J. M. Pino and S. C. Correa. 1998. Insectos comestibles del Estado de México y determinación de su valor nutritivo. Anales Inst. Biol. Univ. Nac. Autón. México Ser. Zool.69: 65-104.

Ramos-Elorduy, J., M. J. M. Pino and V. H. M. Camacho. 2012. Could grasshoppers be a nutritive meal? Food Nutr. Sci.3: 164.

Ramos-Elorduy, J., M. J. M. Pino, E. E. Prado, M. A. Perez, J. L. Otero and O. L. de Guevara. 1997. Nutritional value of edible insects from the state of Oaxaca, Mexico. J. Food Compost. Anal.10: 142-157.

Rios-Velasco, C., D. I. Berlanga-Reyes, C. H. Acosta-Muñiz, A. Romo-Chacón, P. B. Zamudio-Flores, D. R. Sepúlveda-Ahumada and J. L. Jacobo Cuellar. 2014. Caracterización y control microbial del chapulín gordinflón *Brachystola magna* Girard en frijol en el estado de Chihuahua. Available from: http://www.siproduce.sifupro.org.mx/seguimiento/archivero/8/2013/anuales/anu_499-25-2014-05-4.pdf. [Last accessed on 2017 Feb 15].

Rumpold, B. A. and Schlüter, O. K. 2013. Nutritional composition and safety aspects of edible insects. Mol. Nutr. Food Res. 57: 802-823.

Spike, B. P., R. J. Wright, S. D. Danielson and D. W. Stanley-Samuelson. 1991. The fatty acid compositions of phospholipids and triacylglycerols from two chinch bug *species Blissus leucopterus leucopterus* and *B. iowensis* (*Insecta: Hemiptera; Lygaeidae*) are similar to the characteristic dipteran pattern. Comp. Biochem. Physiol. B.99: 799-802.

Uribe-González, E. and M. Á. Santiago-Basilio. 2012. Contribución al conocimiento de enemigos naturales del chapulín (*Orthoptera: Acridoidea*) en el estado de Querétaro, México. Acta Zool. Mex. (n.s.).28: 133-144.

USDA. 2015. Basic Report 16042 Beans pinto mature seeds raw. Available from: http://www.ndb.nal.usda.gov/ndb/foods/show/4781?manu=&fgcd=. [Last accessed on 2017 Jul 10].

Walpole, E. R., H. R. Myers and L. S. Myers. 1999. Probabilidad y Estadística Para Ingenieros. 6th ed. Prentice-Hall Hispanoamericana, Mexico.

Yang, L. F., S. Siriamornpun and D. U. O. Li. 2006. Polyunsaturated fatty acid content of edible insects in Thailand. J. Food Lipids13: 277-285.