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Could Grasshoppers Be a Nutritive Meal?

Julieta Ramos-Elorduy Blásquez*, José Manuel Pino Moreno, Víctor Hugo Martínez Camacho

Instituto de Biología, Departamento de Zoología, Universidad Nacional Autónoma de México, Ciudad de México, México.
Email: *relorduy@ibunam2.ibiologia.unam.mx

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ABSTRACT

The nutritive value of 25 edible Orthoptera in Mexico is shown. Protein content ranges from 43.93% to 77.13% (mix of Edible Acrididade of Puebla). Fat percentage goes from 4.22% to 34.21%. Richest species in ashes were *Arphia fallax* S., *Sphenarium histrio* G. and *Sphenarium purpurascens* Ch. with 16.5%. Energy contribution varies from 14.05 kJ to 21.88 kJ. Their amino acids profile was compared with the WHO/FAO/UNU Pattern (1985). The total quantity of essential amino acids that all insects species provides was superior to those signaled in the pattern. The highest quantity (53.60 g) was for Sphenarium histrio G. Chemical score goes from 50% to 88%. In vitamins, the highest value in Thiamine and Riboflavine was for *Sphenarium magnum* M., in Niacine for S*phenarium borrei* B., in vitamin C and for vitamin D *Acheta domestica* L., and in Vitamin A for *Periplaneta americana* L. In minerals, all species were very rich in magnesium. All the edible orthopterans results were compared with those of the most conventional mexican foods used to obtain proteins. The quantity and quality of the nutrients that these edible orthopterans allows, provides a significant contribution to the nutrition of the peasants who eat them.

Keywords: Edible; Orthoptera; Nutritive; Value; Mexico; Proteins; Fats; Energy

1. Introduction

Among the alternative food that exists, are the grasshoppers. They have a lot of qualities, being primary consumers from ecological point of view, another very important is that even if they are univoltines, constituted a so enormous biomass that people all over the world prepare and eat them [1-4], forward sell or store them, once they are dried.

For this they use different tools and nets of different size, catching by one or various individuals together of variable species and ages. They do that with diverse goals, the main is to use as food, or to give them as gift or as merchandise to sell and/or store, for have something to eat in bad times.

In Mexico the consumption of diverse species of insects by the human beings (Anthropoentomophagy) [5] is an alimentary tradition that still persists [6], such as those of the well-known edible insects, like the white (*Aegiale hesperiaris*) and red (*Comadia redtenbacheri*) agave worms, the "ahuahutle" (eggs of Corixidae and Notonectidae bugs) and "axayacatl" (adults of ahuahutle), of the "jumiles" (*Edessa* sp.), etc., ingested since prehispanic times [7,8]. Most species are ingested in their immature stages (eggs, larvae or pupae) only in a few insects are consumed as adults [9]. In the case of orthopterans all stages are eaten. Frequently, a mix of species is eaten as it happens in the case of many grasshoppers species or the water bugs of the families Corixidae and Notonectidae ("ahuahutle" and "axayacatl") and several wood worms species, because two or three species often coexists together or are sympatric.

For peasants, edible insects are considered as "food to grill" generally prepared on an earthen grill or directly on charcoal. Rural qualified them as clean, savory and tasty little animals [10].

Some edible insects species are marketed in different rural areas, others are selling at a very high price once they are prepared and can as it happens with rice grasshoppers (*Oxya velox* (Fabricius)) in Japan, Thailand, China, Cambodia, Vietnam, etc. or with different grasshopper (*Zonocerus elegans* (Thunberg)), *Dictyophorus spumans* (Thunberg), *Phymateus leprosus* (Fabricius), *P. morbillosus* (Linneo)) in South Africa [9,11,12] and thus, they represent a source of food and money to people of local communities [9,13].

Insects are used as food in many parts of the world; for example in all Central America and Brazil, Equator, Peru, Venezuela, Colombia, also in Canada, United States of America. Moreover in all Asia, Africa or Australia [1-5].

In relation with their nutritive value, several authors have shown that edible insects contains large quantities of proteins of high biological value, [10,14-27], of good

*Corresponding author.

quality [13,20,28-33] and with a high level of digestibility "*in vitro*" and "*in vivo*" [16,34-37] For these reasons insects have been postulated as a source of proteins [15,22,28,38,]. Edible insects also have a great energetic value [17,18,39,40].

Nowadays, we have recorded 547 species of edible insects in México [41], among them: mayflies, dragonflies, grasshoppers, crickets, cockroaches, termites, bugs, cicadas, treehoppers, leafhoppers, Dobsonflies, beetles, caddisflies, butterflies, flies, mosquitoes, bees, bumblebees, wasps and ants.

In the case of the order Orthoptera in Mexico, we have recorded 85 edible species, 54 species belonging to family Acrididae, twelve species of Tettigonidae, 12 species of Blattidae, five species of Gryllidae, three species of Stenopelmatidae and one species of Phasmidae.

We selected several of the most searched and ingested orthopterans (25) species, with wider distributions in the country, to determine their nutritive value and evaluate their contribution to the diet of peasants in different States and ethnos of Mexico and also compare the obtained values with those provided most popular by the Mexican conventional foods, richest in nutrients.

