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Insects as Food from Deserted Areas in Mexico

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Authors' contributions

This work was carried out in collaboration between all authors. Authors VMR and TQB designed the study, wrote the protocol and wrote the first draft of the manuscript. Authors JJFG and CGU managed the literature searches. Author RDG managed the experimental process. All authors read and approved the final manuscript.

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ABSTRACT

Aims: The aim of this paper is to detect the edible insects from an arid zone of the State of Hidalgo, assess their macronutrient value and deliver that information to the local population.
Place and Duration of Study: Convenience sampling of wild insects were provided at an arid zone of the Hidalgo State, northeast of Actopan city located 2,100 masl with an arid and semiarid climate throughout 2015.
Methodology: Macronutrient content of insects from different order (three species of Lepidoptera, two species of Coleoptera, three species of Hymenoptera, one of Orthoptera and one of Hemiptera) were analyzed according to AOAC (1995) methods [1-3].
Results: Results ranged as follows: proteins from 9.85% to 74.85%; lipids from 5.85% to 55.85%, total ashes from 2.95% to 7.15%; fiber from 0.72% to 6.75% and soluble carbohydrates from 8.87% to 79.16%. Data showed that insects have good nutritional values. Their reproduction is seasonal

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but some species can be found all year long and hence represent good alternative to provide food security.

Conclusion: Wild insects collected in an arid zone of Hidalgo State showed adequate chemical composition values for human diet, with significant levels of proteins, low dietary fiber content, high values of fatty acids essential for nutrition and minerals. These small wild animals are a promising source of food to overcome malnutrition problems faced by poor population and provide food security.

Keywords: Health; nutrition; arid zones; insects as food.

1. INTRODUCTION

A large amount of people in semi desert zones live in poverty due to shortage production of food, hence they do not have adequate foodstuff supply, situation that lead to a high index of malnutrition [4]. A possible action to overcome this problem is anthropoentomophagy, which is the consumption of insects as food that natures provides and they are mostly underutilized [5] despite their high nutritional value. Entomophagy goes back to ancient times, where climate changes resulted into the extinction of huge beasts that provided a plentiful food supply, so big beast hunters became collectors of plants and small animals such as insects, lizards and small rodents [6,7]. Semi desert zone at Hidalgo State (north-east of Actopan, Hidalgo) is not suitable for crops, however, flora of Xerophit Thicket mainly *Opuntia* spp, *Agave* spp, mezquite trees (*Prosopis velutina*) and huizache shrubs (*Acacia farnesiana* L.), are appropriate for the reproduction under critical climate and soil conditions of several species of insects that, even though they are a good source of nutrients that would help to low down malnutrition, are not consumed on regular basis by locals. The semi desert zone located at 2100 meters above sea level (masl) with an arid and semiarid climate (BS kw) was selected due to its insect diversity [8] available for consumption in different metamorphosis stages, such as eggs, larvae or adult, raw or prepared in several presentations. Insects play an important role as nutraceutics in human health [9] but also their commercialization would improve the economic status of local people. The aim of this research is to investigate and study edible insects from an arid zone of Hidalgo state, determine their availability and asses their nutritional value to inform by means of direct communication to the population the health benefits of insect consumption and promote their inclusion in the daily diet of people living in the area investigated.

2. MATERIALS AND METHODS

2.1 Sample Collection

Convenience sampling [10-12] of wild insects were provided at an arid zone of the Hidalgo State, northeast of Actopan city located 2,100 masl with an arid and semiarid climate throughout 2015, region of xerophit thicket (Fig. 1), mainly with maguey (*Agave* spp), nopal (*Opuntia* spp), cactus, mezquite tree (*Prosopis velutina*) and huizache (*Acacia farnesiana* L.) bush vegetation. The area was previously visited to contact locals for assistance on insect collection using a hand sorting method, since capturing these organisms request particular techniques familiar to them. Insect taxonomical identification was done according to other authors [13-15].