2. Materials and Methods

2.1. Sampling

Insects previously determined as edible, were collected in several States of Mexico. Samples were gathered using entomological nets, tweezers and by hand. Collected material was kept at –40˚C, in flasks with labels identifying place, date and collector, hosts and the common or local (dialect) name.

2.2. Identification

The mounting, labeling, and taxonomic identification of collected species was made according to appropriated keys according to Otte [42,43] and verified by the specialists in this order at the Laboratory of Entomology of Institute of Biology of the National Autonomous University of Mexico (IBUNAM).

All the insects have been deposited in the National Collection of Edible Insects at the IBUNAM.

2.3. Apparati

To determine water and dry matter, a Thelco model 28 oven was used. Proteins were determined with a Construction Company No. 2730 Kjeldahl Laboratory. Fats were extracted with a Soxhlet flask and a Whatmann cartridge; and fat content was determined with a Precision Scientific Company Soxhlet. To determine ash content, we used a Thermolyne type 1500 oven. Crude fiber was determined with a Construction Company 907 Digestor Laboratory and a Thermolyne type 2200 hot plate. Carbohydrates were determinate by difference.

For amino acid determination [33] a Gold Liquid Chromatography HPLC system from Beckmann (San Ramon, CA U.S.A) combined with: (A) a Model 126 programmable solvent module with an Altex 210A injection valve, (B) a Nec PC 8300 Controller System, (C) a model 427 integrator and (D) a model 121 fluorometer from Gilson (excitation filter 360 nm and emission filter 450 nm); an Ultrasphere XL ODS column (3 mm) and guard column (237520) both from Beckmann, were used.

A speed Vac Concentrator from Savant, a Multi-Flame burner from Fisher, a Multi-Block heater (No. 2093) from Lab-Line Instruments, Inc. (Melrose Park, IL U.S.A) and a PHM 84 research pH meter from Radiometer-Copenhagen were also used in the hydrolysis of the samples at the time of preparation. Samples and solvents were filtered through 0.22 mm porous membranes (XX3001200 and GVWP04-700) from Millipore (Milford, MA USA).

The caloric content was measured in an oxygen bomb calorimeter from Parr Instruments Co. Int. [44]. The results were reported in kilocalories.

2.4. Reagents

The following reagents were used in the proximate analysis: sulfuric acid, boric acid, sodium hydroxide, selenium, ether from Baker (J. T. Baker, S. A. de C. V., Xalostoc Mexico); clorhydric acid and hexane from Merck laboratories (Calle 5 No. 7 Fraccionamiento Industrial Alce Blanco, 53,370, Naucalpan de Juárez Estado de México); Phenolphtalein and green bromocresol were from Sigma of Mexico, (Durango 104, Mexico 7 D.F.).

HPLC grade water was prepared by filtering the deionized water through an organic cartridge from Millipore. Methanol (HPLC grade) was obtained from Baker, sodium acetate from Sigma, and O-phthaldehyde (OPA) from Beckmann. The ingredients used were: water 91.5%, potassium hydroxide 2%, potassium borate 5%, methanol 1%, mercaptoethanol 0.3%, OPA 0.1%, and Brij 35 0.1%. The amino acid kit 22 was purchased from Pierce. Certified fish protein CPSP-90 labeled by Cooperative de Traitment des Produits de la Pêche" was used as the standard.

Essential amino acids were determinate with a LKB 4400-001 Amino Acid Analyzer using iodoacetic acid, obtained from Sigma, hydrochloric acid (6 N) from Pierce, and methanesulphonic acid (4 N) from Pierce (Rockford, Illinois 61105 USA).

2.5. Chemical Analysis

All samples were preserved in liquid nitrogen at –40˚C and then dried in an oven at 50˚C for 3 days. The chemical analyses were performed at the Animal Nutrition and Biochemistry Department of the Faculty of Veterinary Medicine and Animal Breeding at the National University Autonomous of Mexico (UNAM) using the techniques of the Association of Official Analytical Chemist [45]. Derminations; were performed for water content (AOAC No. 934.09), fat (AOAC No. 920.39), crude fiber (strucral carbohydrates) (AOAC No. 962.09), mineral salts (AOAC No. 924.05) and nitrogen-free extract (AOAC No. 968.07). Crude proteins were also determined using the Kjeldahl method (AOAC No. 984.05), and the N conversion factor was 6.25.

Water percentage was calculated by drying the sample in an oven Felisa at 50˚C during 48 h. Fat percentage was calculated by drying fats by extraction in a Soxhlet using petroleum ether; mineral salts by calcinations in a furnace; and crude fiber through two digestions, one with sulfuric acid (1.24 N) the other with sodium hydroxide (1.25 N).

Amino acid content was determined at the Amino Acid Analysis Unit of the Biomedical Research Institute of the UNAM, a laboratory certified by the Ministry of Public Health under Authorization No. 29544, using high performance liquid chromatography HPLC (Ladrón de Guevara *et al.*, 1995). The external standard procedure was used to quantify the amino acids. This method was calibrated with certified fish protein. The 95% confidence limits (C. L.) (t = 2.78 based on 5 replicates) were determined in g/100g of each amino acid.

Vitamins

Vitamin determinations were made by the laboratory American Quality S. A. Vitamin A and D were determined by HPLC in normal phase. Other vitamins were analyzed using the procedures of the AOAC (1975), vitamins C (No. 967.21), Thiamine (No. 942.23), Riboflavine (No. 970.65) and Niacine (No. 961.14).

2.6. Minerals

Mineral elements were quantified by atomic absorption using a Pye Unicam spectrophotometer Model SP-192 of Perkin Elmer.

We analyzed some conventional foods in the same way, to can compare their nutritional value.

Results are the mean of three determinations, and the standard deviation is reported.

3. Results and Discussion

The edible Orthoptera species studied are shown in **Table 1**, there are including the species recorded as edible

Table 1. Taxonomy of some edible Orthoptera of Mexico.

Family	Genus	Species	Provinces of consumption	Common name	Consumption stages
Acrididae (Grasshoppers)	*Melanoplus*	*mexicanus* S.	Hidalgo. Oaxaca.	Chapulín migratorio	Larvae and Adults
	Melanoplus	*femurrubrum* D.G.	Veracruz.	Chapulín de patas rojas	Larvae and Adults
	Encoptolophus	*herbaceus* B.	Hidalgo.	Chapulín de la hierba	Larvae and Adults
	Arphia	*fallax* S.	Hidalgo.	Chapulín, Acachapoli	Larvae and Adults
	Boopedon	*flaviventris* S.	Hidalgo, Oaxaca.	Chapulín cola clara	Larvae and Adults
	Sphenarium	spp.	Hidalgo, Puebla.	Grillo saltón	Larvae and Adults
	Sphenarium	*histrio* G.	Oaxaca.	Chapulín del zacate	Larvae and Adults
	Sphenarium	*borrei B.*	Mexico.	Chapoli	Larvae and Adults
	Sphenarium	*purpurascens* Ch.	Oaxaca, Puebla.	Chapulín de la milpa	Larvae and Adults
	Sphenarium	*magnum* M.	Oaxaca.	Chapulín bandera	Adults
	Sphenarium	*mexicanum* S.	Puebla.	Chapulín del maíz	Adults
	Romalea	sp.	Chiapas.	Grillo oscuro	Larvae and Adults
	Romalea	*colorata* S.	Chiapas.	Grillo rojo	Larvae and Adults
	Taeniopoda	*auricornis* W.	Veracruz.	Grillo negro	Larvae and Adults
	Taeniopoda	sp.	Veracruz.	Grillo prieto	Larvae and Adults
	Plectrottetia	*nobilis* W.	Veracruz.	-	Larvae and Adults
	Trimerotropis	sp.	Distrito Federal.	Chapulin-cito	Adults
	Osmilia (*Abracris*)	*flavolineata* D.G.	Chiapas.	Grillo blanco	Larvae and Adults
Tettigonidae (Katydids)	*Idiarthron*	*subquadratum* S. & P.	Chiapas.	Chacuatete	Larvae and Adults
	Conocephalus	*triops* L.	Chiapas.	Esperanza	Adults
Gryllidae (Crickets)	*Acheta*	*domestica* L.	Michoacán.	Grillitos	Larvae
	Brachytrupes	sp.	Sinaloa	Grillo Gordo	Adults
Blattidae (Cockroaches)	*Blaberus*	sp.	Guerrero.	Cucaracha grande	Adults
	Periplaneta	*americana* L.	Guerrero.	Cucaracha oscura	Larvae and Adults
	Periplaneta	*australasiae* F.	Veracruz.	Cucarachita	Larvae and Adults

in Mexico, family, cientific name, place of collection, consumption stage and common name. The samples belong to the families Acrididae, Tettigonidae, Gryllidae and Blattidae.

The chemical primary parameters of some species studied, are shown in **Table 2**. Sometimes, peasants ingested various species together, and they were analyzed and reported as a mixture. We also indicate the developmenttal stages analyzed in each species. Results are expressed in dry weight basis.

Table 2. Chemical proximate analysis and energy of some edible Orthoptera from Mexico (g/100g of dried sample).