Fig. 1. Xerophit thicket

2.2 Determination of Moisture

Moisture content of the sample was determined using the direct drying method. 10 g of each organism were dried in an oven at 60℃ for 24 h. The samples were powdered in a mortar then passed through a 60 mesh. The fine powder obtained this way was used for further analysis.

2.3 Determination of Lipids

Lipid content determination was carried out by the semicontinuous solvent extraction method [1-3] as follows: The sample (10 g) was extracted with 180 mL of petroleum ether on a Soxhlet apparatus (Sigma-Aldrich, México, México) for 10 h. Petroleum ether was removed by evaporation and the lipidic residue was weighed. All samples were analyzed in triplicate and the results are expressed as mean g/100 g dry basis of sample.

2.4 Determination of Protein

Protein content of sample was determined according to the principle of the Kjeldahl method [1-3]. The sample (1 g) was digested with 15 mL of concentrated sulphuric acid using an electrically heated aluminum block digester. The resulting digest was diluted and then alkalinized with 50 mL 40% sodium hydroxide. This was followed by rapid steam distillation of ammonia from the diluted digest into 25 mL of 4% boric acid for manual titration with 0.2N hydrochloric acid. A conversion factor of 6.25 was used to convert the measured nitrogen content to protein content. All samples were analyzed in triplicate and the results are expressed as mean g/100 g dry basis of sample.

2.5 Determination of Soluble Carbohydrate

Total available carbohydrate content of sample was determined by the Clegg-Anthrone method [16]. The sample (1 g) was digested with 13 mL of 52% perchloric acid to hydrolyze disaccharides, trisaccharides and higher oligomers to their component reducing sugars and reacted with anthrone reagent under acidic condition to produce a blue/green color. Anthrone reagent was prepared by dissolving 0.1% (w/v) anthrone in diluted sulphuric acid (sulphuric acid: water 2.3:1.0 ratio, v/v). An aliquot (1 mL) of appropriately diluted hydrolysate was mixed with 5 mL anthrone reagent. Absorbance of the reaction mixture was measured at 630 nm against a blank after incubated in boiling water for 12 min and cooled. All samples were analyzed in triplicate. Glucose (0-100 mg/L) was used to construct a standard curve for quantification and the results are expressed as mean g/100 g dry basis of sample.

2.6 Determination of Total Ashes

Ash content of sample was determined using the dry ashing method. The sample (10 g) was incinerated in a cold muffle furnace set at 650℃ until whitish/greyish ash was obtained. Organic matter was burned off and the inorganic material remained was cooled and weighed. Ash solution for determination of minerals composition was then prepared by dissolving the resulting ash in 100 mL of 1 N hydrochloric acid [17], 50 mL were taken for the determination of sodium, calcium, potassium, iron, copper, zinc, magnesium and manganese contents, by atomic absorption spectroscopy [18] using a Varian SpectrAA-250 Plus apparatus, which was calibrated with a nitric and percloric acid solution and three standards according to the equipment's manual. All samples were analyzed in triplicate. The results are expressed as mean g/100g of sample for ash content, and mg/100 g of sample for each mineral element. Phosphorus was determined by a colorimetric method [3].

2.7 Determination of Crude Fiber Content

Crude fiber was determined by acid digestion followed by alkaline digestion in a Labconco apparatus (Labconco Corporation, Kansas City, Mo, USA) as follows; in 200 mL of sulfuric acid 0.255 N (1.25%) 2 g of dry, lipid-free sample, was boiled in the condensation apparatus. After 30 min, sample was filtered and washed with hot water and added to a 200 mL of sodium hydroxide solution 0.313 N (1.25%), after 30 min, the sample was filtered and washed with 25 mL of hot sulfuric acid and hot water three times. Then, 25 mL of alcohol was added, dried at 130℃ for 2 h, cooled and weighed. Calcination is at 550℃ for 30 min, then cooled and weighed.