Studied species and Consumed Stage	Proteins	Fats	Ashes	Crude fiber	Carbohydrates	kJ
Hidalgo State						
Melanoplus mexicanus S. (L.A.)	58.9 ± 3.4	11.0 ± 1.2	3.94 ± 0.5	10.01 ± 3.0	16.5 ± 2.5	16.31
Encoptolophus herbaceus B. (L.A.)	57.6 ± 1.6	11.8 ± 2.0	2.87 ± 1.0	11.02 ± 2.8	17.22 ± 2.7	16.94
Arphia fallax S. (L.A.)	71.3 ± 1.4	6.52 ± 1.7	2.41 ± 0.0	11.58 ± 2.6	8.11 ± 1.3	16.27
Boopedon flaviventris B. (L.A.)	59.3 ± 0.0	11.0 ± 2.4	2.98 ± 1.1	10.10 ± 1.8	16.59 ± 2.6	16.81
Sphenarium borrei B. (L.A.)	63.7 ± 1.3	10.4 ± 1.9	3.96 ± 0.8	9.81 ± 1.4	12.4 ± 2.0	16.61
Oaxaca State						
Melanoplus mexicanus S. (L.A.) *Boopedon flaviventris* B. (L.A.) *Sphenarium spp*. (L.A.) &,*	77.1 ± 2.8	4.22 ± 0.5	2.44 ± 0.5	12.17 ± 2.8	4.01 ± 0.5	15.14
Arphia fallax S. (A.), *Sphenarium histrio* G. (A.), *Sphenarium purpurascens* Ch. (L.A.) &*	58.3 ± 1.5	7.41 ± 2.0	16.5 ± 1.0	8.64 ± 1.2	9.11 ± 1.4	12.80
Sphenarium magnum M. (A.)	66.5 ± 1. 4	7.37 ± 1.5	1.68 ± 0.9	11.3 ± 2.6	13.10 ± 2.2	16.06
Puebla State						
Sphenarium spp. (L.A.)	67.8 ± 2.1	11.5 ± 2.0	4.87 ± 0.3	10.51 ± 1.1	4.65 ± 0.6	16.44
Sphenarium purpurascens Ch. (A.)	65.2 ± 1.2	10.8 ± 0.7	2.95 ± 0.7	9.41 ± 1.3	11.63 ± 1.9	16.90
Sphenarium mexicanum S. (A.)	62.1 ± 1.5	10.8 ± 1.7	0.34 ± 0.1	4.06 ± 0.5	22.64 ± 2.9	18.24
Chiapas State						
Romalea sp. (L.A.)	75.3 ± 0.8	12.3 ± 2.0	4.25 ± 0.4	9.73 ± 1.3	0.19 ± 0.1	17.23
Romalea colorata S. (L.A.)	72.7 ± 1.4	16.3 ± 0.7	4.64 ± 0.6	6.33 ± 1.5	0.001 ± 0.1	18.28
Idiarthron subquadratum S & P.(L.A.)	65.2 ± 1.1	8.17 ± 1.1	3.79 ± 1.0	11.10 ± 2.5	4.42 ± 0.5	14.68
Veracruz State						
Conocephalus triops L. (A)	71.0 ± 0.6	n.d.	n.d.	n.d	n.d.	n.d.
Taeniopoda auricornis W. (L.A.)	63.0 ± 1.8	10.2 ± 0.9	3.97 ± 0.8	8.34 ± 1.1	14.52 ± 2.3	16.77
Taeniopoda sp. (L.A.)	71.0 ± 2.0	5.85 ± 1.0	2.95 ± 0.9	10.56 ± 1.9	9.59 ± 1.6	15.48
Taeniopoda sp. (L.A.), *P. nobilis* W. (L.A.), *M. Fémur-rubrum* D.G. (L.A.) &	70.9 ± 1.7	6.06 ± 1.7	3.95 ± 0.3	9.56 ± 1.3	9.51 ± 1.6	15.73
Distrito Federal						
Trimerotropis sp. (L.A.)	65.1 ± 2.0	7.02 ± 0.6	3.78 ± 0.0	10.2 ± 3.0	10.20 ± 1.7	15.25
Michoacán State						
Acheta domestica L. (L.)	64.1 ± 1.2	24.0 ± 0.9	3.55 ± 0.9	6.2 ± 1.5	2.12 ± 0.3	20.11
Sinaloa State						
Brachytrupes sp. (A)	61.2 ± 1.1	18.7 ± 0.9	5.05 ± 0.5	7.42 ± 1.0	7.60 ± 0.7	18.54
Guerrero State						
Blaberus sp. (A.)	43.9 ± 1.5	34.2 ± 1.9	3.33 ± 0.6	8.44 ± 1.1	10.09 ± 1.8	21.88
Periplaneta americana L. (L.A.)	65.6 ± 1.9	28.2 ± 2.0	2.48 ± 0.3	3.00 ± 0.9	0.78 ± 0.0	21.70
Periplaneta australasiae F. (L.A.)	62.4 ± 1.6	27.3 ± 1,5	3.00 ± 0.2	4.50 ± 0.7	2.73 ± 0.2	21.17

Source: *[27] values a1ready reported for Oaxaca state. & Mixed species eaten together and analyzed in this way. n.d. = no determined L. = Larvae, A. = Adults.

The protein content ranged from 43.9% to 77.1%. The highest quantity was found in the mix of species *Melanoplus mexicanus* (Saussure), *Boopedon flaviventris* Bruner and *Sphenarium* spp., and the lowest in *Blaberus* sp. The opposite happens in the fat content, with the percentages going from a high of 34.2% in *Blaberus* sp. to the lowest 4.22% in the mixture of *Melanoplus mexicanus* (Sauss.), *Boopedon flaviventris* B. and *Sphenarium* spp. In ashes, the richest insects were the mixture of *Arphia fallax* Saussure, *Sphenarium histrio* Gerstaecker, and *Sph. Purpurascens* Charpentier already bought at Puebla market.

We calculate that 3.44% (one grasshoppers species) has between 40% of protein, 20.08% (six species) among 50% and 60%, 48.27% (14 species) among 60% and 70%, and 27.58 % (eight species) among 70% and 80%.

Values reported of protein percentage in these insects were superior to some mexican conventional foods used as source of protein (beans, lentils), and similar to those of soybean, chicken, eggs and beef; only fish have a higher protein content (**Table 3**).

Energy contribution of edible mexican Orthoptera varies from 14.05 Kilojoules (*Arphia fallax* S., *Sphenarium histrio* G., *Sph. purpurascens* Ch.) to 21.88 Kilojoules in *Blaberus* sp. (**Table 4**).

Table 3. Range of protein content of edible Orthoptera of Mexico compared with some mexican conventional foods (g/100g of dried sample).

Order	*Percentage*
Orthoptera	43.9 ± 1.5 - 77.1 ± 2.8
Conventional foods	**Percentage**
Beans	23.5 ± 1.0
Lentils	26.7 ± 0.8
Soybean	41.1 ± 0.5
Chicken	43.3 ± 0.6
Egg	46.0 ± 1.1
Beef	54.0 ± 0.7
Fish	81.1 ± 0.8

Table 4. Energy supplied by some edible Orthoptera of Mexico compared with conventional foods (cal/1000g)*.

Orthopterans	kJ	Conventional foods
	12.24	Bean
7 *Arphia fallax* S., *Sphenarium histrio* G. *Sph. purpurascens* Ch.	14.05	
	14.22	Lentil
14 *Idiarthron subquadratum* S. & P.	14.68	
6 *Melanoplus mexicanus* S., *Boopedon flaviventris* S., *Sphenarium* spp.	15.14	
19 *Trimerotropis* sp.	15.25	
	15.32	Carrot
17 *Taeniopoda* sp.	15.48	
18 *Taeniopoda sp*. (L.A.), *P. nobilis* W. *M. fémur-rubrum* D.G.	15.73	
8 *Sphenarium magnun* M.	16.08	
3 *Arphia fallax* S.	16.27	
1 *Melanoplus mexicanus* S.	16.31	
9 *Sphenarium* spp.	16.44	
	19.60	Soybean
5 *Sphenarium borrei* B.	16.61	
6 *M. mexicanus* S., *B. flaviventris* S., *Sphenarium spp.*	16.77	
4 *Boopedon flaviventris S.*	16.81	
10 *Sphenarium purpurascens* Ch.	16.90	
2 *Encoptolophus herbaceus* B.	16.94	
12 *Romalea* sp.	17.23	
	17.80	Amaranth
11 *Sphenarium mexicanum S.*	18.24	
13 *Romalea colorata* S.	18.28	
	18.37	Beef
21 *Brachytrupes* sp.	18.54	
	18.74	Fish
20 *Acheta domestica* L.	20.11	
24 *Periplaneta australasiae* F.	21.17	
23 *Periplaneta americana* L.	21.70	
22 *Blaberus* sp.	21.88	

*Modified from [46].

In **Table 5** we compared the total energy supplied by some edible orthopterans with conventional foods, in average the insects are higher that conventional vegetables: verdures, broad, beans, lentils, pea, chick pea, in the cereals: rye, wheat, rice, oats, maize, and the animals: chicken, fish and beef with the exception of the soybean and pork. The amino acid profile of nine studied species is compared with the preschooler and adult requirements indicated by the WHO/FAO/UNU pattern [47]. In the case of values for all essential amino acids given for adults signaled in it for all essential amino acids, each one of insects species provides higher quantities than those of the pattern and with the values given for preschoolers, we can note that *Melanoplus femurrubrum* (De Geer) is slightly deficient in isoleucine.

In leucine, are slightly *Melanoplus femurrubrum* (De Geer), *Periplaneta australasiae* Fabricius, *Periplaneta americana* Linneo and deficient *Taeniopoda auricornis* (Walker).

In lysine all species have shown a very low degree of deficiency, with the exception of *Melanoplus femurrubrum* (De Geer) and *Brachytrupes* sp. The rest of species are generally slightly deficient, some of them showing minimal differences with the standard values, but *Periplaneta americana* Linneo and *Taeniopoda auricornis* (Walker) are deficient.

In threonine are very slightly deficient *Sphenarium purpurascens* Ch. and *Periplaneta australasiae* Fabricius and deficient *Taeniopoda auricornis* (Walker), also in histidine the last one.

In sulfur amino acids *Brachytrupes* sp. have very low degree of deficiency and aromatic amino acids, and in valine, all the species provide enough quantity of them to meet the standard but all species are limitants in tryptophan, nevertheless, all edible insects posses more quantity of total essential amino acids than both patterns (**Table 6**).

The highest percentage of total essential amino acids (53.60) was for *Sphenarium histrio* Gerstaecker and the lowest (35.45) was for *Periplaneta australasiae* Fabricius. Most of species have an adequate nutritional profile of essential amino acids, even though some of them do not reach the highly demanding quantities for preschooler [48] requirements. The insect's protein quality score done by their content in tryptophan ranged from 50% (*Brachytrupes* sp.) to 88.18% in *Melanoplus femurrubrum* (De Geer) (**Table 6**).

The Orthopteran species with the lower values in total content of essential amino acids, even have a bigger proportion of them than beans, lentils, and soybean; and those species with the highest values exceed all vegetal and animals products analyzed (**Table 7**).