3. RESULTS AND DISCUSSION

3.1 Sample Collection

A total of 10 different species of insects were collected (250 g each) (Table 1).

The availability of insects (Table 2) in desert zones may vary depending on environmental conditions [19], or insect harvesting. Regarding "Escamoles" (ant eggs), even though nests provide them only once a year, sometimes they are available at the beginning and at the end of the season.

Regarding nomenclature (Table 3), some common names of insects may change; although scientific names [15] are the same, local names are different in other states.

Table 1. Collected insects

Insect	Season of collection	Place of collection
Escamoles (*Liometopum apiculatum* M.)	Spring	Near maguey *(Agave* spp.), underground nests 1.5 m depth
Maguey white grub (*Aegiale hesperiaris* K.)	Spring	Maguey (*Agave* spp.) leaves
Nopal grub (*Laniifera cyclades* D.)	Spring	Inside nopal's cladodes
Honeypot (*Myrmecosistus melliger* Ll.)	Spring	Underground holes, fastened to the walls
Black wasp (*Polybia parvulina* R.)	Spring	Honeycomb
Xauis (*Pachilis gigas* B.)	Spring	Mesquite tree's branches (*Prosopius velutina*)
Maguey red worm (*Comadia redtembacheri* H.)	Summer	pathways near maguey (*Agave spp.*)
Opuntia grub (*Metamasius spinolae* V.)	Summer	Inside nopal's cladodes
Botija larvae (*Scyphophorus acupunctatus* G.)	Summer	Head roots (mesontete) of maguey (*Agave* spp.).
Grasshoppers (*Sphenarium purpurascens* Ch.)	Autumn	Bushes

Table 2. Availability of insects (2015)

Scientific name	Insect	J	F	M	A	M	J	J	A	S	O	N	D
Laniifera cyclades D.	Nopal grub				A	A	A	A					
Matamasius spinolae V.	Nopal grub						A	A	A	A			
Polybia parrulina R.	Nopal wasp	L	A	A	A	A				A	A	A	A
Aegiale hesperiaris K.	White grub		L	A	A	A							
Cossus redtenbachieri H.	Red grub						L	A	A	A			
Sciphophoros acupuntatus G.	Botija larvae			A	A	A	A	A	A				
Pachilis gigas B.	Forest bug				A	A	A	A					
Liometopum apiculatum M.	Ant eggs		A	A	A	A							
Myrmecosistus melliger Ll.	Honeypot ant		A	A	A	A							
Sphenarium purpurascens Ch.	Grasshoppers					L	A	A	A	A	A	A	A

Month availability A= Abundant, L= Low

Table 3. Nomenclature of sample species

Common name	Order	Family	Genus	Species
Grasshopper	Orthoptera	Acrididae	*Sphenarium*	*purpurascens* Ch.
Forest bug	Hemiptera	Coreidae	*Pachilis*	*gigas* B.
Botija larvae	Coleoptera	Curculionidae	*Sciphophoros*	*acupuntatus* G.
Nopal grub	Coleoptera	Curculionidae	*Matamasius*	*spinolae* V.
Maguey white grub	Lepidoptera	Megatimidae	*Aegiale*	*hesperiaris* K.
Maguey red grub	Lepidoptera	Cossidae	*Cossus*	*redtenbachieri* H.
Nopal grub	Lepidoptera	Pyralidae	*Laniifera*	*cyclades* D.
Black wasp	Hymenoptera	Vespidae	*Polybia*	*parrulina* R.
Escamoles	Hymenoptera	Formicidae	*Liometopum*	*apiculatum* M.
Honeypot ants	Hymenoptera	Formicidae	*Myrmecosistus*	*melliger* Ll.

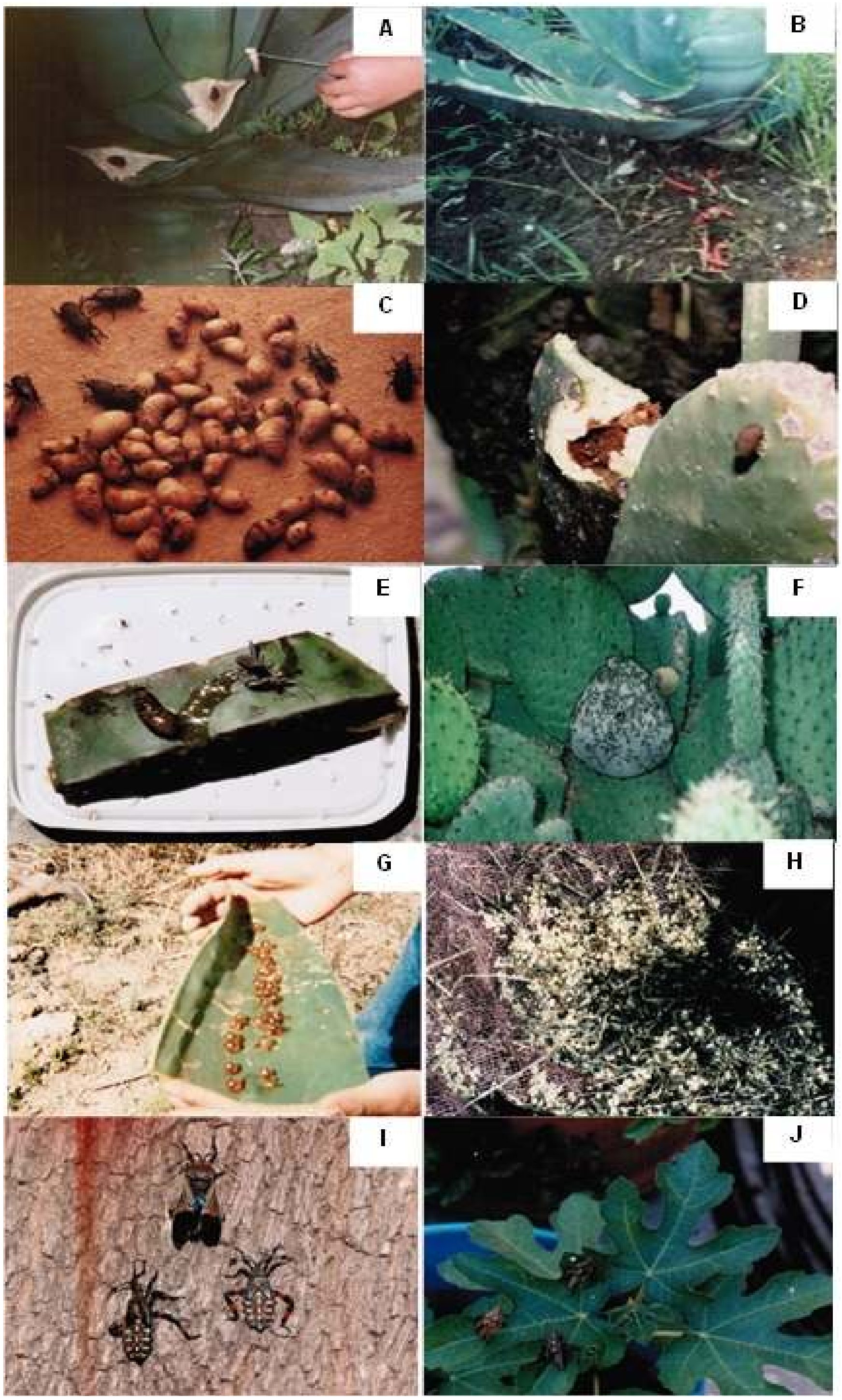

Fig. 2. Images of insects: A) Maguey white grub (*Aegiale hesperiaris K.*); B) Maguey red grub (*Comadia redtembachieri* H.); C) Botija (*Scyiphophorus acupunctatus* G.); D) Nopal grub (*Laniifera cyclades* D.); E) Opuntia grub (*Matamasius spinolae* V.); F) Black wasp (*Polybia parvulina* R.); G) Honeypot; (*Myrmecosistus melliger* Ll.) H) Escamoles; (*Liometopum apiculatum* M.) I) Forest bug/Xauis (*Pachilis gigas* B.); J) Grasshoppers (*Sphenarium purpurascens* Ch.)