In vitamins the highest values are: in thiamine and riboflavine *Sphenarium magnum* M. adults; in niacine *Sphenarium borrei* Bruner adults. In vitamin C and D *Acheta domestica* Linneo larvae and in vitamin A *Periplaneta americana* Linneo larvae, (**Table 8**). In **Table 9** we compare the quantities of vitamins that these insects possess with conventional foods: Orthopteran studied in its highest value presented more thiamine than all other analyzed products with the exception of yeast. Orthopteran species contains more riboflavine than all other analyzed products except liver. When we analyze niacine content, insects have more than milk and eggs. In Vitamin C they have more than only the watermelon. In Vitamin A edible Orthoptera have less than eggs, milk, gourd, spinach, carrot and liver. All the values of the conventional products were taken from [47].

In relation with the total ashes and sodium the mixture of *Sphenarium histrio* G., *Sphenarium purpurascens* Ch. and *Melanoplus femurrubrum* D.G., bought at a Puebla market already cooked and fixed, had the highest values. In potassium, were *Sphenarium magnum* M. and *Sphenarium purpurascens* G. that presented the highest content. With regards to calcium, *Sphenarium* spp. and *Melanoplus mexicanus* S. were the richest. In Zinc was *Sphenarium histrio* G. and the mix of *Sphenarium spp.*, *Arphia fallax* Saussure, *Boopedon af. flaviventris* B., *M. mexicanus* S. and E. herbaceous. In iron, *Sphenarium purpurascens* Ch. and the mixture of *Boopedon af. Flaviventris* B, *Sphenarium borrei* B., and *Melanoplus mexicanus* S. In magnesium, *Boopedon af. flaviventris* B., *Melanoplus mexicanus* S. and *Sphenarium borrei* B. were the highest (**Table 10**). Comparing the mineral proportion supplied by the edible Orthoptera of Mexico, with respect to the values of conventional foods, we can see that insects have more sodium than all foods analyzed, with the exception of wheat in their low value. Potassium content in edible Orthoptera was superior to all of them

Table 5. Energy supplied by some edible Orthoptera of Mexico compared with conventional foods (cal./1000g)*.

Order			*kJ*
Orthoptera		3319.3 - 5239.7	
Conventional Foods			
Vegetables		**Cereals**	
Verdures	1506.2	Rye	1397.5
Broad bean	1624.2	Wheat	1397.5
Beans	1637.4	Rice	1510.4
Lentils	1644.4	Oats	1523.0
Pea	1673.2	Maize	1548.1
Chick-pea	1763.9	**Animals**	
Soybean	1944.7	Chicken	688.7
		Fish	1662.3
		Beef	1735.9
		Pork	2948.5

*Modified from [46].

Table 6. Amino acid content of some edible Orthoptera from Mexico (g/100g of protein).

Species, Analized	*Sphenarium histrio* G.+	*Sphenarium purpurascens* Ch.+	*Boopedon flaviventris* S.+ S.+ S.+ S.++.	*Taeniopoda auricornis.* W.	*Melanoplus femur-rubrum.* D.G.	*Acheta Domestica* L.	*Brachytrupes* sp.	*Periplaneta australasiae* F.F.	*Periplaneta americana* L.	WHO/FAO /UNU 1985.	
Stage	L.A.	L.A.	L.A.	L.A.	L.A.	L.	A.	L.A.	L.A	P.A.	
Essential aminoacids											
Isoleucine	5.3	4.2	4.7	4.12	2.64	4.2	2.71	2.87	3.1	2.8	1.3
Leucine	8.7	8.9	8.8	4.25	5.82	7.3	6.14	5.68	5.6	6.6	1.9
Lysine	5.7	5.7	5.5	4.15	6.17	5.6	5.98	5.60	4.0	5.8	1.6
Methionine	2.0	2.5	1.8	1.89	2.98	1.5	0.79	2.36	3.6		
Cysteine	1.3	1.8	2.0	1.07	1.16	2.1	1.40	0.32	2.0		
Total sulphur a.a.*	**3.3**	**4.3**	**3.8**	**2.96**	**4.14**	**3.6**	**2.31**	**2.68**	**5.6**	**2.7**	**1.7**
Phenylalanine	11.7	10.3	4.1	5.12	2.25	3.3	2.41	3.02	3.1		
Tyrosine	7.3	6.3	7.4	7.64	5.64	4.1	9.28	5.55	6.9		
Total aromatic a.a.**	**19.0**	**16.6**	**11.5**	**12.8**	**7.89**	**7.4**	**11.7**	**7.57**	**10.0**	**7.4**	**2.4**
Threonine	4.0	3.1	4.4	2.06	3.70	3.5	3.86	3.32	3.6	3.4	0.9
Tryptophan	0.6	0.7	0.6	0.58	0.64	0.6	0.55	0.60	0.6	1.1	0.5
Valine	5.1	5.7	5.7	4.90	4.09	6.0	4.04	4.26	6.5	3.5	1.3
Histidine	1.9	2.2	2.4	1.48	2.31	2.1	2.08	1.87	2.0	1.9	1.6
Total essential a.a.	**53.6**	**51.3**	**47.4**	**37.3**	**37.4**	**40.3**	**39.4**	**35.4**	**40.9**	**35.2**	**13.2**
No essential a.a.											
Aspartic acid	9.3	8.7	8.8	5.57	4.24	9.0	4.77	4.37	8.8		
Serine	5.1	4.8	4.3	3.29	2.94	4.9	3.85	3.88	4.5		
Glutamic acid	5.3	10.7	15.4	6.83	6.26	8.0	7.31	6.93	13.0		
Proline	7.2	6.2	6.8	n.d.	2.66	6.7	n.d.	n.d.	6.5		
Glycine	5.3	6.8	7.5	3.06	n.d.	6.0	5.09	4.63	7.1		
Alanine	7.6	6.4	5.9	5.95	n.d.	7.0	6.20	5.22	6.1		
Arginine	6.6	6.0	4.3	3.59	3.21	6.3	3.11	3.20	5.1		
Protein quality score	**55.0**	**64.0**	**55.0**	**64.4**	**88.18**	**55.0**	**50.0**	**86.0**	**68.90**		

*Methionine + cysteine, **Phenylalanine + tyrosine, a.a. = amino acids; + = Oaxaca [27]. L. = Larvae, A. = Adults; P. = Preschooler, A.= Adults n.d. = not determined, Protein quality score is given according to the values standard of WHO/FAO/UNU 1985.

Table 7. Total content of essential amino acids of some edible Orthoptera of Mexico compared with conventional foods (g/100g of protein).

Order	Values
Orthoptera	35.4 to 53.6
Conventional foods	**Values**
Vegetables	
Beans	6.30
Lentils	13.2
Soybean	22.4
Animals	
Fish	40.1
Chicken	42.7
Beef	46.8
Egg	51.5

in their highest value, with the exception of beans. Calcium content in Orthoptera is higher than many products except wheat, maize and beans. In zinc content insects had more than any conventional foods analyzed. With respect to the allowed iron, the vegetables: wheat, barley, oats, soybean and beans provide more quantity than the Orthopteran species. In magnesium the insects species presented the highest values than any conventional foods with the exception of the wheat in the lowest value of orthopterans (**Table 11**).

4. Conclusion

We can conclude that Orthoptera species have a high nutritive value specially those belonging to the family Acrididae that generally allows higher content of the different parameters studied; and also, were the most utilized by people, improving significatively the peasants diet,

Table 8. Content of vitamins A, C, D, B1, B2 and B6 in some edible Orthoptera of Mexico.

Species & Stage of Development	*A Retinol* (*equivs*)	*C Ascorbic Ac.* (mg/l00g.)	*D Calciferol* (μg /100g)	B1 *Thiamine* (mg/l00g.)	B2 *Ribof1avin* (mg/l00g.)	B6 *Niacine* (mg/l00g.)
Sphenarium borrei B. (A.)			4.12	0.50	0.66	5.04
Sph. purpurascens Ch. (A.)				0.27	0.59	1.56
Sph. magnum M. (A.)				0.83	1.28	3.97
Acheta domestica L. (L.)	0.07	25.5	21.3			
A. domestica L. (A.)	0.03	23.9				
Periplaneta americana L. (A.)	2.90	23.8	9.67			
P. americana L. (L.)	16.0	23.8				

A. = Adult, L. = Larvae Equivs = equivalents.

Table 9. Range of vitamins content of some edible Orthoptera of Mexico compared with conventional foods.

Vitamin/Order	Quantity	Conventional Foods*	Quantity*
Thiamine			
Orthoptera	0.27 to 0.87 mg/100g	Rice	0.44
		Wheat of Germ	0.47
		Lean ham	0.58
		Pork	0.75
		Sunflower seed	0.82
		Yeast	1.25
Riboflavine			
Orthoptera	0.59 to 1.28 mg/100g	Trout or chicken	0.19
		Hamburger	0.22
		Pork	0.24
		Egg	0.26
		Yeast	0.34
		Milk	0.05
		Liver	3.52
Niacine			
Orthoptera	1.56 to 3.97 mg/100g	Egg	0.70
		Milk	2.50
		Maize	5.00
		Meat	24.7
Vitamin C			
Orthoptera	23.8 to 25..5 mg/100g	Watermelon	22.0
		Papaya fruit	46.0
		Broccoli	56.4
		Tomato juice	57.0
		Strawberry	60.0
		Orange	62.0
Vitamin A			
Orthoptera	0.03 - 16.0 retinol equivalents	Egg	97.0
		Milk	140.0
		Gourd	857.0
		Spinach	875.0
		Carrot	2025.0
		Liver	9011.0
Vitamin D			
Orthoptera	4.12 - 21.3 μg/100gs		

*[48].

Table 10. Content of several minerals in some edible Orthoptera from Mexico + (g/100g).