3.2 Determination of Moisture

Moisture values (Table 4) ranged from 60.09% to 68.91% in larvaes, in eggs about half of them is water and the rest consists in dry matter, therefore for further consumption, it must be stored in refrigeration or frozen to avoid decomposition. Adults are low in water, dried can be kept in dry containers without risk of spoilage. Honeypot (*Myrmecosistus melliguer* Ll.) cannot be stored, so consumption must be upon collection.

3.3 Determination of Lipids

Lipid constituents are required for a diverse array of cellular processes, including structure, function and energy production. In addition, fat contains more than twice the energy per gram (9 Kcal/g) as does carbohydrates or protein (4 Kcal/g) [20].

Regarding human health, it is recommended that 20-30% [21] of the daily food intake should come from fat and currently dietary recommendations for omega-3 fatty acids are 1.6 g/day for men and 1.1 g/day for women, whereas omega-6 fatty acids recommendations are 17 g/day for men and 12 g/day for women.

The results obtained in this research indicate that lipid content in adult insects ranged from 5.85% in Black wasp (*Polybia parvulina* R.) to 6.12% in Honeypot. On the other hand, Escamoles showed 32.95% and larvae ranged from 30.65% (*Aegiale hesperiaris* K.) to 55.85% (*Matamaius spinolae* V.) and adult forest bug 30.17% (*Pachilis gigas* B.) which demonstrates that insects are a valuable source of this important nutrient that could help people maintain good health. Other studies, still on progress, carried by our investigation group have demonstrated that most fatty acids found in insects are monounsaturated (MUFA) and polyunsaturated (PUFA), which are essential for human health.

3.4 Determination of Protein

Proteins comprise one of five classes of complex biomolecules found in cells and tissues, the others being DNA, RNA, polysaccharides and lipids. However, proteins are fundamental components for cellular and organ function so, the diet most contain enough protein.

The minimum protein intake suggested for a healthy diet is 12% to 15% [21] and protein deficiency has adverse effects on all organs and is of particular concern in infants and young children. In addition, protein energy malnutrition (PEM) may have long-term adverse effects on brain function and patients have reduced immune functions and are hence susceptible to infection [22].

In addition to the aforementioned, malnutrition in both rural and urban places is consequence of protein intake from vegetal sources with low nutritional value in terms of the content of amino acids protein digestibility balance. Besides, though protein from meat is consider the best in terms of this balance, it is much more expensive. Therefore, the study of insects as a non-conventional protein source is important in order to find new and more accessible options for people to fulfill protein requirements by means of the incorporation of this unusual food into their diet, which may help the poorest to deal with nutritional deficiencies.

Our results showed that protein values ranged from 30.25% in nopal grub (*Matamasius spinolae* V.) to 74.85% (Table 5) in grasshoppers, so insects are an important source of proteins and in addition, after metabolic processes, protein excess may be transformed into soluble carbohydrates (useful as source of energy) due to gluconeogenesis. In the case of Honeypot, proteins (9.85%) are lower, suggesting that it is not possible to fulfill diet requirements only with insects but it could be useful for the enrichment of human diet.

3.5 Determination of Soluble Carbohydrate

Carbohydrates are used as energy fuel and for the synthesis of glycoproteins and glycolipids. Soluble carbohydrates needed for human diet (60%) [21] are very low in insects (Table 5); however, as discussed above, protein excess becomes soluble carbohydrates, thus increasing their content. Soluble carbohydrates values ranged from 8.87% in grasshoppers to 43.10% in Black wasp (*Polybia parvulina* R.) and 79.16% in Honeypot. Carbohydrate consumption in humans is mostly in the form of starch; however, an increase has been shown in sugar intake from added sugars, thus increasing the risk of metabolic diseases such as diabetes [23]. With that been said, the low percentages of soluble carbohydrates in insects could be of importance on minimizing the impact of added sugars on the diet.