Species	Total ashes	Na	K	Ca	Zn	Fe	Mg
S. spp., *A. fallax* S., *B. af flaviventris* S., *M. mexicanus* S., *E. herbaceus* B. (L.A.)*	2.40	0.109	0.044	0.051	0.060	0.028	0.728
S. histrio G. (L.A.)	4.79	0.426	0.422	0.096	0.021	0.023	0.744
S. histrio G. (A.), *S. purpurascens* Ch. (L. A.), *M. femurrubrum* D. G. (L.A.)*	8.33	7.05	0.250	0.115	0.017	0.016	0.354
S. magnum M. (A.)	1.68	0.102	0.574	0.088	0.032	0.020	0.352
S. histrio G. (A.)	2.34	1.142	0.177	0.082	0.078	0.016	0.420
S. purpurascens Ch. (A.)	2.14	0.609	0.377	0.112	0.042	0.018	0.424
S. spp. (L.A.)	5.56	0.915	0.068	0.120	0.032	0.044	0.824
A. fallax S. (L.A.)	2.41	0.092	0.062	0.075	0.016	0.022	0.657
B. af. *flaviventris* S., *S. borrei* B., *M. mexicanus* S. (L.A.)*	2.49	0.066	0.062	0.112	0.024	0.038	0.943
B. sp. af. *flaviventris* S. (L.A.)	2.41	0.173	0.066	0.088	0.032	0.024	0.521
M.mexicanus S. (L.A.)	2.14	0.110	0.062	0.120	0.017	0.032	0.740
E. herbaceus B. (L.A.)	2.41	0.150	0.065	0.064	0.016	0.017	0.498
Os (*Abracris*) *flavolineata* D.G. (L.A.)	1.83	0.173	0.065	0.080	0.024	0.019	0.672
Oc. cer. Salinus B. (L.A.)	0.91	0.066	0.062	0.064	0.026	0.027	0.532

*analyzed species were a1ready fixed and bought at market. L. = Larvae, A. = Adult. S. = Sphenarium; *A.* = Arphia, *B.* = Boopedon, *M.* = Melanoplus, *E.* = Encoptolophus, *Os* = Osmilia, *Oc.* = Ochrottetix.

Table 11. Mineral content of edible Orthoptera of Mexico compared with conventional foods* (g/100g).

	Total minerals	Na	K	Ca	Zn	Fe	Mg
Orthoptera	0.34 - 5.05	0.07 - 7.05	0.04 - 0.57	0.05 - 0.12	0.01 - 0.08	0.01 - 0.04	0.35 - 0.94
Vegetables							
Wheat		0.57	0.27	0.15	0.00	0.05	0.36
Barley		0.00	0.16	0.02	0.00	0.05	0.16
Oat				0.10		0.38	0.14
Maize				0.62	0.00	0.023	0.12
Soybean		0.00	0.16		0.00	0.08	0.28
Beans		0.02	1.52	0.16	0.00	0.08	0.18
Carrot		0.05	0.34		0.00		0.02
Banana		0.00	0.37			0.00	0.03
Animals							
Beef		0.06	0.37	0.01	0.00	0.03	0.02
Chicken		0.09	0.32	0.02		0.01	0.02
Fish		0.10	0.25	0.01	0.00	0.03	0.02
Milk				0.12	0.00	0.00	0.01
Egg				0.05	0.00	0.00	0.01

*Modified from [49].

because as it was shown, they generally provide more quantity of the studied nutriments.

Consumption parameters vary depending on the species, ecosystems, season, abundance, weather, habitat and ethnos. Involved Orthopterans are gathered in the field and eaten daily as larvae or adults during the period of their presence or ingested the stored samples already dried in an oven earth, cooking them done or mixed with other meals roasted, fried, simply dried, or incorporated into a special dish. Most of species of the family Acrididae are stored and/or commercialized in different localities of the studied states of Mexico and even in the capital of the country.

In Oaxaca, Puebla, Tlaxcala and Hidalgo States grasshoppers are sold in the local markets and represent an important source of money for collectors, middlemen, salesmen and restaurants, there is one Mexican enterprise than can them already fixe. They are also sold canned in other countries (France, USA, and Japan) [11,50,51]. Van der Waal [12] affirms that in South Africa the sale of grasshoppers is a millionaire business. Because of their biologic, nutritional, economical and for the great demand they have, and because also generally they are easy to cultivate, it is important to do additional research about these edible insects, as well as new methods of a gathering efficiently, production, food technology processing and marketing.

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Proposed Referees

Eraldo Medeiros Costa Neto

Departamento de Ciências Biológicas
Universidade Estadual de Feira de Santana
Km 03, BR 116 Feira de Santana, Bahia Brasil CEP 44031-460
e-mail: eraldont@hotmail.com

Arnold van Huis

Personal Chair, Professor Tropical Entomology
PhD 1981, Wageningen University
Tel: 31-(0)317-484653
E-mail: arnold.vanhuis@wur.nl

Florence V. Dunkel.

Associate Professor, Ph.D from Univ. of Wisconsin
Office: Room 3 Marsh Lab
Lab: Room 6 Marsh Lab
Office - (406) 994-5065
Fax - (406) 994-7600
E-mail: ueyfd@montana.edu

Andrea Pieroni

University of Gastronomic Sciences
Via Amedeo di Savoia 8
I-12060 Pollenzo/Bra (Cn)
Italy
E-mail: a.pieroni@netcologne.de