Table 4. Moisture determination of insects (%)

Insect	*Laniifera Cyclades D.*	*Metamasius spinolae V.*	*Polybia parvulina R.*	*Aegiale hesperiari K.*	*Comadia redtenbacheri H.*
Water	68.37	67.25	49.35	68.91	64.43
Dry sample	31.63	32.75	50.65	31.09	35.57
Insect	***Scyphophorus acupunctatus G.***	***Pachilis gigas B.***	***Liometopum apiculatum M.***	***Myrmecosistus melliger Ll.***	***Sphenarium purpurascens Ch.***
Water	60.09	26.21	51.12	74.43	45.45
Dry sample	39.91	73.79	48.88	25.57	54.55

Dry matter obtained by difference

Table 5. Macronutrient of 10 edible species of insects (g/100 g dry basis)

Insect	Crude proteins	Total ashes	Lipids	Crude fiber	Soluble carbohydrates
Laniifera cyclades D.	45.25	6.62	31.10	1.95	15.08
Metamasius spinolae V.	30.25	2.95	55.85	1.32	9.63
Polybia parvulina R.	41.40	4.51	5.85	5.14	43.10
Aegiale hesperiari K.	41.54	4.21	30.65	1.28	22.32
Comadia redtenbacheri H.	33.14	3.29	42.19	2.41	19.02
Scyphophorus acupunctatus G.	45.93	4.32	38.49	2.12	9.14
Pachilis gigas B.	45.03	4.20	30.17	5.14	15.46
Liometopum apiculatum M.	43.16	7.15	32.95	2.12	14.62
Myrmecosistus melliger Ll.	9.85	4.15	6.12	0.72	79.16
Sphenarium purpurascens Ch.	74.85	3.55	5.98	6.75	8.87

All values are mean of triplicate determination
N. Kjendahl X 6.25 = Proteic nitrogen

3.6 Determination of total ashes

Total ashes ranged from 2.95% in nopal grup (*Metamasius spinolae* V.) to 7.15% in Escamoles (*Liometopum apiculatum* M.) (Table 5). Minerals play a key role in the regulation of metabolic and physiological pathways. Adequate intake is required to maintain homeostasis, cell protection, functionality, and health, while deficiencies are associated with specific illnesses [24]. In this study, minerals were not analyzed separately.

3.7 Determination of Crude Fiber Content

Dietary fiber is the collective term for the many carbohydrate polymers that escape digestion in human small intestine. It contributes to the maintenance of normal bowel function, and the reduction of incidences of several abnormalities of the metabolic syndrome [25]. Dietary fiber in insects is very low (Table 5) ranging from 0.72% in Honeypot to 6.75% in grasshoppers (*Sphenarium purpurascens* Ch.), however concentrations as higher as 27% have been reported [26]. Insoluble chitin is the most common form of fiber in the body of insects contained mainly in their exoskeleton [26].

4. CONCLUSION

Wild insects collected in an arid zone of Hidalgo State showed adequate chemical composition values for human diet. They have highly significant levels of proteins, low dietary fiber content, high values of fatty acids essential for nutrition and minerals, even though they were not analyzed individually, literature reviews showed that minerals such as Na, K, P, Fe, Zn, Ca and Mg play an important role in human nutrition. These small wild animals are a promising source of food to overcome malnutrition problems faced by poor population and provide food security. That's why it is important to create basic sustainability elements to avoid extinction of these species. Moreover, commercialization of these insects could increase the economic status of poor inhabitants of arid zones in different states of Mexico and arid regions worldwide facing similar problems.

ETHICAL APPROVAL

As per international standard or university standard ethical approval has been collected and preserved by the authors.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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